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Environmental Impact and Benefit Assessment for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category

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Abbreviations and Acronyms

ADF—Aircraft Deicing and Anti-icing Fluid
AMS—Aerospace Material Specification
atm—Atmospheres
BAF—Bioaccumulation Factor
BCF—Bioconcentration Factor
BOD—Biochemical or Biological Oxygen Demand
BOD₅—Five Day Biochemical Oxygen Demand
C—Celsius
CASRN—Chemical Abstracts Service Registry Number
CBOD₅—Five Day Carbonaceous Biochemical Oxygen Demand
cfs—Cubic Feet per Second
COD—Chemical Oxygen Demand
DO—Dissolved Oxygen
EPA—United States Environmental Protection Agency
EC_x—Effective Concentration for x% of test organisms
ESRI—Environmental Systems Research Institute
g—Gram
GA/C—General Aviation and/or Cargo
GIS—Geographical Information System
GCV—Glycol Collection Vehicle
IARC—International Agency for Research on Cancer
IRIS—Integrated Risk Information System
kg—Kilogram
K_{oc}—Soil organic carbon adsorption coefficient
K_{ow}—Octanol water partition coefficient
L—Liter
LC_x—Lethal Concentration for x% of test organisms
LOEC—Lowest Observed Effect Concentration
LOAEL—Lowest Observed Adverse Effect Level
m—Meter
MATC—Maximum Allowable Toxicant Concentration
MCL—Maximum Contaminant Level
mg—milligram
mm—millimeter
MSDS—Material Safety Data Sheet
NHD—National Hydrography Dataset
NOEC—No Observed Effect Concentration
NOAEL—No Observed Adverse Effect Level
NPDES—National Pollutant Discharge Elimination System
NRWQC—National Recommended Water Quality Criteria
NWRA—National Wildlife Refuge Area
POTW—Publicly Owned Treatment Works
RfC—Reference Concentration
RfD—Reference Dose
RSEI—Risk-Screening Environmental Indicators model
SAE—Society for Automotive Engineers

SOFP—Snow or Freezing Precipitation

TMDL—Total Maximum Daily Load

µg—microgram

WATERS—Watershed Assessment, Tracking, and Environmental Results

WOE—Weight of Evidence

WTP—Willingness to Pay

1 Introduction

The United States Environmental Protection Agency (EPA) is promulgating effluent limitation guidelines and new source performance standards for the Airport Deicing Point Source Category. The regulations address both the wastewater collection practices used by airports, and the treatment of those wastes. Airports in the scope of this regulation are defined as Primary Commercial Airports with greater than or equal to a 1,000 annual non-propeller-driven aircraft departures. This document discusses environmental impacts associated with deicing operations at these airports and the environmental benefits EPA estimates would result from pollutant discharge reductions under the final regulatory options. This document presents information on the environmental impacts airport deicing discharges have caused in the past and on their potential to do so in the future. The final regulatory options will reduce the frequency and severity of environmental impacts associated with airport deicing discharges. The regulatory options will primarily benefit surface waters, though soil and groundwater resources could benefit from pollutant discharge reductions, as well.

This introduction briefly describes the nature of airport deicing operations and their pollutant discharges and provides an overview of associated environmental impacts. Additional information on the characteristics of airport deicing operations and their discharges is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010). EPA's final rule addresses only those deicing activities that take place on the airfield side of airports where aircraft are active. It does not address pollutant discharges from deicing activities airports undertake to clear snow and ice from parking lots, roads, sidewalks and other airport surfaces beyond the airfield.

Chapter 2 of this document provides information on the chemical composition of airport deicing products used in the United States and discusses the potential for environmental impacts from various formulation ingredients. *Chapter 3* provides information on known locations and levels of U.S. airport deicing operation discharges and associated environmental impacts. *Chapter 4* discusses each of the final regulatory options in terms of the environmental benefits EPA estimates would result from each option.

1.1 Airport Deicing and Anti-icing Operations

The purpose of airport deicing operations is to ensure safe aircraft departures, landings, and travel on airport grounds. Frozen precipitation or frost on aircraft surfaces can compromise aircraft ability to obtain sufficient lift for departures or damage aircraft. Frozen precipitation on the airfield can cause loss of aircraft control due to lack of traction between aircraft wheels and airfield surfaces. Frost and frozen precipitation must be addressed if aircraft are to function safely under winter conditions.

There are two types of snow and ice removal operations. Deicing operations remove snow and ice accumulations from aircraft and airfield surfaces. Anti-icing operations prevent snow and ice from accumulating on aircraft and airfield surfaces, either before accumulation can take place or after a surface has been cleared by deicing operations. Both aircraft and airfield surfaces undergo deicing and anti-icing operations. In this document, the phrase "airport deicing operations" refers generally to all deicing and anti-icing operations that take place at airports.

Aircraft deicing removes snow and ice accumulations from aircraft surfaces. Aircraft deicing includes both "wet weather" and "dry weather" deicing. Wet weather deicing takes place during or after weather

events that coat aircraft surfaces with snow or ice. Dry-weather deicing takes place when ambient temperatures are low enough, typically below 55° F, to allow frost or ice formation on aircraft surfaces. During a typical aircraft deicing process, trained personnel spray specially formulated and heated deicing fluids on aircraft surfaces at high pressure in order to remove snow and ice. Depending on the aircraft, snow and ice accumulation levels, and weather conditions, wet weather deicing of a single aircraft requires the use of a couple hundred to several thousand gallons of aircraft deicing fluid. Dry weather deicing requires less fluid than wet weather deicing because of lower ice accumulations during dry weather conditions.

Aircraft anti-icing takes place when weather conditions threaten to re-contaminate freshly deiced aircraft surfaces with new snow or ice. Aircraft anti-icing fluids are specially formulated to temporarily prevent snow and ice accumulation on deiced aircraft surfaces, protecting aircraft until their departure from an airport. Anti-icing is typically necessary only during wet weather conditions. The process consists of the spraying of a thin layer of anti-icing fluid onto aircraft surfaces by trained personnel. Aircraft anti-icing fluids are viscous and adhere to aircraft surfaces until take-off. The process requires a smaller volume of fluid than the aircraft deicing process.

Airfield pavement surfaces must also be cleared of snow and ice. Pavement deicing and anti-icing operations remove and prevent, respectively, snow and ice accumulations on airfield runways, taxiways, aprons, gate areas, and ramps. Airports use both mechanical and chemical means to clear airfield pavement. Most frequently, airports use mechanical means such as plows, blowers, and brooms to remove ice and snow (US EPA 2011). Because ice and snow can be difficult to remove by mechanical methods alone, many airports also apply liquid or solid chemical pavement deicers. Some of these deicers are applied prior to precipitation events as anti-icers in order to prevent ice formation or ease later removal of snow and ice. Airports also frequently apply sand to increase airfield traction.

Deicing operations typically take place during the winter when low temperatures and freezing precipitation (e.g., snowfall, freezing rain, and ice) occur. Local climate conditions determine both the duration and intensity of deicing seasons at individual airports. The deicing season can begin as early as September and continue through May in colder regions of the U.S. In general, however, December, January, and February are the peak deicing months for U.S. airports, and September and May have the lowest incidence of deicing activity. The majority of airports have a five month deicing season, though some airports have seasons as short as two months or as long as nine months.

The nature, frequency, and intensity of precipitation events also vary from airport to airport. Some airports rarely engage in deicing activities beyond aircraft frost removal, whereas other airports often cope with frequent and heavy snow or ice storms that necessitate both aircraft and pavement anti-icing and deicing. There can even be substantial variability among weeks or seasons at individual airports as weather patterns shift and affect the necessity for deicing activity. The nature and intensity of deicing activities and their associated pollutant discharges therefore vary substantially both among airports and among deicing seasons at individual airports.

1.2 Airport Deicing and Anti-Icing Product Formulations

Airport deicing products include aircraft deicing fluids, aircraft anti-icing fluids, and airfield pavement deicers. The materials used for aircraft deicing and anti-icing are specially formulated fluids with multiple chemical components. Pavements materials are typically simpler formulations and can be either solid or liquid in form.

Four aircraft deicing and anti-icing fluid (ADF) categories are available in the global market: Type I, Type II, Type III, and Type IV. Type I and Type IV are the fluid categories most commonly used at the U.S. primary commercial airports addressed by EPA's final regulatory options.

Type I fluids are aircraft deicers, and Type IV fluids are aircraft anti-icers. By volume, both fluids consist primarily of a freezing point depressant, typically propylene glycol or ethylene glycol, and water. The fluids also contain a relatively small volume, approximately 1-3%, of chemicals commonly known as "additives" which function as surfactants, corrosion inhibitors, pH modifiers, flame retardants, defoamers, dyes, oils, antioxidants, and antimicrobials. Type IV fluids also contain thickeners to increase their viscosity and allow them to adhere to aircraft surfaces until take-off. ADFs function by lowering the temperature at which snow and ice are able to adhere to aircraft surfaces.

Based on data from responses to the EPA Airline Deicing Questionnaire (2006b) the most commonly used ADF at commercial U.S. airports is Type I propylene glycol deicing fluid, accounting for approximately 77% of ADF use or purchase. A recent trend in ADF use has been increasing use of propylene glycol-based ADFs instead of ethylene glycol-based ADFs. *Table 1-1* presents EPA's estimate of national ADF use based on information provided in survey responses for the 2002-2003, 2003-2004, and 2004-2005 deicing seasons. Because glycol levels vary among individual manufacturer's ADF formulations, ADF quantities in *Table 1-1* are normalized to represent 100% glycol levels.

Table 1-1: U.S. Commercial Airports - National Estimate of Aircraft Deicing and Anti-Icing Fluid Use/Purchase *

Chemical	Average Total Airport Use/Purchase (million gallons/year)	Percentage of ADF Use/Purchase
Type I Propylene Glycol Aircraft Deicing Fluid	19.305	77.1
Type IV Propylene Glycol Aircraft Anti-Icing Fluid	2.856	11.4
Type I Ethylene Glycol Aircraft Deicing Fluid	2.575	10.3
Type IV Ethylene Glycol Aircraft Anti-Icing Fluid	0.306	1.2

Source: US EPA Airline Deicing Questionnaire (2006b).

* EPA used the ADF purchase information to represent usage, per airline industry recommendations. See US EPA (2010) for additional details.

Based on responses to the EPA Airport Deicing Questionnaire (2006c), the most commonly used pavement deicer on U.S. airfields is potassium acetate. Potassium acetate represents about 80 percent of all airfield deicing chemical use. A recent trend in pavement deicer use has been for U.S. airports to cease or decrease their use of urea due to water quality impact concerns. *Table 1-2* lists the total estimated national average airfield chemical usage (based on data for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons) for primary commercial airports in the U.S.

Table 1-2: U.S. Commercial Airports - National Estimate of Pavement Deicer Chemical Use

Pavement Deicer Chemical	Estimated Total Airport Use (tons/year)
Potassium acetate	22,538
Airside urea	4,127
Propylene glycol-based fluids	3,883
Sodium acetate	3,100
Sodium formate	1,117
Ethylene glycol-based fluids	774

Source: US EPA Airport Deicing Questionnaire (2006c).

Based on EPA's national estimates of chemical or material usage, approximately 70 percent of airports use chemical pavement deicers with the remaining 30 percent relying on sand application for airfield deicing/anti-icing (US EPA 2011). Additional information on pavement deicer usage is provided in *Table A-1* in *Appendix A*.

The identity and environmental behavior of individual ADF and pavement deicer components is discussed in more detail in *Chapter 2*.

1.3 Airport Deicing Chemical Dispersion in the Environment

Because aircraft deicing and anti-icing fluids (ADFs) and pavement deicers are typically used in very open and exposed outdoor environments, their dispersion begins immediately after application. ADFs are typically applied to aircraft at specific airport locations. These locations vary by airport and can include gate areas, aprons, or deicing pads. ADFs are designed to drip and shear from aircraft surfaces after application in order to avoid compromising aircraft lift during take-off. Type I deicing fluids drip from aircraft relatively quickly. The majority of these fluids fall to the pavement at fluid application sites. The remainder drips or shears from aircraft as they travel on the airfield, primarily falling on pavement and other airfield surfaces. Type IV anti-icing fluids are designed to remain on aircraft surfaces for a longer period of time than Type I deicing fluids to protect aircraft surfaces from snow and ice accumulation until take-off. A relatively small amount of Type IV fluid falls to the pavement at application sites. Most Type IV fluid drips or shears from aircraft during taxiing or take-off, falling primarily on pavement or other airfield surfaces. A lesser quantity of ADF becomes airborne during application or aircraft taxiing and take-off and can be carried by wind to other parts of the airfield or beyond airport property lines.

Little quantified research is available on ADF dispersion after application. EPA's analysis of baseline pollutant loadings to the environment assumed that 75% of Type I fluids fall to the ground at application sites (Switzenbaum et al. 1999). Because Type IV fluids are designed to remain on the aircraft until take-off, EPA assumed that only 10% of these fluids fall to the ground at the point of application (US EPA 2011). The remainder of the fluids disperses in areas beyond the application site.

Airports apply pavement deicers directly to the ground. Treated surfaces can include runways, taxiways, aprons, ramps, and gate areas. The extent of pavement surface deicing varies with the nature of precipitation events.

Once on the ground, ADFs and pavement deicers can disperse in several ways. ADFs and pavement deicers on paved surfaces often flow into stormwater management systems. Many airfields also have vegetated or other pervious surfaces adjacent to paved areas. In these areas, ADFs and pavement can percolate through soil and eventually enter groundwater if present beneath the airport.

ADFs and pavement deicers in stormwater management systems can discharge to surface waters or, in some locations, enter stormwater collection and treatment systems. Airports most frequently collect and treat stormwater originating from ADF application sites. Stormwater from these sites tends to contain higher percentages of deicing pollutants than other airport areas. These areas are also relatively limited in size and therefore provide an easier collection and treatment opportunity. Airports are less likely to collect and treat ADFs and pavement deicers dispersed in other parts of the airfield because of the larger surface areas and larger stormwater volumes involved, both of which increase collection and treatment complexity and expense. In addition, stormwater pollutant concentrations tend to be lower in these areas, though total loadings can still be significant. ADFs and pavement deicers dispersed in the airfield are more likely to discharge to surface waters or infiltrate pervious airfield surfaces.

Because of variability among individual airports in ADFs and pavement deicers usage levels, extent and configuration of paved and pervious areas, and stormwater collection and treatment, there is great variability in the quantities of deicing activity pollutants that reach surface waters at individual airports.

The nature of ADF and pavement deicer dispersion in the environment is discussed in more detail in *Chapter 3*.

1.4 Environmental Impacts from Airport Deicing Operation Discharges

EPA has identified a number of cases in which airport deicing operation discharges to the environment have affected water quality, aquatic ecosystems, and human use of aquatic resources. Identified impacts include:

- Reductions in dissolved oxygen levels in water bodies receiving deicing stormwaters;
- Increased nutrient concentrations in water bodies receiving deicing stormwaters;
- Fish kills downstream of deicing stormwater outfalls;
- Impacts to aquatic ecosystems downstream of deicing stormwater outfalls, including reductions in organism abundance and diversity or elimination of the aquatic community;
- Contamination of groundwater and surface drinking water resources;
- Aesthetic impacts to surface waters, including foaming, noxious odors, and discoloration; and
- Complaints of headaches and nausea by people exposed to deicing stormwater odors.

Of particular and well-known concern is the oxygen demand exerted by ADF and pavement deicer-contaminated stormwater. All of the primary ingredients in ADFs and pavement deicers exert oxygen demand as they decay. As airport deicing materials decay in surface waters, they consume oxygen dissolved in the water column. If the level of dissolved oxygen becomes too low, aquatic organisms can be impaired or killed. Chronic low oxygen conditions can eventually change the biochemistry and overall community structure of aquatic ecosystems.

Discharges of raw or partially treated sewage from cities and towns were a common cause of low oxygen conditions in surface waters prior to implementation of more stringent sewage treatment requirements under the Clean Water Act. The oxygen depletion potential of airport deicing operation discharges is many times greater than that of raw sewage. For example, before application, Type I propylene glycol-based deicing fluid is generally diluted to a mixture containing approximately 50% propylene glycol. Pure propylene glycol has a BOD₅ concentration of approximately 1,000,000 mg/L. A typical diluted propylene-based deicing fluid could therefore have a BOD₅ concentration of approximately 500,000 mg/L. In comparison, raw sewage typically has a BOD₅ concentration of approximately 200 mg/L. The amount of fluid used to deice a single non-propeller-driven aircraft depends on the nature of the precipitation event and the size of the aircraft but can range from a couple hundred to several thousand gallons. Therefore, deicing a single non-propeller-driven aircraft can generate a BOD₅ load greater than that of one million gallons of raw sewage. A large hub airport often has several hundred flights each day. Pavement deicers applied to airfield pavement can also exert significant BOD. The BOD₅ generated from deicing activities at a large airport in a single day can therefore equal the BOD₅ associated with the raw sewage from more than one million people (or a large city) (US EPA 2008a).

In addition to oxygen demanding substances, airport deicing products also contain a number of additives. Some of these additives have toxic or other properties that could harm aquatic ecosystems. Other

additives have not yet been publicly identified because of the proprietary nature of deicing material formulations and the limitations of currently available research on deicing product formulations. Without information on the identity of these additives, it is impossible to determine the potential environmental impacts from these chemicals.

Many of the surface waters to which airports discharge deicing materials are small streams with limited absorption and dilution potential for processing large quantities of oxygen demanding substances and other pollutants. EPA has evaluated the impairment status of a number of surface waters directly receiving airport deicing operation discharges and has found a large number of these waters to be listed as impaired under Section 303(d) of the Clean Water Act (see *Chapter 3*). Many of these waters have the types of impairments that can be associated with airport deicing operation discharges (e.g., depressed dissolved oxygen levels). Other waters are stressed and impaired by other types of pollutants (e.g., PCBs, pathogens). The final regulatory options will reduce the intensity of discharges of airport deicing pollutants to a number of these surface waters and have the potential to improve the health of these impaired aquatic resources.

Environmental impacts associated with airport deicing discharges are discussed in more detail in *Chapter 3*.

2 Airport Deicing Product Components and Environmental Behavior

Airport deicing products include aircraft deicing fluids, aircraft anti-icing fluids, and airfield pavement deicers. Aircraft deicing and anti-icing fluids (ADFs) are used on aircraft. Pavement deicers are used on airport runways, taxiways, aprons, ramps and gate areas. Each type of airport deicing product is specially formulated for the purpose it serves.

This chapter provides information on the basic composition of airport deicing products and summarizes information EPA was able to gather through a review of the literature available on the identity and quantity of specific chemicals used in airport deicing products (*Section 2.1*). This chapter also provides an overview of the environmental behavior and potential environmental impacts associated with these chemicals (*Section 2.2*). In addition to a broad review of the physical properties and fate and transport characteristics of approximately 99 chemicals that may be components or decay products of ADFs and airfield pavement deicers, more detailed discussions are provided for 12 chemical or chemical groups of potential environmental concern (*Section 2.2.2*).

2.1 Airport Deicing Product Components

Many different types of aircraft deicing fluid, aircraft anti-icing fluid and airfield pavement deicer formulations are used at airports in the U.S. Manufacturers use a variety of freezing point depressants and additives to formulate their products. According to responses to EPA's Airport Deicing Questionnaire (2006c), the ADFs most widely used at U.S. airports consists of water, propylene glycol or ethylene glycol as a freezing point depressant, and a range of additives that differ by ADF manufacturer and specified fluid use. Pavement deicers typically consist of a chemical that serves as a freezing point depressant and, in many formulations, various additives. The pavement deicer freezing point depressants most widely used at U.S. airports are potassium acetate, urea, sodium acetate, sodium formate, propylene glycol, ethylene glycol, or a mixture of ethylene or propylene glycol and urea (see *Table 1-2*).

Manufacturers are generally willing to identify the freezing point depressants comprising the bulk of their airport deicing product formulations, but the identity of product additives and their concentration in product formulas is generally considered to be proprietary. Research by parties outside the airport deicing product manufacturing community indicates that some airport deicing products additives have toxic or other properties potentially harmful to aquatic ecosystems. Understanding the identity, quantity, and nature of chemicals present in airport deicing products is a useful step in characterizing the potential environmental risks associated with ADF and pavement deicer discharges. This section summarizes information EPA was able to gather through a review of the literature currently available on the identity and quantity of chemicals used in airport deicing products. A recently released study contains significant additional information on airport deicing products (Ferguson, et al. 2008).

2.1.1 Identification of Airport Deicing Product Components

To determine the chemical composition of ADFs and pavement deicers, EPA reviewed available data sources including Society for Automotive Engineer Aerospace Material Specifications (SAE AMSs), deicing product Material Safety Data Sheets (MSDSs), patent descriptions, peer-reviewed literature, other published reports, and data from EPA airport sampling events.

EPA's determination of the composition of ADFs and pavement deicers is incomplete, however, for several reasons. EPA relied on available data sources to identify components. These sources are limited because many airport deicing product ingredients are proprietary, and manufacturers do not, therefore, identify them in product labels, MSDSs, or other publicly available documents. Because a significant level of effort is required for an outside party to determine a deicing product's composition, the peer-reviewed literature on this subject is limited, particularly for chemicals present in formulations in low concentrations as are most airport deicing product additives. Even when the identity of an additive is available, it is sometimes known only by its trade name, and publicly available information for many such chemicals is limited or nonexistent.

In addition, although EPA endeavored to obtain current information on product formulations, it is possible given manufacturers' ongoing product development that some components listed in the literature are no longer in use. It is also possible that some components listed in patents have never been used either because a patented product has never been brought to market or because a final product incorporates only some of a wide group of possible components listed in a patent.

Despite these limitations, the results of the literature review provide an indication of the types and quantities of chemicals typically used in airport deicing product formulations.

2.1.1.1 *Standard Composition of Aircraft Deicing Fluids and Aircraft Anti-icing Fluids*

Four categories of aircraft deicing and anti-icing fluids (ADFs) are currently manufactured for the global market: Type I, Type II, Type III, and Type IV. Of these four categories, Type I and Type IV are the two categories commonly used at U.S. commercial airports.

ADFs are developed and manufactured to industry standards published in the U.S. by the Society for Automotive Engineers (SAE). SAE Aerospace Material Specifications (AMS) 1424 and 1428 are adopted on a voluntary basis by manufacturers and governments and include performance requirements for the three types of ADFs used in the U.S. (Types I, II, and IV).¹ The Association for European Airlines and the International Standards Organization publish similar standards, which are adopted voluntarily by manufacturers and governments in Europe and throughout the world, respectively. *Table 2-1* compares the characteristics and uses of the fluid categories.

¹ Type III fluid is rarely used and intended only for small aircraft. AMS 1424 applies to SAE Type I fluids, and AMS 1428 applies to SAE Type II, III, and IV fluids (Boeing 2008).

Table 2-1: Comparison of Aircraft Deicing and Anti-Icing Fluid Characteristics by Type

	Function	Characteristics
Type I	Aircraft Deicing Fluid	➤ Low viscosity ➤ Provides short-term protection because flows quickly off aircraft surfaces after application ➤ Typically dyed orange to aid in identification and application of a consistent layer on aircraft ➤ Typically heated (130° - 180° F) and applied as a high pressure spray to remove snow, ice, and frost
Type II	Aircraft Anti-icing Fluid	➤ Contains a polymeric thickening agent to prevent immediate flow off aircraft surfaces and provide protection until aircraft take-off ➤ Fluid remains in place until aircraft attains speed of approximately 100 knots, at which point fluid shears from aircraft ➤ Typically colorless ➤ Useful only for larger aircraft ➤ Use of Type II fluids is diminishing in favor of Type IV fluids
Type IV	Aircraft Anti-icing Fluid	➤ Contains a polymeric thickening agent to prevent immediate flow off aircraft surfaces and provide protection until aircraft take-off ➤ Fluid remains in place until aircraft attains a certain speed, at which point fluid shears from aircraft ➤ Typically dyed green to aid in identification and application of a consistent layer on aircraft ➤ Provides longer-term protection than Type II fluids

Sources: Corsi et al. (2007); Ritter (2001).

Freezing point depressants comprise the majority of ADFs. One study in the literature states that a freezing point depressant, either ethylene glycol or propylene glycol, typically makes up 50% to 80% of ADF product as applied (Johnson et al. 2001). The rest of the product consists of water and various additives. These additives function as surfactants, corrosion inhibitors, thickeners, flame retardants, pH modifiers, defoamers, dyes, antimicrobials, oils, chelators, and antioxidants.

Surfactants help ADFs spread evenly across aircraft surfaces by lowering fluid surface tension. Thickeners are used in Type II, III, and IV fluids to increase fluid viscosity and allow them to maintain their protective position on aircraft surfaces until take-off.

A single formulation does not necessarily contain a different chemical for each additive function. Some formulations contain components that serve multiple functions. Other formulations need only contain a subset of additives because of beneficial interactions among component chemicals.

Three main classes of additives have been identified in the literature as widely used by ADF manufacturers: the corrosion inhibitors/ flame retardants benzotriazole (BT) and methyl-substituted benzotriazole (MeBT) (Cornell 2001; Pillard et al. 2001), the surfactant alkylphenol ethoxylates (APEOs) (Nieh 1992; Corsi et al. 2006), and the pH modifier triethanolamine (Boluk et al. 1999).

Less information is available on the proportions in which the various components are present in ADF formulations. One study states that typical ADFs consist of 50% to 80% ethylene glycol or propylene glycol and 20% to 50% water (Breedveld et al. 2002). A second study states that, in undiluted form, Type I deicing fluids consist of 88% propylene glycol or ethylene glycol, 0.5% to 0.6% methyl-substituted benzotriazole (MeBT) mixture, 1% to 2% proprietary additives (corrosion inhibitors, buffer, and surfactants), and water (Cornell 2001). A third study states that ADFs contain 0.5% to 0.6% MeBT and that the commercial mixture of MeBT is 45% 4-MeBT and 55% 5-MeBT (Pillard et al. 2001).

A number of patents exist for ADFs based on freezing point depressants other than ethylene glycol or propylene glycol (e.g., pentaerythritol, glycerol, sorbitol, xylitol and other chemicals) (Simmons et al. 2007). According to responses to EPA's Airport Deicing Questionnaire (2006c), ADFs based on these components are not used at major U.S. airports.

2.1.1.2 *Standard Composition of Airfield Pavement Deicers*

Several basic types of pavement deicers are used at U.S. primary commercial airports. These deicers include formulations consisting primarily of potassium acetate, urea, sodium acetate, sodium formate, propylene glycol, ethylene glycol, or a mixture of propylene or ethylene glycol and urea. These primary ingredients serve as freezing point depressants.

Pavement deicers are more simply formulated than ADFs and consist primarily of the primary freezing point depressant ingredient. Potassium acetate, sodium formate, and sodium acetate formulations are known to contain corrosion inhibitors, as well (Switzenbaum et al. 1999; Shi 2008; USDOT 2007) though the corrosion inhibitors' chemical identity is not known.

2.1.1.3 *Detailed Listing of Potential Airport Deicing Product Components*

Table 2-2 presents the chemicals for which EPA found some evidence of use in airport deicing product formulations through its literature review. Many of the chemicals in the table below are presented and discussed in Ferguson et al. 2008.

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Johnson et al. (2001)	U	1303-96-4	Borax	Corrosion inhibitor
Johnson et al. (2001)	U	532-32-1	Sodium benzoate	Corrosion inhibitor
Corsi et al. (2006)	U	29878-31-7	4-methyl-1H-benzotriazole	Corrosion inhibitor
Ashrawi and Coffey (1993)	Y	-	Cobratec TT-50S, tolyltrizole solution	Corrosion inhibitor
Hu et al. (1998)	Y	110-65-6	Butyne-1,4diol	Corrosion inhibitor
Hu et al. (1998)	Y	107-19-7	Propargyl alcohol	Corrosion inhibitor
Hu et al. (1998)	Y	62-56-6	Thiourea	Corrosion inhibitor
Boluk et al. (1999)	Y	-	Sandocorin 8132, sodium dodecylbenzene sulfonate	Corrosion inhibitor
Moles et al. (2003)	Y	7778-53-2	Potassium phosphate	Corrosion inhibitor
Moles et al. (2003)	Y	10006-28-7	Potassium silicate	Corrosion inhibitor
Moles et al. (2003)	Y	13870-28-5	Sodium silicate	Corrosion inhibitor
Boluk et al. (1999); Hu et al. (1998); Nieh (1992)	Y	-	Benzyltriazole	Corrosion inhibitor
Boluk et al. (1999); Hu et al. (1998); Moles et al. (2003); Nieh (1992)	Y	29385-43-1	Tolyltriazole	Corrosion inhibitor
Johnson et al. (2001) and Hu et al. (1998)	Y	7631-99-4	Sodium nitrate	Corrosion inhibitor
Hu et al. (1998)	Y	-	AF-9020, polydimethylsiloxane	Defoamer
Hu et al. (1998)	Y	-	DC 1520, silicone antifoam	Defoamer
Boluk et al. (1999)	Y	-	Foamban	Defoamer
Hu et al. (1998), Boluk et al. (1999); Ma and Comeau (1990)	Y	-	Silicone antifoam ²	Defoamer
Coffey et al. (1995)	Y	-	Eosin orange, tetrabromofluorescein	Dye
Chan et al. (1995)	Y	-	Malonyl green, C.I. Pigment Yellow 34	Dye
Lockyerm et al. (1998)	Y	-	Shilling green	Dye
Chan et al. (1995); Lockyerm et al. (1998)	Y	-	FD&C Blue #1, alphazurine	Dye
Chan et al. (1995); Lockyerm et al. (1998)	Y	-	FD&C Yellow #5, tartrazine	Dye
Johnson et al. (2001)	U	95-14-7	Benzotriazoles	Flame Retardant and Corrosion Inhibitor

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Corsi et al. (2006)	Y	136-85-6	5-Methyl-1H-Benzotriazole	Flame Retardant and Corrosion Inhibitor
Ashrawi and Coffey (1993); Bloom (1986); Boluk et al. (1999); Hu et al. (1998); König-Lumer et al. (1982); Nieh (1992)	Y	57-55-6	1,2-Propylene glycol	Freezing point depressant
Back et al. (1999)	Y	608-66-2	Dulcitol	Freezing point depressant
Back et al. (1999)	Y	115-77-5	Pentaerythritol	Freezing point depressant
Boluk et al. (1999)	Y	25322-68-3	Polyethylene glycol, mw from 62 to 106	Freezing point depressant
Sapienza et al. (2003)	Y	97-64-3	Ethyl lactate	Freezing point depressant
Sapienza (2003)	Y	147-85-3	Proline	Freezing point depressant
Sapienza (2003)	Y	72-17-3	Sodium lactate	Freezing point depressant
Sapienza (2003)	Y	54571-67-4	Sodium pyrrolidone carboxylate	Freezing point depressant
Lockyern et al. (1998); Westmark et al. (2001)	Y	107-88-0	1,3-Butanediol	Freezing point depressant
Ashrawi and Coffey (1993); Boluk et al. (1999); Nieh (1992)	Y	25265-71-8	Dipropylene glycol	Freezing point depressant
König-Lumer et al. (1982); Lockyern et al. (1998)	Y	504-63-2	1,3-Propylene glycol	Freezing point depressant
Boluk et al. (1999); Westmark et al. (2001)	Y	112-27-6	Triethylene glycol	Freezing point depressant
Back et al. (1999); Sapienza et al. (2003)	Y	69-65-8	Mannitol	Freezing point depressant
Back et al. (1999); Simmons et al. (2007)	Y	149-32-6	Erythritol	Freezing point depressant
Back et al. (1999); Boluk et al. (1999); Westmark et al. (2001)	Y	56-81-5	Glycerol	Freezing point depressant
Back et al. (1999); Sapienza (2003); Sapienza et al. (2003)	Y	50-70-4	Sorbitol	Freezing point depressant
Ashrawi and Coffey (1993); Boluk et al. (1999); König-Lumer et al. (1982); Ma and Comeau (1990); Nieh (1992)	Y	111-46-6	Diethylene glycol	Freezing point depressant
Corsi et al. (2006)	Y	57-55-6	Propylene glycol	Freezing point depressant

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Corsi et al. (2006)	Y	107-21-1	Ethylene glycol	Freezing point depressant
Comfort (2000)	Y	127-08-2	Potassium Acetate	Freezing point depressant
US EPA (2000a)	Y	590-29-4	Potassium Formate	Freezing point depressant
Comfort (2000)	Y	127-09-3 (anhydrous)	Sodium Acetate	Freezing point depressant
Comfort (2000)	Y	141-53-7	Sodium Formate	Freezing point depressant
US EPA (2000a)	Y	57-13-6	Urea	Freezing point depressant
Hu et al. (1998); König-Lumer et al. (1982)	Y	-	Mineral oil	Oil used as hydrophobic agent
Ma and Comeau (1990)	Y	-	Dimethyl polysiloxane	Oil used as hydrophobic agent
Ma and Comeau (1990)	Y	-	White mineral oil (10 cSt)	Oil used as hydrophobic agent
Lockyer et al. (1998)	Y	112-53-8	1-dodecanol	Oil used as hydrophobic agent
Nieh (1992)	Y	7558-79-4	Disodium phosphate	pH Modifier
Hu et al. (1998)	Y	7758-11-4	Dipotassium phosphate	pH Modifier
Boluk et al. (1999)	Y	111-42-2	Diethanolamine	pH Modifier
Boluk et al. (1999)	Y	141-43-5	Monoethanolamine	pH Modifier
Boluk et al. (1999)	Y	102-71-6	Triethanolamine	pH Modifier
US EPA (2000a)	Y	1310-58-3	Potassium hydroxide	pH Modifier
Ashrawi and Coffey (1993); Boluk et al. (1999); Hu et al. (1998)	Y	1310-73-2	Sodium hydroxide	pH Modifier
Haslim (2004)	U	112-53-8	Dodecanol ⁴	Surfactant/Defoaming agent
Corsi et al. (2003)	Y	-	Alcohol ethoxylates	Surfactant
König-Lumer et al. (1982)	Y	-	Sodium alkylbenzenesulfonate	Surfactant
Bloom (1986)	Y	-	Oleic acid diamine	Surfactant
Bloom (1986)	Y	-	Oleyl propylene diamine	Surfactant
Bloom (1986)	Y	-	Palmitic acid diamine	Surfactant
Ashrawi and Coffey (1993)	Y	-	Aliphatic alcohol ethoxylates	Surfactant
Boluk et al. (1999)	Y	-	Siponate A-2466, sodium dodecylbenzene	Surfactant
Boluk et al. (1999)	Y	-	Sodium dodecylbenzene sulfonate ³	Surfactant

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
Boluk et al. (1999)	Y	-	Tergitol TMN-10, branched secondary alcohol ethoxylate	Surfactant
Westmark et al. (2001)	Y	-	Emerest 2660 (OEG-12 oleate)	Surfactant
Westmark et al. (2001)	Y	-	Emsorb 6900 (PEG-20 sorbitan oleate)	Surfactant
Corsi et al. (2003)	Y	-	Decyl alcohol ethoxylate	Surfactant
Corsi et al. (2003)	Y	-	Lauryl alcohol ethoxylate	Surfactant
Corsi et al. (2003)	Y	-	Lauryl alcohol phosphoric acid-ester ethoxylate	Surfactant
Ashrawi and Coffey (1993); Nieh (1992)	Y	-	Ethylene oxide / propylene oxide block copolymers	Surfactant
Nieh (1992)	Y	-	Nonylphenol ethoxylate	Surfactant
Nieh (1992)	Y	-	Octylphenol ethoxylate	Surfactant
Corsi et al. (2007)	Y	-	Alkylphenol ethoxylates	Surfactant
Tye et al. (1987)	Y	9062-07-1	Iota-carrageenan	Thickening Agent
Tye et al. (1987)	Y	-	Kappa-carrageenan	Thickening Agent
Ma and Comeau (1990)	Y	9004-62-0	Hydroxyethylcellulose	Thickening Agent
Westmark et al. (2001)	Y	-	Welan gum	Thickening Agent
Ashrawi and Coffey (1993); Nieh (1992)	Y	-	Polyacrylic acid ¹	Thickening Agent
König-Lumer et al. (1982); Nieh (1992)	Y	-	Cross-linked polyacrylic acid	Thickening Agent
Lockyerm et al. (1998); Ma and Comeau (1990); Westmark et al. (2001)	Y	-	Xanthan gum	Thickening Agent
Johnson et al. (2001)	U	123-91-1	Dioxane ⁵	
Johnson et al. (2001)	U	75-07-0	Acetaldehyde	
Johnson et al. (2001)	U	75-21-8	Ethylene oxide	
Johnson et al. (2001)	U	-	Polyamines	
Johnson et al. (2001)	U	37306-44-8	Triazoles	
US EPA (2000a)	Y	117-81-7	Bis (2-ethylhexyl) phthalate	
US EPA (2000a)	Y	84-74-2	Di-N-Butyl Phthalate	

Table 2-2: Identification of Airport Deicing Product Components

Source	Current	CASRN	Chemical Name	Characterization
US EPA (2000a)	Y	100-41-4	Ethylbenzene	
US EPA (2000a)	Y	-	M- + P-Xylene	
US EPA (2000a)	Y	112-40-3	N-Dodecane	
US EPA (2000a)	Y	108-88-3	Toluene	
Corsi et al. (2006)	Y	25154-52-3	Nonylphenol	
Corsi et al. (2006)	Y	-	Octylphenol	

1. Carbopol polyacrylic acid 1610, 1621, 1622, 672, and 934 were listed in the literature.
2. Silicone antifoam was listed in the literature as SAG 7133, SAG 1000, and Siltech E-2202.
3. Siponate DS and Siponate DDB-40 sodium dodecylbenzene sulfonate were listed in the literature.
4. CASRN for this chemical is provided as that of 1-dodecanol.
5. CASRN for this chemical is provided as that of 1,4-Dioxane.

U = Unknown if chemical is currently used in deicing formulas.

Y = Chemical identified as currently used in deicing formulas as of the date of reference publication.

Of the 111 identified ingredients, 61 (55%) were identified in sources that were published in 2000 or later.

2.2 Environmental Behaviors of Airport Deicing Product Components

This section provides an overview of the characteristics of many of the potential airport deicing product components identified in *Table 2-2*. EPA's review focused on characteristics that influence a component's potential to disperse in and impact the environment. The ultimate behavior of ADFs and pavement deicers in the environment is a function of both chemical-specific factors and airport-specific hydrological, geochemical, biological, and climatic factors. This chapter presents chemical-specific information which is then considered in environmental context in *Chapter 3*.

It is important to note that the individual components of ADFs and pavement deicers have varying fate and transport properties that cause deicing products to disaggregate into their individual components once they enter the natural environment. Fresh and concentrated wastestreams located closer to the point of ADF and pavement deicer application are more likely to reflect original product properties. Older and more dilute wastestreams further from the site of application have characteristics determined by the presence or absence of individual pollutants and the transformation and transport processes they have undergone. For this reason, it is important to consider the nature of individual product components in addition to the nature of the original product.

The Society for Automotive Engineers (SAE) sets technical standards for aircraft deicing and anti-icing fluids (ADFs). At this time, SAE requirements addressing ADF environmental impacts are limited. SAE AMS 1424 requires Type I fluids entering the market after August 2002 to have a mammalian toxicity (LC_{50}) greater than 5,000 mg/L and a fluid aquatic toxicity (LC_{50} for several different aquatic organism species) greater than 4,000 mg/L (SAE 2007). Research has shown that even at levels less than 4,000 mg/L, sub-lethal toxic effects will be exerted on aquatic organisms (Corsi et al. 2006). In addition, the toxicity standard does not apply to Type IV fluids, the more toxic of the two commonly used ADFs (Corsi et al. 2006). SAE also provides no guidance for ADF BOD or COD content. SAE has considered setting toxicity standards for additional fluids (US EPA 2000a) as well as a more stringent toxicity requirement for Type I fluids.

Appendix A contains tables that summarize information on the physiochemical properties of many known and potential ADF and pavement deicer components and their potential decay products as cited in *Table 2-2*. Except where otherwise noted, all of the information in the tables is from the U.S. National Library of Medicine's Hazardous Substances Databank and ChemFinder databases, which compile data from a wide variety of sources. In some cases, the sub-citations within these databases are incomplete or not supplied and therefore cannot be reported here. Other information sources include deicing and chemical-specific literature, as cited in the tables. For some physiochemical properties, information either does not exist or was not attainable from these sources; therefore a number of table entries are blank.

EPA collected information on components present in airport deicing products regardless of whether they were present in large and small proportions. Although some components (such as many deicing product additives) constitute a relatively small proportion of ADFs and pavement deicers, their properties may be such that they contribute disproportionately to toxic or other harmful effects to the environment associated with airport deicing discharges.

Components are organized in functional groups in *Table A-2* through *Table A-39*. For example, *Table A-2* contains information for chelators, *Table A-3* contains information for sugar-based freezing point depressants, and *Table A-4* contains information for acetate-based freezing point depressants, etc. A number of the substances within a table share similar properties. Other substances may have very different or unknown properties. These attributes are noted in each table. *Table A-40* presents available

information on ecological toxicity values associated with potential components. *Table A-41* presents information on human health effects associated with potential components.

Characteristics of 12 of the 99 potential ADF and pavement deicer components are presented in greater detail in *Section 2.2* and in *Table A-42* through *Table A-53* in *Appendix A*. These 12 components or component groups were chosen for a more detailed analysis for one or more of the following reasons: the component is a well-known ingredient in airport deicing products; the component is released to the environment in significant quantities; or the component has environmental impact potential.

2.2.1 Environmental Behaviors

EPA collected information on a wide variety of individual chemical environmental behaviors of potential interest in the context of discharges from airport deicing activities. Information was collected on traits of interest for assessing a chemical's ability to disperse in the environment, its potential to impacts aquatic ecosystems and organisms, and its potential to impact human health and aquatic resource uses such as drinking water supply, recreation, and aesthetic enjoyment.

Chemical-specific factors such as water solubility, affinity for solid surfaces and organic matter, volatility, degradation rates and products, and microbial acclimation needs influence environmental fate and transport of ADF and pavement deicer components. Some components have traits that elevate their potential for environmental impact in the aquatic environment.

Chemical-specific factors alone do not determine potential for environmental impact. Hydrological, geochemical, biological, and climatic factors all influence fate and transport of ADFs and pavement deicers in the environment. Specific factors can include flow volumes and patterns in receiving waters, water and soil/aquifer chemistry, microbial community characteristics, aquatic biological community composition, amount and intensity of sunlight, quantity and type of precipitation, and air temperature range and seasonal distribution.

Individual component traits must therefore be considered in concert with information about discharge quantities and the nature of the receiving environment in order to fully assess potential for environmental impact. The summary below presents the information EPA was able to gather on individual chemical traits. *Chapter 3* discusses these traits in the context of the discharge environment.

2.2.1.1 Fate and Transport Behaviors

After application of ADFs to aircraft or pavement deicers to airfield pavement, environmental fate and transport of the chemicals in these products depends on both physical processes and chemical-specific behaviors.

Airport deicing product components enter the aquatic environment through a variety of physical pathways. Most deicing chemicals discharge to the aquatic environment through stormwater discharge to surface waters. A certain quantity of chemicals enters surface waters through groundwater discharge or aerial deposition. Some deicing wastewaters undergo treatment but can retain certain components unaffected by treatment. These components can enter the aquatic environment when treated wastewaters are discharged to surface waters. Once in surface water, components may travel to downstream surface waters.

Airport deicing product components can also percolate into soil horizons. The components can accumulate, degrade, or move into groundwater. Components in groundwater can accumulate, degrade, or travel with groundwater flow.

During the physical transport of individual components, chemical-specific processes are underway, as well. To help assess environmental fate, transport, and impact potential from ADF and pavement deicer components on aquatic ecosystems and organisms, EPA gathered information on three characteristics:

- Volatilization
- Adsorption
- Biodegradation

These traits are described in further detail below.

Volatilization

Volatilization is a process whereby chemicals dissolved in water escape into the air. Chemicals with higher volatilization potential are typically of less concern to aquatic receptors because they tend to enter the atmosphere before discharge to surface waters or to be removed quickly from the water column. Some volatile pollutants can be a concern to human health, however, if inhaled.

EPA used the air/water partitioning coefficient H to estimate a chemical's volatilization potential. H represents the ratio of a chemical's aqueous phase concentration to its equilibrium partial pressure in the gas phase (at 25 degrees Celsius). Units are typically expressed as atm.m³/mole.

Volatilization data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Adsorption

Adsorption is a process whereby chemicals associate preferentially with organic carbon found in soils and sediments. Highly adsorptive compounds tend to accumulate in sediments. In aquatic ecosystems, such chemicals are more likely to be taken up by benthic invertebrates and to affect local food chains. Both accumulation in sediment and local food chain impacts make these chemicals more likely to affect predator organisms higher on the food chain, including human beings.

EPA gathered information on the adsorption coefficient (K_{oc}) to assess the potential of organic ADF and pavement deicer components to associate with sediment organic carbon. K_{oc} represents the ratio of the target chemical adsorbed per unit weight of organic carbon in the soil or sediment to the concentration of that same chemical in solution at equilibrium.

Metals in the aquatic environment typically concentrate in the sediment phase but do not bind to organic carbon (except nickel). EPA assumes that all metals show a high affinity for sediments independent of their negligible K_{oc} values.

Adsorption data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Biodegradation

Biodegradation is a process whereby organic molecules are broken down by microbial metabolism. Biodegradation represents an important removal process in aquatic ecosystems. Compounds that are readily biodegraded generally represent lower intrinsic toxicity and accumulation hazards because they can be eliminated more rapidly from ecosystems. These compounds are therefore less likely to create long-term toxicity problems or to accumulate in sediments and organisms. Chemicals that biodegrade slowly or not at all can accumulate and linger for longer periods of time in sediments, and represent a greater hazard to aquatic receptors.

EPA gathered information on biodegradation half-life to estimate the potential for an organic chemical to biodegrade in the aquatic environment. Biodegradation half-life represents the number of days a compound takes to be degraded to half of its starting concentration under prescribed laboratory conditions.

Biodegradation data for individual deicing product components is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

2.2.1.2 Aquatic Organism and Community Impact Behaviors

Aquatic organisms and communities are exposed to airport deicing product components when they enter surface waters. EPA gathered information on three chemical-specific behaviors relevant to examining airport deicing product components' potential to directly impact aquatic organisms and communities:

- Aquatic Toxicity
- Bioconcentration Factors
- Chemical and Biological Oxygen Demand

These traits are described in further detail below.

Aquatic Toxicity

EPA gathered information on both acute and chronic aquatic toxicity. Acute toxicity assessments show the impact of a pollutant after a relatively short exposure duration, typically 48 and 96 hours for invertebrates and fish, respectively. The primary endpoint of concern is mortality, reported as the LC₅₀. The LC₅₀ represents the concentration lethal to 50% of test organisms for the given duration of the exposure.

Chronic toxicity assessments indicate the impact of a pollutant after a longer-duration exposure, typically from one week to several months. The endpoints of concern are one or more sub-lethal responses, such as changes in reproduction or growth of the affected organisms. The results are reported in various ways, including EC₅, EC₁₀, or EC₅₀ (i.e., the concentrations at which 5%, 10%, or 50% of test organisms show a significant sub-lethal response), NOEC (No Observed Effect Concentration), LOEC (Lowest Observed Effect Concentration), or MATC (Maximum Allowable Toxicant Concentration). MATC is defined as the highest level of a chemical acceptable in a water supply above which a specific effect occurs.

The summary also contains information on National Recommended Water Quality Criteria set by EPA to protect aquatic organisms from acute and toxic effects. Acute and chronic aquatic toxicity data for several ADF and pavement deicer components are summarized in *Table A-40* in *Appendix A*.

Bioconcentration Factors

The bioconcentration factor (BCF) is a good indicator of the potential for a chemical dissolved in the water column to be absorbed by aquatic biota across external surface membranes such as gills. The BCF is expressed in units of liters per kilogram and is defined as follows:

$$\text{BCF} = \frac{\text{equilibrium chemical concentration in target organism (mg/kg, wet weight)}}{\text{mean chemical concentration in surrounding water (}\mu\text{g/L)}}$$

EPA examined BCF values because they can indicate chemicals with the ability to bioconcentrate in aquatic organisms and transfer up the food chain if they are not metabolized and excreted. Pollutant transfer up the food chain can result in significant levels of pollutant exposure for predator organisms (including human beings) consuming contaminated fish, shellfish, or other aquatic organisms.

The bioaccumulation factor (BAF) is a better measure than the BCF of the potential for a chemical dissolved in the water column to be taken up by aquatic biota because it accounts for vertical accumulation of the chemical in the food chain, whereas the BCF does not. For this reason, BCFs underestimate risk to aquatic organisms. Because field-measured BAFs are not readily available for many chemicals, EPA instead collected BCFs for deicing product components. This information is summarized in *Table A-2* through *Table A-40* in *Appendix A*.

Chemical and Biological Oxygen Demand

Oxygen demand, or the oxygen consumed by a substance when decaying in water, is reported as either biochemical or biological oxygen demand (BOD), carbonaceous biochemical oxygen demand (CBOD), or chemical oxygen demand (COD). BOD is a measure of the amount of oxygen consumed by the biological processes that break down organic matter in water. The greater the BOD level, the greater the degree of pollution (US EPA 2008f). CBOD is a test method that departs from customary methods for determining BOD in its use of a chemical inhibitor to block nitrification, thus preventing the nitrogenous, or second stage, BOD from being consumed. COD is a measure of the oxygen-consuming capacity of inorganic and organic matter present in water. COD is expressed as the amount of oxygen consumed in milligrams per liter (mg/l). Results do not necessarily correlate to BOD results because the chemical oxidant in the COD test may react with substances that bacteria do not metabolize (US EPA 2008f).

EPA has developed aquatic life NRWQC for ambient DO that take into account life stages and temperature preferences of different types of fish. The 7-day mean DO concentration for early life stages is 9.5 mg/l for cold water fish and 6.0 mg/l for warm water fish. The 7-day mean minimum DO for older life stages is 5.0 mg/l for cold water fish and 4.0 mg/l for warm water fish (US EPA 1986). Low dissolved oxygen levels are the reason for the listing of 5,401 miles of impaired waters in the United States or about 13% of total impaired miles (US EPA 2008b).

A well-known example of ecological alteration due to high BOD levels is the anoxia that is an annual occurrence throughout the Chesapeake Bay. For several months every year, large areas of the bay are unfit for fish or shellfish (US EPA 1998b). A past example of BOD impact was the Delaware River in the vicinity of Philadelphia and Camden. Every summer for many years, this area experienced severe DO “blocks” due to excessive BOD input from point sources. The anoxic conditions prevented several anadromous fish species (e.g., Atlantic menhaden and shad) from migrating upstream to spawn. Since the early 1980s, however, conditions have improved to the point that these species are once again able to swim upstream in large numbers to reproduce (Delaware Estuary Program 1996).

2.2.1.3 Human Health and Aquatic Resource Use Impact Behaviors

Human beings can be exposed to airport deicing product components through several aquatic resource pathways. Exposure occurs when a pollutant comes into contact with the human envelope—the lungs, gastrointestinal tract, or skin—resulting in inhalation, ingestion, or dermal absorption. Human beings also experience aesthetic impacts through sight, smell, and taste of aquatic resources affected by airport deicing discharges.

Human beings come into contact with surface waters during recreational activities such as fishing, nature observation, boating, and swimming. Exposure can involve skin contact, fish consumption, or inhalation of volatile chemicals. People who live in communities near surface waters containing airport deicing discharges can also inhale chemicals that volatilize from surface waters.

Drinking water is an additional exposure pathway. Many drinking water supply systems draw water from surface water sources. If a drinking water treatment process does not remove airport deicing product

components from source water, human beings can be exposed to them through water ingestion or dermal exposure and inhalation during bathing. Airport deicing product components can also enter groundwater and be drawn into industrial, commercial, municipal, and residential wells. Some groundwater undergoes treatment before use and some is used without treatment, particularly groundwater from residential wells.

To help assess the potential for impacts to human health and aquatic resource use from ADF and pavement deicer components, EPA gathered available information on component toxicity, carcinogenic potential, and aesthetic impact potential. These traits are described in further detail below.

The assessment of human health risk from a pollutant has four traditional steps:

1. Hazard Identification
2. Exposure Assessment
3. Dose-Response Analysis
4. Risk Characterization.

The amount of chemical human beings are exposed to through ingestion, inhalation, or dermal absorption is an important variable contributing to risk associated with that chemical. A dose-response function is used to fully characterize human health risk from a given chemical. This section summarizes information available on chemical-specific characteristics. *Chapter 3* summarizes information available on the quantities of deicing chemicals airports discharge to the environment, the manner in which they disperse, and the potential for human exposure.

Human Toxicity

EPA examined human health toxicity data both for outcomes resulting in cancer and for outcomes other than cancer (e.g., increased liver weight or respiratory effects). EPA's Integrated Risk Information System (IRIS) and other toxicity databases separate outcomes into these two types. The reasoning for this delineation is the assumption that there is no safe level of exposure to cancer-causing chemicals. Even a small exposure increases cancer risk to a certain extent. For chemicals that result in health effects other than cancer, there is thought to be a threshold level below which exposure is "safe."

Some chemicals are toxic at low doses. Other chemicals must be present at high levels to create a toxic effect. Some chemicals display hormesis and are beneficial at low doses, yet toxic at higher doses. Information on chemical toxicity is available in the toxicological and epidemiological literature. The discipline of toxicology utilizes laboratory studies on animals (*in vivo*) or cells (*in vitro*). Epidemiological studies examine human health outcomes in relation to chemical exposures on a day-to-day basis (time series studies) or over many years (cohort studies). Data on personal exposures to a chemical integrated over the population of interest and combined with chemical toxicity information are used to estimate human health risk from a chemical. Unfortunately, the toxicity of many chemicals either has not been studied or is not well understood.

EPA located toxicity information for 12 chemicals and chemical categories listed as potential ADF and pavement deicer components. EPA reviewed the following information sources for this data:

- Integrated Risk Information System (IRIS)
- Risk-Screening Environmental Indicators Model (RSEI)
- National Recommended Water Quality Criteria (NRWQC)
- Maximum Contaminant Levels for Drinking Water (MCLs)
- Peer-reviewed journal articles and government reports

Table A-41 in *Appendix A* summarizes the results for all 12 chemicals and chemical categories for which EPA was able to locate information.

Cancer Outcomes

EPA and the International Agency for Research on Cancer (IARC) use weight of evidence (WOE) classifications to qualitatively define carcinogens based on available data. The EPA defines six WOE guidelines, described below. IARC uses a similar scheme.

Category Weight-of-Evidence:

- A. Sufficient evidence from epidemiological studies to support a causal relationship between exposure to the agent and cancer.
- B1. Limited evidence from epidemiological studies and sufficient animal data.
- B2. Sufficient evidence from animal studies but inadequate or no evidence or no data from epidemiological studies.
- C. Limited evidence of carcinogenicity in animals and an absence of evidence or data in humans.
- D. Inadequate human and animal evidence for carcinogenicity, or no data.
- E. No evidence for carcinogenicity in at least two adequate animal tests in different species or in both adequate epidemiological and animal studies, coupled with no evidence or data in epidemiological studies.

For chemicals with a sufficient WOE, quantitative measures have been set. Since there is thought to be no safe level of exposure for carcinogens, many databases report slope factors or unit risks for carcinogens. There may be an oral slope factor (corresponding to ingesting a chemical in food), a drinking water unit risk (corresponding to ingesting a chemical in drinking water), and an inhalation unit risk (corresponding to inhaling a chemical from the air).

IRIS notes that the Oral Slope Factor represents the upper-bound (approximating a 95% confidence limit) estimate of the slope of the dose-response curve in the low-dose region for carcinogens. The units of the slope factor are usually expressed as the inverse of milligrams per kilogram-day (mg/kg-day^{-1}). The Inhalation Unit Risk is defined as the upper-bound excess lifetime cancer risk estimated to result from continuous exposure to an agent at a concentration of 1 gram per cubic meter (g/m^3) in air.

A number of assumptions are used to develop these values. For example, a person is assumed to weigh 70 kilograms, drink 2 liters of water per day, and breathe air at a rate of 20 cubic meters per day continuously for 70 years. Other assumptions are made in regard to animal-to-human extrapolation as most toxicological studies are performed on animals rather than humans. Assumptions are also made about low-dose extrapolations since study animals are generally exposed to much higher levels of pollutants than humans are expected to encounter.

Non-cancer Outcomes

For compounds resulting in health effects other than cancer, safe exposure thresholds are deemed to exist. IRIS has developed both reference doses (RfDs) and reference concentrations (RfCs), corresponding to ingestion and inhalation exposures.

IRIS states: "...the RfDs and RfCs are estimates (with uncertainty spanning perhaps an order of magnitude) of daily exposure [RfD], or continuous inhalation exposure [RfC], to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime."

Because most toxicological studies are conducted on animals, animal-to-human and low-dose extrapolation assumptions are also a factor in determining RfCs and RfDs. Generally, a point of departure from a toxicological study is selected and divided by uncertainty factors to account for these issues. Care must be taken when comparing RfD or RfC values from IRIS to other reference levels, because other reference sources may not use the same uncertainty factors or may use none at all.

Water Quality Guidelines

EPA also examined two types of water quality standards for this analysis. National Recommended Water Quality Criteria (NRWQC), set by EPA, aim to protect the health of human beings who consume water and aquatic organisms or solely aquatic organisms from contaminated aquatic habitats. The criteria, expressed in micrograms per liter ($\mu\text{g/L}$), represent surface water pollutant concentrations that are likely to cause adverse health effects in human beings if exceeded.

EPA also examined human health-based drinking water criteria. These criteria are usually presented as Maximum Contaminant Levels (MCLs) and are also developed by EPA. MCLs for non-carcinogens represent chemical-specific concentrations (expressed in $\mu\text{g/L}$) below which adverse health effects are not expected in exposed populations. MCLs for carcinogens represent chemical-specific concentrations (expressed in $\mu\text{g/L}$) that generally are expected to result in less than one additional cancer case per million lifetime exposures if the level is not exceeded in drinking water supplies.

Aesthetic Impacts

Human beings experience aesthetic impacts to aquatic resources in a variety of ways including impacts to water's visual appearance or its smell or taste. These impacts can affect human use or enjoyment of affected water and surrounding areas.

Objectionable tastes, odors, colors, and foaming have been reported in surface waters containing airport deicing operation discharges. These effects are generated in at least two ways. First, certain deicing product components are inherently likely to cause these effects. For example, dyes can directly add color to water. Airport deicer components and their breakdown products (e.g., urea, ammonia, ethylene glycol, propylene glycol, polymers of acrylic acid, and ethanolamines, have characteristic and potentially unpleasant odors. Glycols have a distinctive sweet odor. Solvents such as ethylbenzene, toluene, and xylenes can also add objectionable odors to water and their volatility lowers the detection threshold of those odors. Information on taste is not as readily available as information for odor, but glycols are known to have a somewhat sweet flavor and many surfactants taste bitter. The causes of foaming are not clear.

The second route by which ADFs and pavement deicers can cause adverse aesthetic impacts is through die-off of aquatic biota. Fish, macrophytes, and invertebrates can die when dissolved oxygen levels fall in or toxic substances enter surface water. Algae and heterotrophic microorganisms inhabiting the water column can die, as can the epilithon, the biotic layer covering the substrate of a stream or lake. This dead biomass can decay aerobically if the water recovers sufficient oxygen, or anaerobically in a process

known as putrefaction, which generates particularly foul odors. This decomposition process also releases proteins, polysaccharides, and other organic compounds which can provide building blocks for the generation of persistent foams in water. Under the resulting anoxic conditions, the reduction of iron and manganese ions to more soluble species can impart color to water (Zitomer 2001).

2.2.2 Detailed Airport Deicing Product Component Profiles

This section summarizes available information on 12 ADF and pavement deicer components or component groups. These components were chosen for a more detailed analysis for one or more of the following reasons: the component is a well-known ingredient in airport deicing products; the component is released to the environment in significant quantities by airport deicing operations; or the component has environmental impact potential. Additional information on these components is summarized in *Table A-42* through *Table A-53* in *Appendix A*.

2.2.2.1 Acetate

Sodium acetate and potassium acetate are used as freezing point depressants in airfield pavement deicers and are applied in large quantities at a number of airports. The dissolution of these chemicals after application releases acetate ($C_2H_3O_2$) into the environment in its ionic form. Acetate can impact aquatic environments through consumption of dissolved oxygen during degradation. This section and *Table A-42* of *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of acetate.

Fate and Transport

Acetate is not expected to volatilize (US NLM 2008).

Acetate ions are soluble in water (US NLM 2008). The solubility of acetate from particular compounds, for example sodium acetate, depends on the solubility of those compounds. Sodium acetate has a solubility of 1,190 grams per liter at 0° C (US NLM 2008).

The degree to which acetate ions adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater depends on site-specific factors. The rate of transport of acetate through soil will depend on a combination of the degradation rate and interactions with soils/sediments. Therefore, transport rates will be site-specific (US NLM 2008).

Acetate is rapidly biodegraded under aerobic conditions in surface water, groundwater, and soil (US NLM 2008). Acetate is also anaerobically biodegradable (US NLM 2008). Acetate in soil, derived from calcium magnesium acetate, was completely degraded within three to six days (D'Itri 1992). Since aerobic degradation is rapid, acetate plumes are rare, except possibly in anaerobic groundwater (Maest 2008). Formate can slow the breakdown of acetate in anaerobic environments (US NLM 2008). Acetate degradation produces bicarbonate, carbon dioxide, and water (D'Itri 1992).

Acetate has a moderately high BOD falling between the BODs of urea and formate. Acetate's BOD and COD are lower than those of propylene and ethylene glycol. One formulated pavement deicer product consisting primarily of sodium acetate is reported to have a BOD₅ of 0.58 g O₂/g product (Fyve Star, Inc. 2008).

Ecological Effects

Acetate anions decay through a process that consumes dissolved oxygen present in surface waters and groundwater. Chemicals that exert oxygen demand during the degradation process reduce the level of dissolved oxygen available for aquatic organisms, which require a certain level of dissolved oxygen to

function and survive. For additional information on the impacts of oxygen demand, see Sections 2.2.1.2, 2.2.2.1, and 2.2.2.2.

Human Health and Aquatic Resource Use Effects

EPA's literature search did not locate conclusive reports on the human health effects of acetate. Acetate may contribute to aesthetic impacts, however. Acetate decomposition consumes dissolved oxygen in surface waters. Low dissolved oxygen levels in surface waters can cause unpleasant odors and discoloration of water.

2.2.2.2 Alcohol Ethoxylates

Alcohol ethoxylates ($\text{CH}_3(\text{CH}_2)_n(\text{OCH}_2\text{CH}_2)_y\text{OH}$) are a major class of non-ionic surfactants that are widely used in a variety of consumer and industrial products, including laundry detergents (HERA 2007). Their use in ADFs as a surfactant additive has been documented in the literature. Their use may, in part, be in response to concerns about potential environmental impacts associated with the use of nonylphenol ethoxylate surfactants. Surfactants typically compose less than 2% of ADFs by volume. This profile and Table A-41 in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of alcohol ethoxylates.

Fate and Transport

Alcohol ethoxylates are a class of nonionic surfactants possessing alkyl chains with 12 to 18 carbons and ethoxylates with 0 to 18 units (Belanger et al. 2006).

Sorption to organic carbon and solids in the water column and subsequent burial in sediments is an important removal process in aquatic systems. Rates of sorption vary by ethoxymer and increase with increasing number of ethoxylate units and attendant hydrophobicity (Belanger et al. 2006). In soil, sorption to solids and organic carbon is a significant partitioning process (Belanger et al. 2006), and can reduce the chemical's rate of migration through the soil. Rates of sorption vary by ethoxymer, and increase with increasing hydrophobicity (Belanger et al. 2006).

Anaerobic breakdown has been documented in laboratory experiments simulating wastewater treatment (Belanger et al. 2006). Aerobic degradation also occurs. Rates of biodegradation vary by compound, but extremely rapid biodegradation is expected for all ethoxymers (Belanger et al. 2006). Rapid degradation was observed in natural estuarine waters with an alkyl half-life of 2.1 days and an ethoxy half-life of 6.3 days under environmental conditions (temperature unknown) (Vashon 1982). Linear and monobranched alcohol ethoxylates were completely biodegraded within 20 days and approximately 5% of the initial amount of multibranched alcohol ethoxylates remained after 30 days (Marcomini et al. 2000, as cited in Environment Canada 2002a).

Alcohols and fatty alcohols are alcohol ethoxylates' primary degradation products (Belanger et al. 2006). Anaerobic degradation also produces methane. The degradation intermediates of alcohol ethoxylates are less toxic than the parent compounds, and polyethylene glycol is the primary intermediate product (Environment Canada 2002a). Aerobic degradation occurs by stepwise removal of ethylene oxide units, and simultaneous degradation of the alkyl chain can also occur, proceeding to complete degradation into carbon dioxide and water (Environment Canada 2002). However, the following intermediate products are also expected, depending on the form of the parent compound (Environment Canada 2002):

- **Parent Compound:** Linear alcohol ethoxylates

Intermediate Compounds: Linear fatty alcohol, carboxylic fatty acid, polyethylene glycol, monocarboxylated polyethylene glycol, and dicarboxylated polyethylene glycol.

➤ **Parent Compound:** Monobranched alcohol ethoxylates

Intermediate Compounds: Carboxylated alcohol ethoxylates with a carboxylic group on the alcohol chain, monocarboxylated polyethylene glycol, dicarboxylated polyethylene glycol, carboxylated alcohol ethoxylates with a carboxylic group on the polyethoxylic chain, and carboxylic fatty acid.

➤ **Parent Compound:** Multibranched alcohol ethoxylates

Intermediate Compounds: Carboxylated alcohol ethoxylates with a carboxylic group on the polyethoxylic chain and carboxylic fatty acid.

Alcohol ethoxylates can also increase the mobility of other substances through soil and groundwater because of their physical properties as nonionic surfactants (Krogh et al. 2003).

Ecological Effects

Available information suggests that alcohol ethoxylates can have acute and chronic toxic effects on aquatic organisms. These effects vary by carbon chain length. Typical alcohol ethoxylate surfactant chain length ranges from 9 to 18 carbons and 3 to 8 ethoxylate groups. Toxicity generally declines as the number of ethoxylates increases (Campbell 2002).

A summary of chronic toxicity data from 60 studies conducted between 1977 and 2004 on fish, aquatic invertebrates, and aquatic plant and algae species states that alcohol ethoxylates' effects on aquatic species include reduced growth rates, impaired reproduction, and reduced survival of neonates, as well as acute mortality. Alcohol ethoxylates may cause diminished growth rates and reduced cell counts in algae species at concentrations as low as 0.03 mg/L (Belanger et al. 2006).

The concentrations at which alcohol ethoxylates lead to acute mortality in aquatic species are similar to the concentrations at which nonylphenol ethoxylates lead to acute mortality. However, alcohol ethoxylates degrade more quickly in the aquatic environment to relatively non-toxic compounds, whereas nonylphenol ethoxylate degradation typically yields nonylphenol, which is toxic as well as persistent in the aquatic environment.

Human Health and Aquatic Resource Use Effects

Human beings have regular contact with alcohol ethoxylates through a variety of industrial and consumer products such as soaps, detergents, and other cleaning products (US EPA 2000b). Exposure to these chemicals can occur through ingestion, inhalation, or contact with the skin or eyes. Studies of acute toxicity show that volumes well above a reasonable intake level would have to occur to produce any toxic response. Moreover, no fatal case of poisoning with alcohol ethoxylates has ever been reported. Multiple studies investigating the acute toxicity of alcohol ethoxylates have shown that the use of these compounds is of low concern in terms of oral and dermal toxicity (HERA 2007).

Clinical animal studies indicate these chemicals may produce gastrointestinal irritation such as ulcerations of the stomach, pilo-erection, diarrhea, and lethargy. Similarly, slight to severe irritation of the skin or eye was generated when undiluted alcohol ethoxylates were applied to the skin and eyes of rabbits and rats. The chemical shows no indication of being a genotoxin, carcinogen, or mutagen (HERA 2007). No information was available on levels at which these effects might occur, though toxicity is thought to be substantially lower than that of nonylphenol ethoxylates. Concentrations of alcohol ethoxylates in aquatic resources affected by airport deicing discharges are expected to be fairly low.

2.2.2.3 Dyes

Manufacturers add dye to ADFs to help ADF users track their presence on aircraft and airfield surfaces and to help them to distinguish Type I from Type IV fluids. Numerous dyes are found in ADFs, including alphanurine, tetrabromofluorescein, tartrazine, malonyl green, and shilling green dyes. Because of the proprietary nature of ADF formulations, the identity of all ADF dyes in use is not known. Type I ADFs are typically orange, and Type IV ADFs are typically green. Dyes and other ADF additives typically compose less than 2% of ADF volume. While some ADF dyes have been found to be safe for human consumption and are regularly used as food colorants, others may be detrimental to ecosystems or have unknown impacts. This section and *Table A-44* in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of ADF dyes.

Fate and Transport

Dyes are a diverse group of substances. Fate, transport, and partitioning behaviors depend on the specific dye in question. Most ADF dyes are expected to be at least somewhat water-soluble. Dyes reported as present in ADFs include: eosin orange (tetrabromofluorescein), FD&C Blue #1 (alphanurine), FD&C Yellow #5 (tartrazine), malonyl green (C.I. Pigment Yellow 34), and shilling green.

EPA was unable to locate information on the fate and transport behavior of these dyes through its literature search. However, in general, dyes tend to absorb ultraviolet radiation and have the potential to form decay products more toxic than the original parent dye compound.

Ecological Effects

The ecological effects of many ADF dyes have not been well documented.

Tetrabromofluorescein, a red dye, is not considered to be toxic to aquatic organisms except in very high concentrations. Aquatic invertebrates may have a somewhat lower sensitivity threshold than fish. It is not likely to bioaccumulate (Environment Canada 2008a).

No toxicity testing data is available for alphanurine, but some studies suggest that long-term degradation products of this dye may be of concern (ScienceLab 2005).

Malonyl green uses C.I. Pigment Yellow 34 which is a substance listed as being of environmental concern in the European Union due to the potential for highly toxic effects from two of its constituents, lead chromate and lead sulfate. These substances are also considered to be persistent in the environment and potentially bioaccumulative (Environment Canada 2008b).

EPA found no toxicity data for shilling green or tartrazine through its literature search.

Human Health and Aquatic Resource Use Effects

EPA found limited information on human health effects of ADF dyes through its literature search. Dyes may contribute to discoloration of surface waters downstream of airport deicing discharge outfalls.

2.2.2.4 Ethylene Glycol

Ethylene glycol (C₂H₆O₂) is well known as one of two freezing point depressants used in most Type I and Type IV ADFs. Most of the ADF currently applied at U.S. airports is based on the other main freezing point depressant, propylene glycol, but a sizeable fraction of current ADF usage continues to be based on ethylene glycol. These fluids are applied in large quantities at a number of airports. Before dilution for application, an ADF can consist of nearly 90% ethylene glycol. For this reason, large quantities of ethylene glycol are released to the environment during airport deicing activities. Ethylene glycol is also

used in some airfield pavement deicer formulations. Ethylene glycol contamination has been detected in surface waters, groundwater, sediments, and wastewater discharges at or near airports using ADFs.

When released to surface waters in large quantities, the chemical has the potential to consume large quantities of dissolved oxygen from the water column, potentially affecting the ecosystem and human use of aquatic resources. This profile and *Table A-45* in *Appendix A* summarize available information on the environmental fate and transport, ecological effects, and human effects of ethylene glycol.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of ethylene glycol. As discussed in previous sections, deicing products containing ethylene glycol can enter surface waters, soil, and groundwater on or near airports.

Volatilization of ethylene glycol from soil or water is not, in general, expected. However, ethylene glycol can be released into the atmosphere by spray application of ADFs to aircraft, particularly under windy conditions, and by shearing of ADFs from aircraft during taxiing and take-off. Ethylene glycol's atmospheric half-life is 50 hours at 25° C (US NLM 2008).

Ethylene glycol is freely soluble in water and is highly mobile in both surface water and groundwater (US NLM 2008). Tracer experiments appear to show that ethylene glycol moves through soil with groundwater. It adsorbs poorly to clay and sandy clay soils (US NLM 2008).

Ethylene glycol undergoes rapid microbial degradation in both soil and water. It can be degraded both aerobically and anaerobically (Johnson et al. 2001). Photolysis and hydrolysis are expected to be insignificant degradation pathways.

As with other glycols, unacclimated microbial communities in surface waters and soils often experience a lag of several days before degradation begins. Microbial communities acclimated to glycol inflows can begin degradation much sooner. Additives in ADFs, however, can significantly delay degradation (Johnson et al. 2001) as can low temperatures (US NLM 2008). Even though ethylene glycol itself may be completely degraded within a few days under optimal conditions, the full theoretical biological oxygen demand may not be observed for several weeks (US NLM 2008).

Ethylene glycol degradation requires a great deal of oxygen, with a reported CBOD₅ of 0.4 to 0.7 g O₂/g of ethylene glycol or 400 to 800 g O₂ per liter of ethylene glycol (D'Itri 1992).

In various field soils, 90% to 100% degradation of ethylene glycol was observed in 2 to 12 days (study temperatures unknown). Ethylene glycol in ADFs was completely degraded in soils along airport runways within 29 days at 8° C (US NLM 2008). Ethylene glycol in river water degraded completely in three days at 20° C and in 5 to 14 days at 8° C (US NLM 2008). Ethylene glycol should exhibit minimal partitioning to sediments or suspended particles in water. Given these behaviors, the distance ethylene glycol travels in surface water, groundwater, and soil will depend primarily on the balance between rates of transport and degradation (US NLM 2008).

Anaerobic degradation can be complete, producing methane and carbon dioxide, or incomplete, producing ethanol and acetate (Johnson et al. 2001). When there is insufficient oxygen to allow complete aerobic degradation, anaerobic degradation occurs unless inhibited by ADF additives or high concentrations of metabolic byproducts.

Ecological Effects

Ethylene glycol toxicity data for aquatic organisms is relatively limited in its scope and availability. However, available data indicates ethylene glycol may cause general chronic toxicity effects at high concentrations (>3400 mg/L), including slower growth and inhibited reproduction. It can also cause acute mortality. A study by Corsi et al. (2006) found that in certain Type I formulations, ethylene glycol contributed as much as 87% of the total toxic effect to the algae *Selenastrum capricornutum*. However, it contributed a much smaller percentage of the toxicity of the formulation to the fathead minnow (35%), the daphnid *Ceriodaphnia dubia* (47%), and Microtox testing (9%). It also contributed a much smaller percentage of the toxicity of a Type IV formulation to all four of the aforementioned tests (ranging from less than 1% to 19%).

Ethylene glycol is known to exert high levels of biological oxygen demand (BOD) during degradation in surface waters. This process can adversely affect aquatic life by consuming oxygen aquatic organisms need to survive (Corsi et al. 2001). Large quantities of dissolved oxygen (DO) in the water column are consumed when microbial populations decompose ethylene glycol. As described above, ethylene glycol degradation requires a great deal of oxygen, with a reported CBOD₅ of 0.4 to 0.7 g O₂/g of ethylene glycol, or 400 to 800 g O₂ per liter of ethylene glycol (D'Itri 1992).

Sufficient DO levels in surface waters are critical for the survival of fish, macroinvertebrates, and other aquatic organisms. If oxygen concentrations drop below a minimum level, organisms emigrate, if able and possible, to areas with higher oxygen levels or eventually die (US EPA 1993). This effect can drastically reduce the amount of useable aquatic habitat. Reductions in DO levels can reduce or eliminate bottom-feeder populations, create conditions that favor a change in a community's species profile, or alter critical food-web interactions.

An example of dissolved oxygen impacts deriving from airport deicing operation discharges is the impairment of Gunpowder and Elijah Creeks in northern Kentucky. News reports have shown that discharges from Cincinnati/Northern Kentucky International Airport, specifically ethylene glycol, are to blame for the creeks' states, which were so degraded at the time of the reports that they did not support life (Kelly and Klepal 2004).

Human Health and Aquatic Resource Use Effects

Human exposure to ethylene glycol can occur through dermal contact, inhalation, ingestion, and eye contact (NIOSH 2005a). Exposure typically targets the eyes, skin, respiratory system, and central nervous system, and manifests through irritation to the eyes, skin, nose, and throat; nausea, vomiting, abdominal pain, lassitude (weakness, exhaustion); dizziness, stupor, convulsions, central nervous system depression; and skin sensitization (NIOSH 2005a). Effects can occur at concentrations as low as 2 mg/kg*day. Children and adults are expected to similarly express pollutant exposure symptoms (US HHS 2007a).

No negative health effects have been reported in persons chronically exposed to ethylene glycol at natural levels found in the environment (US HHS 2007b), though available monitoring data indicate that ethylene glycol is typically found only near areas of release (e.g., production facilities and airports). Workers involved in airport deicing operations have produced urine samples containing ethylene glycol. Further research is still needed, however, to fully assess the cancer potential, developmental toxicity, and other human health impacts of this pollutant, particularly with respect to the general public (US HHS 2007b).

Several articles have reported a strong sweet odor downstream from airport deicing outfalls which is believed to derive from ethylene and/or propylene glycol (e.g., Eddy 1997). Additionally, anoxic waters,

which can result from the high BOD ethylene glycol exerts, typically produce a strong, unpleasant odor (State of Ohio Environmental Protection Agency 2001).

2.2.2.5 Formate

Sodium formate is used as a freezing point depressant in airfield pavement deicers and is used in large quantities at a number of airports. The dissolution of sodium formate after application releases formate (CH_2O_2) into the environment in its ionic form. Formate can impact aquatic environments through consumption of dissolved oxygen during degradation. This section and *Table A-46 of Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of formate.

Fate and Transport

Formate is not expected to volatilize (US NLM 2008).

Formate ions are very soluble in water though the solubility of formate in compounds depends on the solubility of those compounds (US NLM 2008). Sodium formate has a solubility of 972 g/L at 20° C (US NLM 2008). Depending on site-specific factors, formate ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater (US NLM 2008).

Formate is slowly hydrolyzed in water (US NLM 2008). It is subject to rapid aerobic degradation, and can be anaerobically degraded by methanogens (US NLM 2008). Researchers observed that the aerobic degradation rate appears to decrease sharply with decreasing temperatures (Hellsten et al. 2005). The aerobic degradation of formate produces carbon dioxide and bicarbonate (Hellsten et al. 2005).

Formate has a slightly lower BOD and COD than acetate and a lower BOD and COD than ethylene and propylene glycol. Sodium formate granules in one formulated deicing product (Kilfrost CIM) are reported to have a COD of 0.3 g O_2 /g product. The product's BOD was not reported (Reeves et al. 2005).

Ecological Effects

Formate anions decay through a process that consumes dissolved oxygen present in surface waters and groundwater. Chemicals that exert oxygen demand during the degradation process reduce the level of dissolved oxygen available for aquatic organisms, which require a certain level of dissolved oxygen to function and survive. For additional information on the impacts of oxygen demand, see Sections 2.2.1.2, 2.2.2.1, and 2.2.2.2.

Human Health and Aquatic Resource Use Effects

EPA's literature search did not locate conclusive reports on the human health effects of acetate. Formate may contribute to aesthetic impacts, however. Formate decomposition consumes dissolved oxygen in surface waters. Low dissolved oxygen levels in surface waters can cause unpleasant odors and discoloration of water.

2.2.2.6 Nonylphenol and Nonylphenol Ethoxylates

The widespread use of nonylphenol ethoxylates ($\text{C}_9\text{H}_{19}\text{-C}_6\text{H}_4\text{O}(\text{CH}_2\text{CH}_2\text{O})_n\text{H}^a$) as a surfactant additive in Type I and Type IV ADF formulations has been well documented in the literature. Nonylphenol is a common decay product of nonylphenol ethoxylates. Surfactants typically comprise less than 2% by volume of ADFs. There is currently uncertainty, however, over the extent to which manufacturers have recently modified ADF formulations to replace nonylphenol ethoxylates with other types of surfactants.

Nonylphenol ethoxylates and nonylphenol can have toxic and estrogenic properties and persist in the environment. They can cause mortality and endocrine disruption in aquatic organisms. Some preliminary data suggest that nonylphenol may cause cancer and reproductive problems in human beings.

Nonylphenol ethoxylate and nonylphenol contamination has been detected in surface waters, groundwater, sediments, aquatic organisms, and wastewater discharges at or near airports using ADFs. This profile and *Table A-47* in *Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of nonylphenol and its ethoxylates.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of nonylphenol ethoxylates and nonylphenol. As discussed in previous sections, airport deicing products containing nonylphenol ethoxylates and nonylphenol can enter surface waters, soil, and groundwater on or near airports.

Nonylphenol and its ethoxylates are a large class of alkylated phenols with varying physical properties; fate, transport, and partitioning behavior vary somewhat by ethoxymer.

Nonylphenol has very low volatility. Its ethoxylates are also not expected to volatilize readily. However, nonylphenol ethoxylates can be released into the atmosphere by spray application of ADF to aircraft, particularly under windy conditions, and by shearing of ADF from aircraft during taxiing and take-off. Nonylphenol ethoxylates are expected to degrade rapidly in air (Environment Canada 2002).

Nonylphenol ethoxylates are likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymer and degree of hydrophobicity. Migration of nonylphenol ethoxylates through the soil has been observed (Environment Canada 2002). In water, as in soil, nonylphenol ethoxylates may sorb to organic matter or particulates (Environment Canada 2002). The decay product nonylphenol is likely to partition to sediments and mineral particles in water and soil but can still leach through soils (Environment Canada 2002).

Degradation of nonylphenol ethoxylates varies by ethoxymer and tends to produce some recalcitrant compounds with endocrine disrupting potential, including nonylphenol, nonylphenol monoethoxylate, nonylphenol diethoxylate, nonylphenoxycetic acid, and nonylphenoxyethoxycetic acid (Environment Canada 2002). Observed half-lives for nonylphenol ethoxylates in environmental media range from 3 to 26 days under ideal aerobic conditions with an acclimated microbial community (Staples et al. 2001). For nonylphenol, a biphasic degradation profile has been observed in soils with relatively rapid initial degradation of 30-50% during the first several weeks and the remainder degrading with a half-life of approximately 90 days (Environment Canada 2002). Degradation rate also appears to be strongly dependent on the environmental medium. Half-lives of nonylphenol range from 2.4 hours to 0.74 d in water (US NLM 2008). The photolytic half-life of nonylphenol in the upper layer of surface water is 10-15 hours but is much slower in deeper layers. In a sediment mesocosm, a half-life of 66 days was observed for nonylphenol (Environment Canada 2008a).

Ecological Effects

Nonylphenol ethoxylates are highly toxic to many aquatic species. Nonylphenol ethoxylates degrade quickly and are therefore chiefly of concern because of their acute effects. Nonylphenol, the primary degradation product of nonylphenol ethoxylates persists in water for substantially longer time periods than nonylphenol ethoxylates and is more likely to contribute to chronic, as well as acute, effects. It is one of the most prevalent contaminants in U.S. streams, both in terms of the number of streams affected and the concentrations found (US EPA 2005).

The primary impacts of these chemicals on aquatic life are sublethal toxic effects, although at sufficient doses both can cause mortality. Nonylphenol ethoxylate toxicity has not been studied to the same extent as nonylphenol toxicity, but several types of adverse impacts have been noted. These impacts include acute mortality in some sensitive species at concentrations as low as 2.8 mg/L, reproduction impacts,

diminished egg emergence in aquatic animals, and growth impairment in algae and aquatic animal species. Nonylphenol ethoxylates are not thought to bioaccumulate in any species (Environment Canada 2001). A study by Corsi et al. (2006) found that in certain Type I and Type IV deicing formulations, nonylphenol ethoxylates were responsible for 40 to 50% of toxicity in one Type I and one Type IV formulation for several species. However, it was not detected in three of the other formulations tested, and was responsible for only a small fraction of toxicity in the remaining four.

An EPA study of the effects of nonylphenol on aquatic life found that at concentrations as low as 0.01 mg/L, impacts include reproduction impairment, reduced numbers of live offspring, diminished growth, and reduced offspring survival (US EPA 2005). Several other studies address estrogenic or other reproductive effects, including evidence suggesting increased vitellogenin concentrations in fish from chronic nonylphenol exposure and, at high concentrations, impacts on sex ratios and spawning habits. Nonylphenol has also been shown to inhibit growth and cellular counts in algae and to potentially bioaccumulate in some mollusk species. EPA has stated that the maximum acceptable one-hour average concentrations of nonylphenol in freshwater is 28 µg/L and 7.0 µg/L in saltwater. The maximum acceptable four-day average is 6.6 µg/L in freshwater and 1.7 µg/L in saltwater (US EPA 2005).

Human Health and Aquatic Resource Use Effects

Human exposure to nonylphenol and its ethoxylates can occur through ingestion, inhalation, and absorption through the eyes or skin (US EPA 2006a). Fish consumption is the largest contributor to human exposure, and is estimated to account for roughly 70 to 80% of typical daily doses (UNEP et al. 2004). This pollutant primarily affects the upper respiratory system and kidneys. Exposure symptoms can include skin and eye irritation, tissue decay, swelling, mottled kidneys, lethargy, coughing, wheezing, shortness of breath, headache, nausea, diarrhea, and vomiting. Data show that low concentrations of these chemicals act as mild irritants. High concentrations of nonylphenol and its ethoxylates may be extremely destructive to the upper respiratory tract, eyes, and skin (US EPA 2006a, Cox 1996), but human beings are unlikely to encounter such concentrations through exposure to aquatic resources contaminated by airport deicing products. The no observed adverse effect level is considered to be 10 mg/kg*day.

Current evidence of this pollutant as a genotoxin or carcinogen is inconclusive, but data seem to suggest that nonylphenol ethoxylates cause breast cancer cells to increase in number. Nonylphenol has also demonstrated estrogenic behavior, causing an increase in breast tumor numbers and size, reproductive problems, and various hormonal disruptions (UNEP et al. 2004).

2.2.2.7 Polyacrylic Acid

Polyacrylic acid ($C_3H_4O_2$)_n is composed of a connected series of acrylic acid monomers. This chemical is used as a thickener in some Type IV ADFs to make them viscous enough to maintain their position on aircraft surfaces until aircraft take-off. Thickeners and other ADF additives typically make up less than 2% of ADF volume. During degradation in the natural environment, polyacrylic acid can break down into its component monomers. Polyacrylic acid and acrylic acid monomers have been linked to human health problems, adverse impacts on aquatic life, and disruptions of aquatic community trophic webs. This section and *Table A-48 in Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of polyacrylic acid.

Fate and Transport

Polyacrylic acids comprise a family of polymers. They are usually marketed as mixtures of polymers by molecular weight. The behavior of these mixtures in the environment may vary somewhat, but overall they are fairly similar (US NLM 2008).

Polyacrylic acids are not expected to volatilize from water or moist soil (US NLM 2008). Slow volatilization from dry soil is possible (US NLM 2008). They are not expected to adsorb to soils or particulates, therefore potential for transport in soils, surface waters, and groundwater is high (US NLM 2008).

Biodegradability decreases with an increasing number of polymerized units and increasing formula molecular weight. Biodegradability drops off sharply between molecular weights 700 and 1,000, and for polymers with more than seven units (Larson et al. 1997). It appears that monomers and dimers of acrylic acid are completely biodegradable, but there is evidence that polymers of three to seven units are incompletely biodegraded (Larson et al. 1997).

Non-polymerized (monomeric) acrylic acid biodegrades fairly quickly under both aerobic and anaerobic conditions. For example, it was 68% degraded within two weeks with an activated sludge inoculum. In a 42-day anaerobic study with a sewage seed inoculum, 71% was degraded (US NLM 2008).

It is possible for substances such as polyacrylic acids, which are slowly biodegradable, to accumulate in soils and to enhance the growth of microbial biomass in those soils. If microbial growth is high enough, the pores of the soil can become plugged with microbial biomass. This process can lead to plume spreading as new loadings of polyacrylic acid contaminated runoff are forced around regions of low permeability.

Ecological Effects

Acute toxicity impacts on numerous invertebrates and fish have been noted for acrylic acid, primarily in the form of mortality but also in the form of behavioral changes in the water flea (*Daphnia magna*). Some studies also note growth rate inhibition and biomass reductions in green and blue-green algae. These effects may occur at levels as low as 0.17 mg/L (IPCS 1997).

Human Health and Aquatic Resource Use Effects

Exposure to acrylic acid can occur through inhalation, ingestion, and skin or eye contact, and can cause a variety of ailments including irritation to the eyes, skin, and respiratory system; eye and skin burns; skin sensitization; and lung, liver, and kidney disease (as revealed through animal studies) (NIOSH 2005b).

Currently there have been no reports of poisoning incidents in the general population. Most data indicate that this pollutant is of low to moderate acute toxicity by the oral route (NOAEL 140 mg/kg/day), and moderate acute toxicity by the inhalation (LOAEL 15 mg/m³) or dermal route. It is unclear what concentration is non-irritant. Available reproduction studies indicate that acrylic acid is not teratogenic (i.e., does not cause birth defects) and has no effect on reproduction. The current data available are inconclusive regarding carcinogenic health hazards associated with acrylic acid exposure (US NLM 2008).

Acrylic acid monomers have a strong acrid odor, though no reports have linked this odor specifically to airport deicing discharges (BAMM 2006).

2.2.2.8 Potassium

Potassium acetate is used as a freezing point depressant in airfield pavement deicers and is applied in large quantities at a number of airports. The chemical is typically applied in liquid form and releases potassium into the surrounding environment in its ionic form. Following dissolution after application, solid forms of potassium acetate also releases potassium in its ionic form to the environment. Potassium can elevate measures of salinity, conductance, or total dissolved solids (TDS) in surface waters. It can impact aquatic environments and, at high levels, cause health problems in human beings. This section and

Table A-49 of Appendix A summarize data on the environmental fate and transport, ecological effects, and human effects of potassium.

Fate and Transport

Ionic potassium is highly soluble and highly mobile in both surface water and groundwater. In soil, potassium can accumulate in areas where there is insufficient water available to transport it through the soil horizon. Otherwise, it is transported easily through soil and can enter and travel with groundwater.

As an elemental ion, potassium is not subject to decay and persists in the environment. It is not expected to volatilize.

Ecological Effects

Most freshwater surface waters contain a small quantity of potassium. Fish require potassium for growth, reproduction, and survival. Freshwater fish actively assimilate potassium from food and water. Saltwater fish are generally at lower risk of potassium deficiency than freshwater fish because marine water contains higher levels of potassium than fresh water. High potassium loadings or long turnover times, however, can create surface water ion balance issues that can impact aquatic organism functioning and survival (Public Sector Consultants 1993).

Exposure to high levels of potassium can cause osmoregulatory dysfunction in aquatic organisms. Freshwater fish tissues typically have higher potassium content than surrounding water. Under normal conditions, freshwater fish use their gills, circulatory system, and kidneys to work against this osmotic gradient in order to prevent the influx of excess water and the loss of potassium from their tissues. Specialized cells in fish gill epithelium use potassium and sodium ions to transport chloride into or out of fish tissue (Jobling 1996). In marine fish, chloride ions are pumped from fish against an osmotic gradient. This process helps to maintain optimal osmotic potential between the fish and its environment.

The process moves potassium ions in the opposite direction in freshwater fish. The gill has mechanisms which actively work to re-import potassium into the blood in order to replace potassium lost through the gills. When external potassium levels exceed internal potassium levels, these osmoregulatory mechanisms can lead to rapid fish dehydration, ionoregulatory system imbalance, and impairment to fish functioning and survival.

Exposure to excessive potassium concentrations can interfere with these essential osmoregulatory mechanisms in both freshwater and saltwater fish, requiring fish to expend more energy to maintain homeostasis or, if concentrations are high enough, cause death through ionic imbalance.

In lakes, increased salt concentrations can also lead to increased density of water layers, leading to or exacerbating stratification during cold or still weather to the point that normal seasonal overturn does not occur (D'Itri 1992).

Plants use potassium to regulate ion transport. Plants exposed to high concentrations of potassium suffer adverse effects similar to those associated with potassium deficiencies by causing deficiencies in magnesium and calcium (Motavalli et al. 2008), which are essential for growth, reproduction, and survival.

Human Health and Aquatic Resource Use Effects

Potassium is an essential part of the human diet. This element is an essential in preventing and treating high blood pressure, hypoglycemia, diabetes, kidney disease, obesity, and potentially paralysis. The absence of adequate potassium in the diet may lead to listlessness, fatigue, gas pains, constipation,

insomnia, and low blood sugar. Moreover, deficient individuals may have weak muscles and a slow, irregular pulse (IFIC 2005).

This element is beneficial at lower levels but may have detrimental health impacts if consumed in excess. U.S. health guidelines advise that no more than 4,700 mg potassium be consumed each day (US HHS and DoA 2005). However, many humans do not consume *enough* potassium. Human beings may ingest potassium from airport deicing discharges through consumption of contaminated drinking water sources.

2.2.2.9 Propylene Glycol

Like ethylene glycol, propylene glycol ($C_3H_8O_2$) is a well-known freezing point depressant used in many Type I and Type IV ADFs. These fluids are applied in large quantities at a number of airports. Most ADF in current use at U.S. airports is based on propylene glycol. Before dilution for application, an ADF can consist of nearly 90% propylene glycol. Propylene glycol is also used in some airfield pavement deicer formulations. For this reason, large quantities of propylene glycol can be released to the environment during airport deicing activities. Propylene glycol contamination has been detected in surface waters, groundwater, sediments, and wastewater discharges at or near airports using ADFs.

Though more expensive than ethylene glycol, propylene glycol is considerably less toxic to human beings and other mammals. When released to surface waters in large quantities, however, it has the potential to consume large quantities of dissolved oxygen from the water column, potentially affecting the ecosystem and human use of aquatic resources. This profile and *Table A-50* in *Appendix A* summarizes available information on the environmental fate and transport, ecological effects, and human effects of propylene glycol.

Fate and Transport

This section summarizes the environmental fate and transport characteristics of propylene glycol. As discussed in previous sections, deicing products containing propylene glycol can enter surface waters, soil, and groundwater on or near airports.

Volatilization of propylene glycol from soil or water is not, in general, expected (US NLM 2008). However, propylene glycol can be released into the atmosphere by spray application of ADF to aircraft, particularly under windy conditions, and by shearing of ADF from aircraft during taxiing and take-off. Propylene glycol's atmospheric half-life is 32 hours at 25° C (US NLM 2008).

Propylene glycol is freely soluble in water, and has very high mobility in soils, sediments, surface water, and groundwater (US NLM 2008). Estimates of $\log K_{OW}$ for propylene glycol are low, and range from –0.92 (US NLM 2008) to –1.41 (French et al. 2001, as cited in Jaesche et al. 2006). These low estimates of K_{OW} support the observations of Jaesche et al. (2006), who found negligible soil sorption in laboratory experiments. Propylene glycol should also exhibit minimal partitioning to sediments or suspended particles in water. Given these behaviors, the distance propylene glycol travels in surface water, groundwater, and soil will depend primarily on the balance between rates of transport and degradation.

Propylene glycol undergoes rapid microbial degradation in both soil and water. It can biodegrade under both aerobic and anaerobic conditions. For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins. Microbial communities acclimated to glycol inflows can begin degradation much sooner. Additives in ADFs, however, can significantly delay degradation (Johnson et al. 2001). In microcosm experiments under aerobic conditions, degradation rates of up to 95 milligrams of propylene glycol per day per kilogram of dry soil were observed by Klecka et al. (1993; as cited in Jaesche et al. 2006). Jaesche et al. (2006) found that in subsoil materials, the anaerobic

degradation of propylene glycol was very slow and was dependent on the import of microbiota from surface soils.

Propylene glycol degradation is also temperature-dependent. In laboratory experiments with field-collected soils, propylene glycol was not observed to degrade anaerobically at 4° C, and degraded anaerobically at 20° C only in soil that was rich in organic matter (Jaesche et al. 2006).

During anaerobic wastewater treatment, propylene glycol degrades first to propionaldehyde, then to propionate and 1-propanol. The final products are acetate, methane, and carbon dioxide (Jaesche et al. 2006).

Propylene glycol degradation requires a great deal of oxygen, with an estimated CBOD₅ of 1 g O₂/g of propylene glycol, or 1,000 g O₂ per liter of propylene glycol (Mericas and Wagoner 1994; Safferman et al. 1998, all as cited in Johnson et al. 2001).

Anaerobic degradation of propylene glycol can increase the efflux of terminal electron acceptors such as iron and manganese (hydr)oxides from soils (Jaesche et al. 2006). Over time, continued input of propylene glycol can therefore lead to a reduction in soil's redox potential, promoting anoxic conditions in the soil (Jaesche et al. 2006).

Ecological Effects

Data on propylene glycol's toxicity for aquatic organisms is relatively limited, though it is generally perceived as being relatively low. Available data indicate that propylene glycol may cause general chronic toxicity effects, including slower growth and inhibited reproduction, as well as acute mortality at concentrations greater than 5000 mg/L. A study by Corsi et al. (2006) found that in certain Type I formulations, propylene glycol had a greater toxic effect on its own than did the formulation.² However, it contributed a much smaller percentage of the toxicity of the formulation to the fathead minnow, the daphnid *Ceriodaphnia dubia*, and Microtox testing for both Type I and Type IV fluids (ranging from less than 1% to 51%).

Propylene glycol is known to exert high levels of biological oxygen demand (BOD) during degradation in surface waters. This process can adversely affect aquatic life by consuming oxygen aquatic organisms need to survive (Corsi et al. 2001). Large quantities of dissolved oxygen (DO) in the water column are consumed when microbial populations decompose ethylene glycol.

Sufficient DO levels in surface waters are critical for the survival of fish, macroinvertebrates, and other aquatic organisms. If oxygen concentrations drop below a minimum level, organisms emigrate, if able and possible, to areas with higher oxygen levels or eventually die (US EPA 1993). This effect can drastically reduce the amount of useable aquatic habitat. Reductions in DO levels can reduce or eliminate bottom-feeder populations, create conditions that favor a change in a community's species profile, or alter critical food-web interactions.

Human Health and Aquatic Resource Use Effects

Unlike ethylene glycol, a cause of acute toxicity in human beings and other mammals, propylene glycol is generally considered to be safe and a rare cause of toxic effects. Human exposure to propylene glycol can occur through dermal contact, inhalation, ingestion, and eye contact

² The paper explains that this may be caused either by uncertainty in calculating the relative toxicity factors, or by the possibility that the interactions of all chemicals in a deicing formulation may result in lower toxicity than propylene glycol alone.

Humans typically come in contact with propylene glycol through ingestion of food and medications and through dermal contact with cosmetics or topical medications. Background concentrations in foods range from < 0.001% in eggs and soups to about 15% in some seasonings and flavorings. No health effects have been reported in persons chronically exposed to propylene glycol at levels found in the environment. Some special-risk groups may be more sensitive at lower levels; these include neonates, infants and the elderly, or those with pre-existing skin or eye conditions or allergies (US HHS 2007b).

Extensive topical application has been known to cause burns to the skin. The common use of propylene glycol in burn creams has been associated with hyperosmolality, lactic acidosis (the build-up of lactic acid in the body), intravascular hemolysis (the rupturing of blood vessels), central nervous system depression, seizures, coma, hypoglycemia (low blood sugar) and renal failure, although only in very high doses (US HHS 2007b). For example, one study found an LD50 in the rat of 30,000 mg/kg (US EPA 2000a). However, it is expected that this level of exposure through human contact with propylene glycol-contaminated aquatic resources would be very unlikely.

Several news articles have reported strong sweet odors downstream from airport deicing outfalls which are believed to be linked to ethylene glycol and propylene glycol discharges (e.g., Hopey 1998). Additionally, anoxic waters, which can result from the high BOD propylene glycol exerts, typically produce a strong, unpleasant odor (State of Ohio Environmental Protection Agency 2001).

2.2.2.10 Sodium

Sodium acetate and sodium formate are used as freezing point depressants in airfield pavement deicers and are applied in large quantities at a number of airports. The dissolution of these chemicals after application releases sodium into the environment in its ionic form. Sodium can elevate measures of salinity, conductance, or total dissolved solids (TDS) in surface waters. It can impact aquatic environments and, at high levels, cause health problems in human beings. This section and *Table A-51 of Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of sodium.

Fate and Transport

Sodium is highly soluble and highly mobile in both surface water and groundwater. In soil, sodium can accumulate in areas where there is insufficient water available to transport it through the soil horizon. Otherwise, it is transported easily through soil and can enter and travel with groundwater.

When sodium replaces calcium in soil through an anion exchange process, the structure of the soil can deteriorate, and aeration and water availability decrease (D'Itri 1992). Poor soil structure due to high sodium levels can also increase the soil mobility of metals (Amrhein and Strong 1990, as cited in D'Itri 1992).

As an elemental ion, sodium is not subject to decay and persists in the environment. It is not expected to volatilize.

Ecological Effects

Most freshwater surface waters contain a small quantity of sodium. High sodium loadings or long turnover times, however, can create surface water ion balance issues that can impact aquatic organism functioning and survival (Public Sector Consultants 1993).

Freshwater aquatic organisms are very sensitive to excess sodium in surface waters. Exposure to high levels of sodium can cause osmoregulatory dysfunction. Freshwater fish tissues typically have higher sodium content than surrounding water. Under normal conditions, freshwater fish use their gills,

circulatory system, and kidneys to work against this osmotic gradient in order to prevent the influx of excess water and the loss of sodium from their tissues.

Sodium loss and water influx takes place at the fish gill surface. Specialized cells in fish gill epithelium use potassium and sodium ions to transport chloride into or out of fish tissue (Jobling 1996). In marine fish, chloride ions are pumped from fish against an osmotic gradient. This process helps to maintain optimal osmotic potential between the fish and its environment.

In freshwater fish, the process moves ions in the opposite direction. The fish's circulatory system moves excess water to the kidney where it is rapidly excreted. The gill has mechanisms which actively work to re-import sodium into the blood in order to replace sodium lost through the gills. When external sodium levels exceed internal sodium levels, these mechanisms can contribute to rapid fish dehydration, ionoregulatory system imbalance, and impairment to fish functioning and survival.

Exposure to excessive potassium concentrations can interfere with these essential osmoregulatory mechanisms in both freshwater and saltwater fish, requiring fish to expend more energy to maintain homeostasis or, if concentrations are high enough, cause death through ionic imbalance.

In lakes, increased salt concentrations can also lead to increased density of water layers, leading to or exacerbating stratification during cold or still weather to the point that normal seasonal overturn does not occur (D'Itri 1992).

Both aquatic and terrestrial plants are susceptible to damage following exposure to excess sodium in surface water, soil, porewater, and groundwater. Sodium-induced plant damage occurs in several ways (Moran et al. 1992). First, increasing osmotic pressure of the surrounding water (for aquatic plants) or soil solution increases sodium migration into and water diffusion from the cells, causing dehydration. Second, sodium ion accumulation in plant tissues can reach toxic concentrations. This is often visible in leaf margins, as transpiration pulls water into the leaves. As water evaporates from leaves, sodium ions remain behind and accumulate to toxic levels (University of Illinois Extension 2008). Sodium inhibits many enzymes in plants and is particularly harmful when intracellular potassium is low relative to sodium, as discussed below (Zhu 2007). Third, sodium stress induces the production of abscisic acid, which causes stomata to close and reduces gas exchange and photosynthesis (Zhu 2007).

In addition, the mineral composition of the soil can become unbalanced, making plant nutrient absorption more difficult (Moran et al. 1992). Sodium out-competes potassium for uptake by plant roots, eventually leading to potassium deficiency. Sufficient potassium levels are critical for maintaining adequate cell turgor (fluid pressure), membrane potential, and enzymatic activity (Zhu 2007).

Human Health and Aquatic Resource Use Effects

Sodium is a necessary component of the human diet. While this element is vital in small amounts, excessive consumption may have adverse health effects. Health guidelines advise humans to consume 2,300 mg (1 teaspoon) of sodium per day (US HHS and DoA 2005). At elevated levels, this element is known to cause high blood pressure and possibly calcium loss. Human beings may ingest sodium from airport deicing discharges through consumption of contaminated drinking water sources.

2.2.2.11 Tolyltriazoles, Benzotriazoles, and Methyl-substituted Benzotriazoles

The Society of Automotive Engineers (SAE) requires glycol-based ADFs to contain a fire suppressant because of concerns about ADF flammability in some aircraft electrical systems. The use of tolyltriazoles ($C_7H_7N_3$), benzotriazoles, or methyl-substituted benzotriazoles as flame retardants and corrosion inhibitors in ADFs has been documented in the literature. Tolyltriazole refers to a mixture of the 4-methyl

and 5-methyl isomers of benzotriazole. Methyl-substituted benzotriazoles have a methyl group attached to the benzene ring. These chemicals, along with other ADF additives, typically comprise less than 2% of ADF volume. Studies have identified the presence of these chemicals in drainage ditches, groundwater, wells, and soils on or near airports where ADFs have been used. This profile and *Table A-52* in *Appendix A* summarizes data on these chemicals' environmental fate and transport, ecological effects, and human effects.

Fate and Transport

Volatilization of tolyltriazole is not expected (US NLM 2008).

Benzotriazoles are highly polar and dissolve well in water (Weiss et al. 2006). All triazoles are expected to be highly mobile in surface water, groundwater, and soils (US NLM 2008, Breedveld et al. 2003). Methyltriazoles are known to be mobile in groundwater (US NLM 2008). However, triazoles may protonate in some environmental matrices, and the cationic form would be expected to bind to organic material and clays (US NLM 2008). Methylbenzotriazole was found to sorb to digested sludge (Gruden et al. 2001), and thus may be able to bind to organic carbon in soil. Sorption is not expected to be very significant in soils, however. Breedveld et al. (2003) found that benzotriazole showed very little sorption in various soil matrices, and only peat and compost with a high organic carbon content showed significant sorption.

Photolysis is a potential route of degradation in environmental media with high exposure to light (US NLM 2008).

Biodegradation of these compounds varies by isomer. 5-methylbenzotriazole is much more aerobically degradable than the 4-methylbenzotriazole isomer (Weiss and Reemtsma 2005). The same pattern was observed in bench-scale bioreactor experiments in which 5-methyltriazole was completely biodegraded within 17 days, but 4-methyltriazole was only 25% biodegraded after 28 days, and the remainder was recalcitrant to further degradation (Weiss et al. 2006). Furthermore, 5-methylbenzotriazole was found to be "unstable" in cooling towers (an aerobic environment), whereas 4-methylbenzotriazole was not degraded (Gruden et al. 2001).

Another study found that methylbenzotriazole (isomer not specified) was not anaerobically digestible in lab experiments (Gruden et al. 2001). Anaerobic degradation was not observed for benzotriazole and its derivatives in lab reactor experiments (Tham and Kennedy 2005). Davis et al. (2000) have demonstrated that higher plants and white rot fungi can take up and degrade triazoles. No information was located on the degradation products of benzotriazoles.

Weiss and Reemtsma (2005) found that both benzotriazole and 4-methylbenzotriazole survived bank filtration treatment although 5-methylbenzotriazole did not. Ozonation appears to be capable of almost completely removing benzotriazole and 4- and 5-methylbenzotriazole from wastewater and might also be able to remove them during drinking water treatment, where this technology is used (Weiss et al. 2006).

One study found that up to 300 mg/l of benzotriazole only slightly inhibited the anaerobic degradation of glycols, that up to 20 mg/l of 5,6-dimethylbenzotriazole did not inhibit their anaerobic degradation, and that 300 mg/l of 5-methylbenzotriazole was capable of severely inhibiting their anaerobic degradation (Johnson et al. 2001).

Benzotriazole and methylbenzotriazole have been detected in groundwater near an airport at levels greater than 100 mg/l. This concentration is high enough to be potentially toxic to microbiota, fish, and invertebrates (Cancilla et al. 1998). At two airports, 4-methyltriazole was detected in all wells sampled,

but 5-methyltriazole was not detected in any of the wells (Cancilla et al. 2003 and Cancilla et al. 1998). Breedveld et al. (1997) reported soil concentrations of up to 13 mg/kg in a drainage ditch and up to 1.1 mg/l in groundwater at Oslo Airport one to two years after deicing was discontinued.

Ecological Effects

Triazoles are a major contributor to ADF toxicity and may be responsible for the majority of total toxicity in some formulations (Corsi et al. 2006). Triazoles are several orders of magnitude more acutely toxic than glycols to multiple aquatic species, including the bluegill (*Lepomis macrochirus*) and the water flea (*Daphnia magna*). The LC₅₀ for the waterflea for tolyltriazole is 74 mg/L. Tolyltriazole is considered to be more toxic than other benzotriazoles. Though not likely to bioaccumulate, triazoles may persist in the aquatic environment due to their resistance to natural degradation (British Environment Agency 2000).

Human Health and Aquatic Resource Use Effects

EPA's search of publicly available literature yielded no consistent or conclusive information on the impact of triazoles on human health or the aesthetic attributes of receiving waters.

2.2.2.12 Urea (Ammonia)

Urea (NH₂CONH₂) is used as a freezing point depressant in airfield pavement deicers and is applied in large quantities at a number of airports. It is typically used as a solid pavement deicer or in combination with ethylene or propylene glycol as a liquid pavement deicer. Urea is also a common fertilizer that enhances plant growth. Urea forms ammonia (NH₃) during decay. Ammonia is toxic to aquatic organisms at low concentrations and can cause both organism mortality and reproduction impairment. Ammonia can further decay in aquatic environments into several nitrogen-containing compounds (e.g., nitrate) that can fertilize aquatic plants and foster biological overgrowths. Ammonia may cause minor to severe dermal or pulmonary irritation to human beings who come into contact with it. Urea and ammonia have been documented as contaminants in surface waters, groundwater, and soil in and near airports using urea as a pavement deicer. This section and *Table A-53 of Appendix A* summarize data on the environmental fate and transport, ecological effects, and human effects of formate.

Fate and Transport

Urea has a low vapor pressure and is not expected to volatilize readily from soil or water (US NLM 2008). Ammonia, a by-product of urea degradation, is quite volatile.

Urea has a solubility of 545 g/l, making it reasonably soluble (US NLM 2008). Urea is transported readily in surface water and its presence has been documented in groundwater at several airports using urea as a pavement deicer. This is despite the fact that urea's soil infiltration is thought to be minimal except where the soil is sandy (D'Itri 1992). Transport Canada (1990) (as cited in D'Itri 1992) reported that between 64 and 100% of applied urea can reach surface waters via overland flow. Urea can also accumulate in snowbanks and be released as a large load in a short amount of time during snowmelt (D'Itri 1992).

Urea biodegrades well under aerobic conditions and produces ammonia which eventually degrades to nitrate. The degradation rate is temperature dependent and is expected to be slow during winter. After 14 days in river water at 8° C, degradation was almost nil (Evans and Patterson 1973 as cited in D'Itri 1992). At 20 degrees Celsius, urea fully degraded to ammonia within 4 to 6 days (Cryotech 2008).

Urea contains 46% nitrogen by weight, making it a potential contributor to undesirable eutrophication of surface waters (D'Itri 1992). Urea's BOD is approximately 1.8 g O₂/g urea (Cryotech 2008) and is much higher than that of acetate and formate-based pavement deicers, as well as higher than that of ethylene glycol or propylene glycol-based pavement deicers and ADFs.

Ammonia levels in runoff from airports have been commonly reported at levels between 2 and 15 mg/L and can be higher (D'Itri 1992). These levels are potentially toxic to fish and other aquatic organisms.

Ecological Effects

Urea is not particularly toxic to aquatic life. However, urea degrades to ammonia which is highly toxic to many aquatic organisms. EPA established a National Recommended Water Quality Criterion for ammonia in 1984 and last revised it in 1998. Because of ammonia's unique properties, the criteria are dependent on pH, temperature, and organism life stage. Ammonia is most toxic in its un-ionized form which is more likely to exist at higher temperatures and pH levels. If salmonids are present, acute criteria range from 0.885 to 32.6 mg N/l, depending upon pH. If salmonids are not present, acute criteria range from 1.32 to 48.8 mg N/l. Chronic criteria, which do not vary according to salmonid presence or absence, range from 0.254 to 3.48 mg N/l, depending upon pH (US EPA 1998a).

Ammonia is capable of causing acute mortality in many aquatic organisms, particularly at higher concentrations. Ammonia can also cause a host of chronic effects in aquatic organisms, including reproduction inhibition, diminished juvenile growth, and reduced embryo and neonate survival. Salmonid fish are particularly sensitive, and EPA's ammonia standard is stricter for water bodies in which they are present. For example, one study determined an LC₅₀ for the rainbow trout (*Oncorhynchus mykiss*) of 0.068 mg/L (US EPA 1998a). Ammonia has been noted as a major cause of fish kills (US EPA 1991; USDA 1992). In addition, if surface water substrate sediments are enriched with nutrients, the concentrations of nitrites on the overlying water can be raised enough to cause nitrite poisoning or "brown blood disease" in fish (USDA 1992).

Ammonia further decays in aquatic environments to nitrates. Nitrates function as a source of nitrogen nutrients. Surface water eutrophication due to excessive nutrient levels can produce ecological impacts such as nuisance algal blooms, death of underwater plants (due to reduced light penetration through turbid waters), reduced dissolved oxygen levels, and impaired aquatic organism populations.

Human Health and Aquatic Resource Use Effects

A person ingests an average of 0.36 mg/day of ammonia through drinking water sources (US HHS 2004). Ammonia begins to be noticeable to drinking water consumers at 35 ppm (taste) to 50 ppm (odor). Low levels of exposure may not cause any problems in healthy individuals but may harm sensitive individuals such as those with asthma. At higher concentrations, ammonia exposure may also cause skin burns to the exposed area. Children respond to ammonia exposure in much the same way as adults. No evidence has been found to suggest that low-level chronic ammonia exposure causes birth defects or other developmental problems. However, chronic exposure has been found to cause transient respiratory distress (US HHS 2004).

Data for assessing the carcinogenic potential of ammonia are limited. At consumption levels of 200 milligrams per day, ammonia may act as a cancer promoter. However, well-designed animal studies have not yet been conducted in order to better elucidate ammonia's role as a potential carcinogen (US HHS 2004).

At high exposure levels, effects include irritation to the eyes, nose, and throat; dyspnea (breathing abnormalities), wheezing, and chest pain; pulmonary edema; pink frothy sputum; skin burns, and vesiculation (formation of blisters or vesicles) (NIOSH 2005c). Human exposure to such high levels through aquatic resources contaminated by airport deicing discharges is not expected.

3 Environmental Impact Potential under Current Airport Deicing Practices

This chapter summarizes the potential environmental impacts of airport deicing operation discharges under current conditions and industry practices. *Chapter 4* presents information on environmental improvements and benefits expected under each of EPA's final regulatory options.

This chapter provides information on facilities within scope of the final rule (*Section 3.1*), discusses factors that influence airport deicing pollutant discharges to the environment and provides an overview of current airport deicing pollutant discharges (*Section 3.2*), discusses factors influencing pollutant concentrations in surface waters (*Section 3.3*), summarizes documented environmental impacts from airport deicing activities (*Section 3.4*), and discusses potential impacts to impaired waters and other resources (*Section 3.5*).

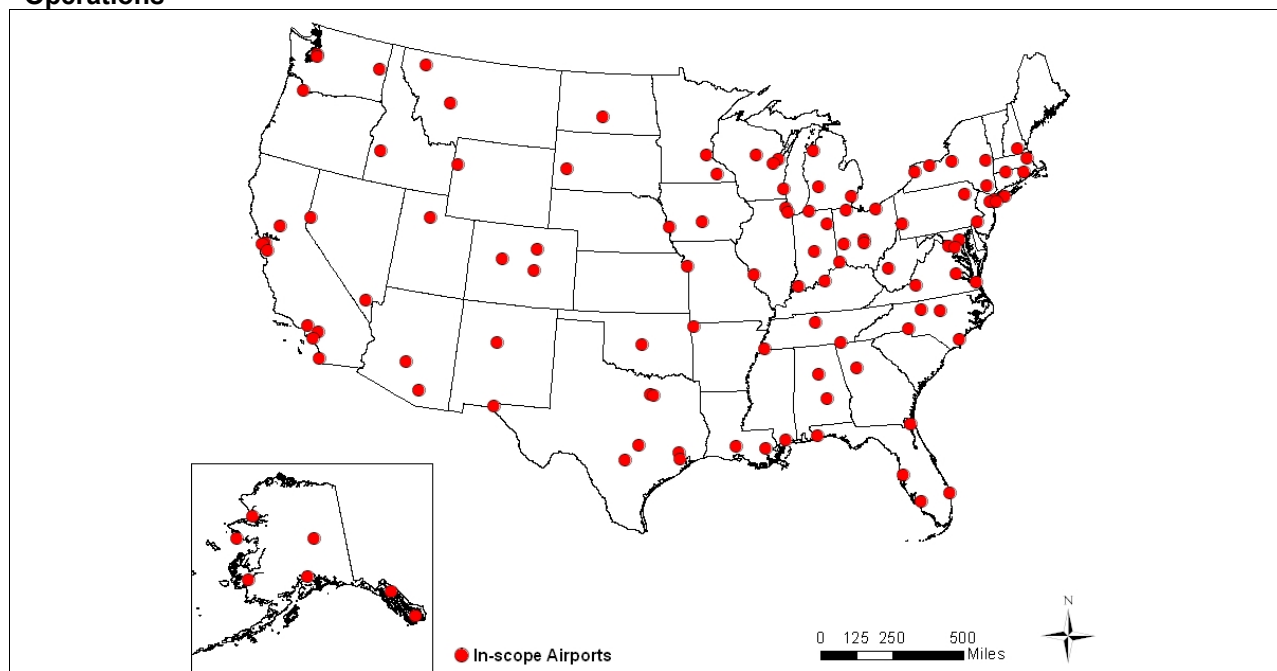
3.1 Universe of In-scope Airports

In determining the scope of the final regulatory options, EPA aimed to capture those airports that perform the majority of deicing operations in the United States. EPA's final regulatory options address airports with the following characteristics:

- Classified by FAA as primary commercial airports;
- Not categorized by FAA as general aviation or cargo airports;
- Greater than or equal to 1,000 non-propeller-driven aircraft departures annually; and
- Conduct aircraft or airfield pavement deicing operations.

EPA focused on primary commercial airports with greater than or equal to 1,000 annual non-propeller-driven aircraft departures because these airports are more likely to operate during inclement winter weather and conduct the majority of airport deicing operations. Although deicing takes place at some general aviation and cargo airports and primary commercial airports with fewer than 1,000 annual non-propeller-driven aircraft departures (see *Table 3-1*), EPA focused on an airport category that conducts the majority of airport deicing activity. *Table B-1* in *Appendix B* lists the airports within scope of the final regulatory options. *Figure 3-1* presents a map of the in-scope airports listed in *Appendix B*.

Figure 3-1: In-scope Airports for EPA's Effluent Guideline Regulations for Airport Deicing Operations



As shown in *Figure 3-1*, airports engaging in deicing activities are widely distributed throughout the U.S. These airports vary greatly, however, in the levels at which they conduct aircraft and pavement deicing and in their discharge environments. These variables are discussed in *Section 3.2*.

3.2 Airport Deicing Pollutant Discharges to the Environment

Airport deicing pollutant discharges to the environment vary widely among individual airports. Pollutant discharges can also vary widely from day to day at any individual airport. This variability is driven by individual airport deicing practices and environmental contexts and the weather-dependent nature of deicing activities and discharges. This section discusses a number of factors that influence airport deicing pollutant loads and also describes EPA's quantified estimates of national and individual airport deicing pollutant discharges.

3.2.1 Factors Influencing Airport Deicing Pollutant Discharge to the Environment

Several factors influence the nature and quantity of pollutant loadings to the environment at individual airports:

- Deicing product selection;
- Air traffic composition and levels;
- Airport treatment and collection practices;
- Airfield design; and
- Weather conditions.

3.2.1.1 Deicing Product Selection

Deicing product choice is the first determinant of deicing pollutant loadings at an individual airport. A variety of ADF and pavement deicer formulations are available for purchase and use by airports and airlines. These formulations contain one or two of several freezing point depressants, which constitute most of the formulation, as well as a variety of chemical additives. The formulations chosen by an airport or airlines affect the chemicals that will discharge to the environment. For example, an airport that chooses a potassium acetate-based pavement deicer will discharge potassium, undegraded acetate, COD/BOD, and unidentified additives to the environment; whereas an airport that chooses a urea-based pavement deicer will discharge undegraded urea, ammonia, nitrates, and higher levels of BOD/COD to the environment. For additional information on the types and quantities of different chemicals found in ADF and airfield pavement deicer formulations, see *Chapter 2*.

Multiple factors drive deicing product choice including airport climate, product performance, cost, availability, and compatibility with aircraft and airport infrastructure. Weather conditions also strongly influence the need for use of different types of airport deicing products. For example, during winter freezing precipitation events, the use of Type I ADF for aircraft deicing, Type IV ADF for aircraft anti-icing and pavement deicers may all be necessary to maintain aircraft operations. Environmental release of chemicals from all three product types would therefore be expected under these conditions. During calm winter conditions, use of only Type I ADF to remove light layers of frost from aircraft may be necessary, and under these conditions releases of chemicals associated with Type IV ADF and pavement deicers would not be expected.

3.2.1.2 Air Traffic Composition and Levels

Airports vary widely in the types of aircraft using their facilities and in total number of aircraft departures during the winter deicing season. EPA has focused the scope of the rule on those airports that have higher levels of non-propeller-driven aircraft departures (1,000 or more annually). Non-propeller-driven aircraft are more likely than other types of aircraft (e.g., propeller-driven aircraft) to continue operating during inclement winter weather. Airports with larger numbers of non-propeller-driven aircraft departures are more likely to use ADF and pavement deicers to maintain operations and therefore are more likely to discharge deicing pollutants.

The type of non-propeller-driven aircraft also makes a difference in the quantity of ADF released to the environment since larger non-propeller-driven aircraft require larger quantities of ADF than smaller non-propeller-driven aircraft for both deicing and anti-icing.

In addition, all other factors being equal, airports with larger numbers of non-propeller-driven aircraft and other aircraft departures will use larger quantities of deicing products.

3.2.1.3 Airport Deicing Pollutant Treatment and Collection Practices

Airports vary widely in the nature of their deicing pollutant collection and treatment practices. All airports discharge some or all of their deicing pollutants to surface waters near airports. Some airports collect a

portion of their deicing wastewaters and either treat them on-site or send them off-site to a publically owned treatment works (POTW) or other facility for treatment and discharge. Other airports discharge stormwater containing deicing pollutants to soil and groundwater. Many airports have a combination of these discharge conditions. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) provides additional information on the collection and treatment systems found at individual airports.

ADF and pavement deicer chemicals disperse widely during use. Type I and Type IV ADF drip and shear from aircraft during application, taxiing, and take-off. Airports apply pavement deicers to large expanses of airfield pavement found at many airports, including aprons, gate areas, taxiways, and runways. Due to this widespread product dispersion, large quantities of airport stormwater frequently contain some level of deicing pollutants. The large quantities and dispersed nature of contaminated stormwater make it difficult for airports to collect and treat more than a fraction of released deicing product. For this reason, most airports discharge the majority of their deicing pollutants to the environment.

Deicing collection and treatment systems vary in design and effectiveness by airport. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) describes collection and treatment technologies and their effectiveness in reducing deicing pollutant discharges in detail. For today's final rule, EPA assessed two ADF stormwater collection technologies and one stormwater treatment technology for the purpose of constructing regulatory options for existing airports. The assessed collection technologies include glycol collection vehicles (GCVs) and GCVs used in combination with "plug and pump" systems. The assessed treatment technology is anaerobic fluid bed (AFB) biological treatment. EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010) also discusses other approaches airports use to reduce discharge of deicing pollutants to surface waters.

3.2.1.4 Airfield Design

The configuration of airport grounds and infrastructure relative to surface waters, pervious surfaces, and groundwater also affect deicing pollutant dispersion in the environment. Influential airport design elements include:

- Stormwater infrastructure collection and delivery efficiency;
- Runway and taxiway proximity to surface waters;
- Airfield imperviousness;
- Airfield slope; and
- Amount of vegetation buffer between impervious areas and surface waters.

Stormwater collection and delivery systems at airports vary in their design delivery efficiency and condition. Some systems deliver large fractions of airport stormwater to a chosen destination quickly and without substantial volume loss during delivery. Other systems are designed or are in a condition such that substantial volumes of stormwater are lost prior to ultimate discharge. Pervious or partially pervious system elements such as unlined ditches and ponds and leaking stormwater pipes and storage units allow stormwater loss. Deicing pollutants in stormwater lost from collection and delivery systems typically enter the soil column where they degrade, accumulate, or eventually enter groundwater if present on airport grounds. Groundwater and the pollutants it contains may ultimately discharge to nearby surface waters or flow beyond airport property lines. In these situations, infiltration may slow and reduce

pollutant discharges to surface waters, but not eliminate them. In other cases, pollutants in groundwater may degrade before they discharge to surface waters or cross airport property lines.

Deicing pollutants can also degrade during stormwater transport and storage. Degradation rates are slower under cold temperatures and increase as temperatures rise. Systems that discharge stormwater more slowly, particularly those that hold stormwater until later in the year when average temperatures rise, allow greater opportunity for degradation of deicing pollutants prior to discharge. The degradation process can remove some chemicals of concern in deicing discharges. In some cases, however, degradation can create new pollutants of concern or a volume of stormwater with very low dissolved oxygen levels, both of which can be of concern if discharged to surface waters in sufficient quantities. For additional information on airport deicing product degradation products, see *Chapter 2*.

In general, the closer airport runways and taxiways are to surface waters, the greater the potential for deicing pollutants to enter those waters through stormwater flow, groundwater flow, or aerial deposition. Shorter distances reduce pollutant loss from stormwater transport systems, degradation, and soil retention. Shorter distances also make it more likely that ADF released to the air during taxiing and takeoff can be carried by the wind to surface waters. Some airport takeoff flight paths extend directly over surface waters and ADF shed during takeoff can fall directly into those surface waters. Conversely, greater distances increase opportunities for pollutant loss, retention, and degradation.,

As the imperviousness and slope of the airport grounds increase, the amount of stormwater runoff available to mobilize and carry deicing pollutants to surface waters tends to increase. Pervious areas on airfields can include areas of vegetation or bare soil as well as paved areas with cracked surfaces. Vegetation buffers between impervious areas where ADF and pavement deicers are initially released and surface waters can decrease the amount of stormwater and pollutants entering surface waters by providing an opportunity for stormwater infiltration and pollutant accumulation or degradation in the soil column.

Pollutants associated with Type IV fluids and pavement deicers, in particular, are affected by overall airfield design because of their widespread dispersion in the airfield. A smaller proportion of Type I fluids are affected by overall airfield design because most are released to the environment close to ADF application sites. Type I ADF dispersion is therefore most influenced by the design of the particular portions of the airfield that contain and drain stormwater from ADF application sites.

3.2.1.5 Weather Conditions

Because the use of ADF and airfield pavement deicers is so weather-dependent, deicing pollutant discharges among individual airports vary widely with differences in climate and typical winter weather conditions. Deicing pollutant discharges can also vary widely from year-to-year and day-to-day at individual airports as winter weather conditions vary at airports on seasonal and daily bases. In addition to influencing choice of deicing product for application, as discussed above, weather conditions also influence the quantity of product applied and its dispersion in the environment.

Important factors influencing the quantity and dispersion of airport deicing products include:

- Precipitation type (e.g., freezing rain, sleet, snow, rain or a mixture);
- Ground and air temperatures;
- Precipitation event magnitude; and
- Precipitation event timing.

Winter precipitation types range from rain to freezing rain, sleet, and snow. Some individual precipitation events contain two or more of these precipitation types. Precipitation type affects both the quantity of deicing product used as well as its dispersion. For example, freezing rain tends to coat aircraft with ice. Ice coatings tend to require greater quantities of Type I ADF to remove than loose, dry snow or light frost.

Precipitation type and ground and air temperatures also affect pollutant dispersion. Precipitation that is liquid, such as rain, or that melts, such as snow on a warm ground surface, mobilizes deicing pollutants and moves them through stormwater transport systems to discharge more quickly than solid precipitation that accumulates on airfield surfaces. After a snow event, a significant quantity of ADF and pavement deicers can be trapped in plowed snowbanks or snow storage units and will not enter stormwater transport systems or surface waters, soil, or groundwater until ground and air temperatures are high enough to allow the snow to melt. Rates and timing of snowmelt can vary widely among airports (e.g., Fairbanks International in Alaska versus Dallas-Fort Worth International in Texas) and among winter seasons or snow events at individual airports.

Ground and air temperatures are also important in their influence on rates of pollutant degradation since higher temperatures allow higher degradation rates.

Strong winds associated with some weather events can increase aerial deposition of ADF on the airfield and adjacent surface waters.

Another factor that influences deicing pollutant discharge is precipitation event magnitude. In general, as precipitation quantity increases, use of greater quantities of ADF and pavement deicer is required. In addition, larger precipitation events tend to produce more stormwater. Larger quantities of stormwater tend to mobilize and discharge deicing pollutants more quickly than smaller quantities of stormwater. The timing of stormwater availability from a specific event will, however, be dependent on the type of precipitation and its melting rate, as discussed above. Because larger stormwater quantities move deicing pollutants more quickly, they may reduce the quantity of pollutants that infiltrate soil and other pervious airport surfaces.

Another important factor is the timing of precipitation events. Precipitation events that take place during periods of high air traffic levels (e.g., holidays, morning rush times) require deicing operations for a greater number of aircraft and the use of greater quantities of deicing materials (see *Aircraft Traffic Composition and Levels* above).

3.2.2 Quantified Airport Deicing Pollutant Discharge Estimates

EPA estimated seasonal pollutant discharges from airport deicing operations based on current airport practices and conditions. EPA had sufficient information to quantify a portion of the total discharge of chemical oxygen demand (COD) and ammonia from airport deicing operations. A more detailed description of EPA's estimation methodology and results is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

Table 3-1 presents facility-specific ADF application site and pavement deicer COD discharges for each airport within scope of the final rule.. EPA did not have sufficient information to estimate facility-specific discharges from individual airports EPA did not survey. As discussed above, COD discharge levels in Table 3-1 do not reflect COD discharges associated with Type I and Type IV ADF dispersed beyond ADF application sites.

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application	
		Site COD Discharge (pounds/year)	Airport Service Level
Albany Intl	213,511	103,086	Small Hub
Albuquerque Intl Sunport	2,617	491,959	Medium Hub
Aspen-Pitkin Co/Sardy Field	36,366	85,963	Non-Hub
Austin Straubel International	117,358	355,646	Small Hub
Austin-Bergstrom Intl	9,976	137,629	Medium Hub
Baltimore-Washington Intl	866,733	1,289,506	Large Hub
Bethel	143,501	47,733	Non-Hub
Birmingham Intl	0	47,717	Small Hub
Bismarck Municipal	9,195	200,305	Non-Hub
Bob Hope	0	0	Medium Hub
Boeing Field/King County Intl	5,851	29,510	Non-Hub
Boise Air Terminal/Gowen Fld	631,466	272,543	Small Hub
Bradley Intl	440,956	1,669,398	Medium Hub
Buffalo Niagara Intl	913	1,718,928	Medium Hub
Central Wisconsin	299,374	416,170	Non-Hub
Charlotte/Douglas Intl	381,832	1,308,047	Large Hub
Cherry Capital	36,467	0	Non-Hub
Chicago Midway Intl	797,303	0	Large Hub
Chicago O'Hare Intl	8,248,121	8,204,552	Large Hub
Cincinnati/Northern Kentucky International	1,740,966	772,137	Large Hub
City of Colorado Springs Municipal	128,158	433,971	Small Hub
Cleveland-Hopkins Intl	1,532,252	3,480,467	Medium Hub
Dallas Love Field	125	213,039	Medium Hub
Dallas/Fort Worth International	10,373	557,682	Large Hub
Denver Intl	2,012,384	729,709	Large Hub
Des Moines Intl	289,289	460,483	Small Hub
Detroit Metropolitan Wayne County	1,056,284	0	Large Hub
El Paso Intl	0	0	Small Hub
Eppley Airfield	171,538	1,058,801	Medium Hub
Evansville Regional	16,585	192,217	Non-Hub
Fairbanks Intl	819,984	299,205	Small Hub
Fort Wayne International	761,916	511,705	Non-Hub
General Edward Lawrence Logan Intl	1,589,955	9,147,072	Large Hub
General Mitchell International	742,538	898,664	Medium Hub
George Bush Intercontinental Arpt/Houston	0	56,571	Large Hub
Gerald R. Ford International	38,863	563,544	Small Hub
Glacier Park Intl	710	367,815	Non-Hub

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application Site COD Discharge (pounds/year)	Airport Service Level
Greater Rochester International	168,122	1,152,208	Small Hub
Gulfport-Biloxi Intl	0	0	Small Hub
Hartsfield - Jackson Atlanta Intl	179,433	1,382,287	Large Hub
Helena Regional	0	0	Non-Hub
Indianapolis Intl	768,086	2,728,125	Medium Hub
Jackson Hole	0	0	Non-Hub
Jacksonville Intl	0	0	Medium Hub
James M Cox Dayton Intl	99,807	357,499	Small Hub
John F Kennedy Intl	2,837,634	5,155,239	Large Hub
John Wayne Airport-Orange County	0	0	Medium Hub
Juneau Intl	1,018,715	430,969	Small Hub
Kansas City Intl	344,044	1,200,632	Medium Hub
Ketchikan Intl	a	a	Non-Hub
La Guardia	1,383,792	4,216,728	Large Hub
Lafayette Regional	0	14,201	Non-Hub
Lambert-St Louis Intl	2,921,256	1,154,584	Large Hub
Long Island Mac Arthur	0	166,102	Small Hub
Louis Armstrong New Orleans Intl	0	0	Medium Hub
Louisville Intl-Standiford Field	447,728	490,009	Medium Hub
Lovell Field	0	39,586	Non-Hub
Manchester	306,0048	1,715,962	Medium Hub
Mc Carran Intl	0	60,923	Large Hub
Memphis Intl	334,157	1,946,410	Medium Hub
Metropolitan Oakland Intl	0	0	Large Hub
Minneapolis-St Paul Intl/Wold-Chamberlain	782,829	5,968,923	Large Hub
Montgomery Rgnl (Dannelly Field)	0	2,214	Non-Hub
Nashville Intl	93,454	349,329	Medium Hub
Newark Liberty Intl	1,520,336	10,762,687	Large Hub
Nome	22,429	28,231	Non-Hub
Norfolk Intl	*	235,637	Medium Hub
Norman Y. Mineta San Jose International	0	0	Medium Hub
Northwest Arkansas Regional	352,337	293,595	Small Hub
Ontario Intl	0	334	Medium Hub
Outagamie County Regional	130,836	551,842	Non-Hub
Palm Beach Intl	0	0	Medium Hub
Pensacola Regional	0	0	Small Hub
Philadelphia Intl	1,362,130	1,436,522	Large Hub
Phoenix Sky Harbor Intl	0	0	Large Hub
Piedmont Triad International	228,269	655,787	Small Hub
Pittsburgh International	703,466	3,689,998	Large Hub
Port Columbus Intl	356,775	2,927,149	Medium Hub
Portland Intl	178,213	855,437	Medium Hub

Table 3-1: Partial Chemical Oxygen Demand Discharges from Pavement Deicers and ADF Application Sites at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer COD Discharge (pounds/year)	ADF Application Site COD Discharge (pounds/year)	Airport Service Level
Raleigh-Durham Intl	134,976	977,382	Medium Hub
Ralph Wien Memorial	43,492	23,743	Non-Hub
Rapid City Regional	10,907	242,540	Non-Hub
Reno/Tahoe International	48,138	569,580	Medium Hub
Richmond Intl	174,098	339,643	Small Hub
Rickenbacker International	45,481	102,180	Non-Hub
Roanoke Regional/Woodrum Field	62,222	314,124	Non-Hub
Rochester International	*	197,799	Non-Hub
Ronald Reagan Washington National	371,666	1,229,789	Large Hub
Sacramento International	0	0	Medium Hub
Salt Lake City Intl	2,488,385	1,687,338	Large Hub
San Antonio Intl	*	121,626	Medium Hub
San Diego Intl	0	0	Large Hub
San Francisco International	0	0	Large Hub
Seattle-Tacoma Intl	56,346	1,502,208	Large Hub
South Bend Regional	69,136	0	Small Hub
Southwest Florida Intl	0	0	Medium Hub
Spokane Intl	1,063,075	0	Small Hub
Stewart Intl	370,095	184,745	Non-Hub
Syracuse Hancock Intl	6,729	791,854	Small Hub
Tampa Intl	0	0	Large Hub
Ted Stevens Anchorage Intl	6,082,395	2,265,902	Medium Hub
Theodore Francis Green State	91,602	572,884	Medium Hub
Toledo Express	137,067	359,704	Non-Hub
Tucson Intl	0	17,873	Medium Hub
Washington Dulles International	1,810,018	5,686,802	Large Hub
Wilkes-Barre/Scranton Intl	*	405,801	Non-Hub
Will Rogers World	30,291	472,260	Small Hub
William P Hobby	0	0	Medium Hub
Wilmington Intl	0	20,756	Non-Hub
Yeager	79,800	283,685	Non-Hub

Chemical oxygen demand (COD) loads were calculated from data provided in response to the EPA Airport Deicing Questionnaire (2006c) and the EPA Airline Deicing Questionnaire (2006b).

* – The airport reported that the quantity of pavement deicer usage was unknown (US EPA 2006c).

a) Ketchikan was sent an airport questionnaire but did not respond.

EPA also estimated facility-specific annual ammonia discharges from urea pavement deicer use for airports within scope of the final rule (*Table 3-2*). EPA does not have sufficient information to estimate facility-specific ammonia discharge levels at individual airports EPA did not survey.

Table 3-2: Ammonia Discharge from Deicing Operations at Surveyed Airports within Scope of the Final Rule

Airport Name	Pavement Deicer Ammonia Discharge (pounds/year)
Austin Straubel Intl	25,387
Bethel	38,105
Boise Air Terminal/Gowen Field	152,740
Bradley Intl	9,478
Central Wisconsin	69,856
Charlotte/Douglas Intl	84,821
Fairbanks Intl	187,883
Fort Wayne Intl	161,593
General Edward Lawrence Logan Intl	5,782
Glacier Park Intl	189
Juneau Intl	270,506
Manchester	20,844
Northwest Arkansas Regional	10,186
Piedmont Triad Intl	52,441
Raleigh - Durham Intl	35,841
Ralph Wien Memorial	5,659
Reno/Tahoe Intl	6,330
Ronald Reagan Washington National	44,141
Salt Lake City Intl	634,519
South Bend Regional	18,358
Spokane Intl	281,824
Stewart Intl	85,905
Ted Stevens Anchorage Intl	1,423,212
Yeager	15,572

EPA was able to create national estimates of COD and ammonia discharges from ADF application sites and pavement deicers. EPA estimated national COD loads from ADF application sites using discharge estimates for airports EPA surveyed in conjunction with airport weighting factors developed as part of the EPA Airport Deicing Questionnaire sample frame. EPA estimated COD and ammonia loads from pavement deicer use using reported usage levels for airports EPA surveyed in conjunction with airport weighting factors. A more detailed description of EPA's COD estimation methodology is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2011). Table 3-3 presents the estimate of current national COD loads from ADF application sites and pavement deicers by airport hub size category. COD discharges associated with ADF dispersed in areas beyond ADF application sites are not reflected by the figures in Table 3-3.

Table 3-3: Estimate of National Baseline COD Discharges from ADF Application Sites and Airfield Pavement Deicing by Airport Hub Size Category

Airport Hub Size	ADF Application Site COD Discharge (pounds/year)	Pavement Deicer COD Discharge (pounds/year)
Large	65,999,304	33,121,243
Medium	26,678,898	12,086,529
Small	9,255,083	7,161,186
Nonhub	16,408,625	6,641,781
General Aviation/Cargo	2,268,284	1,309,591
Total	120,610,194	60,320,330

EPA also calculated current, baseline national ammonia discharges associated with airport use of urea as a pavement deicer. These discharges are presented by airport hub size category in *Table 3-4*.

Table 3-4: Estimate of National Baseline Ammonia Discharges from Airfield Pavement Deicing by Airport Hub Size Category

Airport Hub Size	Ammonia Discharge (pounds/year)
Large	769,263
Medium	1,495,705
Small	1,286,277
Nonhub	852,775
General Aviation/Cargo	NA
Total	4,404,020

Other pollutants in addition to COD and ammonia discharge from airport deicing operations. EPA has not quantified discharge levels of these other pollutants. *Chapter 1* discusses current levels of airport deicing product usage in the U.S. *Chapter 2* discusses the range of pollutants potentially present in ADF and pavement deicer products.

3.3 Factors Influencing Airport Deicing Pollutant Concentrations in Receiving Surface Waters

Pollutant concentrations in the environment, as well as total discharges, are of interest because of their influence on the manner in which some pollutants impact the environment. As discussed in *Chapter 2*, a number of pollutants have threshold levels above which impacts have been documented.

A number of factors influence airport deicing pollutant concentrations in surface waters. An important factor is the total quantity of pollutants discharging to surface waters. Factors influencing total pollutant discharges from airports are discussed in *Section 3.2*.

ADFs and pavement deicers, as applied, contain certain concentrations of chemicals (see *Chapter 2*). Before they enter surface waters, however, ADF and pavement deicers typically undergo dilution with precipitation and, in some cases, a certain amount of degradation. Pollutant concentrations in deicing-contaminated stormwater are typically lower, therefore, than the concentrations found in airport deicing products as-applied.

When deicing pollutants enter surface waters, they are typically diluted further. Receiving water volume, waterbody flow rate, and waterbody mixing dynamics influence dilution levels. Surface water characteristics such as vegetation, stream slope, presence of ice and snow cover, stream channel obstacles,

and tidal influences can significantly affect flow rate and mixing. High vegetation levels and low stream channel slopes tend to retard flow. Channel depressions can slow low flows and significantly increase residence times of deicing pollutants in receiving streams. Snow pack and ice in streams can also alter flow either by altering stream channel characteristics. Snow pack and ice can create depressions in a channel that can reduce stream flow. They can also increase flow by filling in existing stream channel depressions and reducing resistance to flow. Stream channel obstacles such as woody debris, rocks, and falls can increase turbulence and mix pollutants with greater volumes of water. Tidal currents can also increase mixing and dilution.

Many of the surface waters that directly receive airport deicing pollutants are small, low-flow, and relatively low-slope streams. *Figure 3-2* summarizes available flow rate data for surface waters directly receiving deicing discharges from airports EPA surveyed. According to available data, 62% of initial receiving waters have a flow rate of 20 cubic feet per second (cfs) or less.

Figure 3-2: Initial Receiving Water Discharge Flows at EPA Surveyed Airports

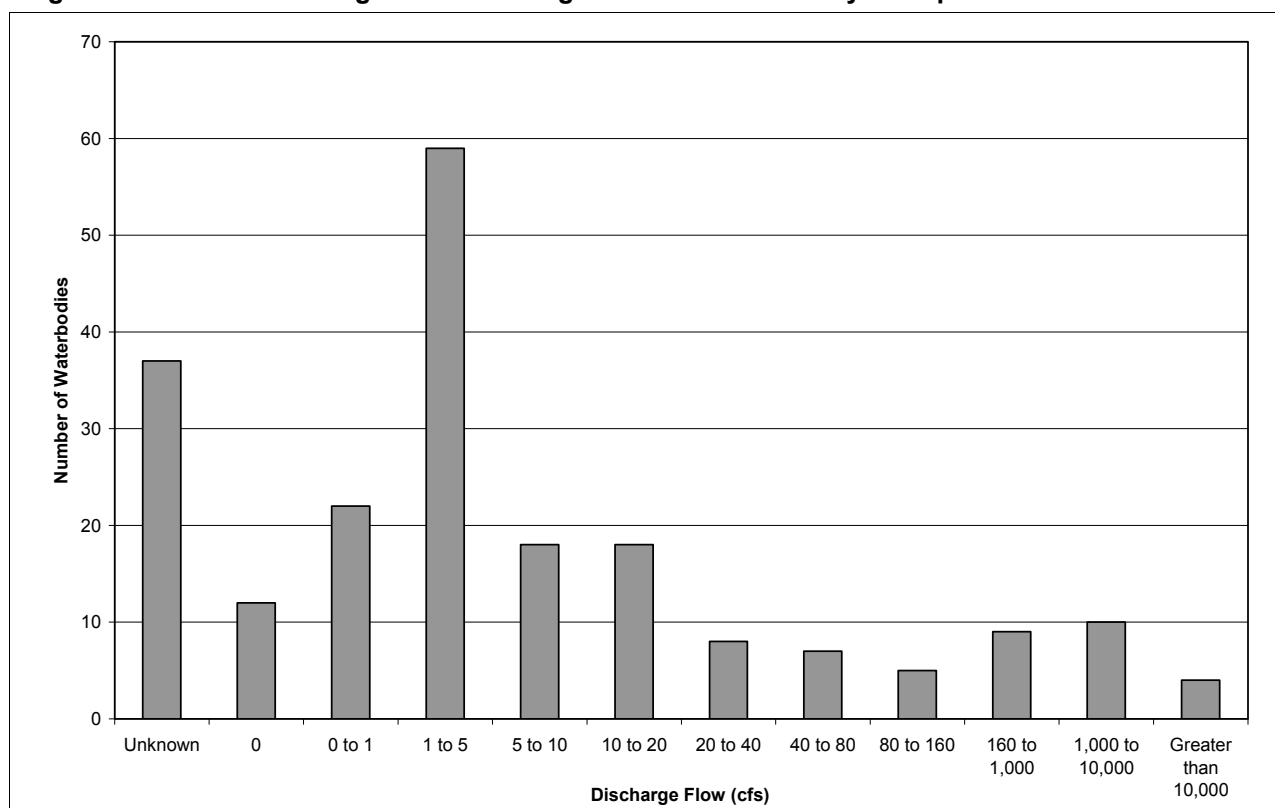
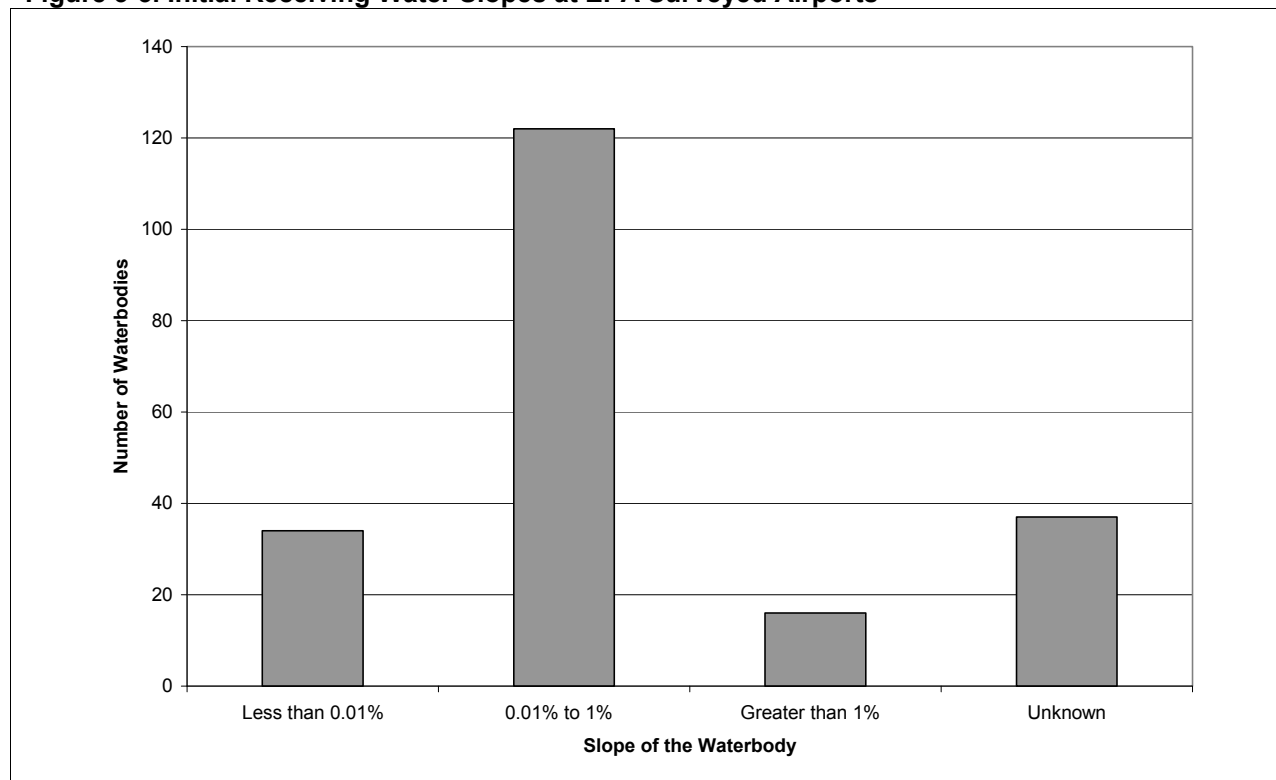


Figure 3-3 summarizes available slope data. According to available data, 75% of initial receiving waters have a slope of less than 1%.

Figure 3-3. Initial Receiving Water Slopes at EPA Surveyed Airports



Low slope and flow streams are more likely to show impacts from deicing pollutant discharges because of the lower volume of water available for pollutant dilution and the potential for greater pollutant retention time.

Rate of pollutant delivery versus rate of dilution is an important dynamic. The frequency and timing of deicing and precipitation events during the winter season affect both rates. As described in *Section 3.2.1*, precipitation quantity and type is an important determinant of the quantity and rate at which pollutants are delivered to surface waters. Precipitation quantity and type also affects the quantity of surface water flow available for dilution of discharged pollutants as well as the rate at which those pollutants travel downstream. High levels of rain or melted precipitation typically create higher surface water flow and move pollutants downstream more quickly. Numerous combinations of precipitation and deicing event frequency and intensity result in highly variable deicing pollutant delivery to and dilution in receiving surface waters.

Surface water degradation processes are another important factor influencing waterbody pollutant concentrations. These depend heavily on temperature, residence time, oxygen availability, and the composition of the bacteria and vegetation community present in receiving surface waters.

3.4 Documented Environmental Impacts from Airport Deicing Pollutant Discharges

EPA searched publicly available literature for information on airport deicing pollutant discharges and their connection to environmental impacts. Literature sources included the peer-reviewed literature, state reports, newspapers, government agency reports, and a variety of organization publications. This section describes the results of EPA's literature search that was completed in December of 2007. EPA compiled

more than 90 individual documents describing environmental impacts from airport deicing discharges. In some cases, deicing pollutant discharges have been definitively linked to environmental impacts. In other cases, impact linkage to deicing pollutants is suggested, rather than definitive. Compiled articles describe a wide range of airport and discharge conditions.

Surface waters are often subject to multiple stressors (e.g., pollutants from airport activities other than deicing, other industrial discharges, invasive species). Determining the source(s) of a water's impairment can be difficult and requires complex analyses that have not yet been conducted and published. EPA has summarized suggested, as well as definitive, impact cases in this section because of the additional information they provide on potential environmental impacts from deicing pollutant discharges. Approximately half of the articles describe impacts with a definitive connection to airport deicing pollutant discharges.

The majority of the environmental impact documentation focuses on impacts observed in surface waters directly receiving airport deicing pollutant discharges. Wildlife impacts such as fish kills or other organism deaths are the most frequently described environmental impact. *Table 3-5* summarizes the total number of studies EPA found on different types of environmental impacts and that were categorized as having either a definitive or suggested connection to airport deicing discharges.

Table 3-5: Documented Environmental Impacts Associated with Airport Deicing Discharges

Impact	Connection to Airport Deicing Definitive	Connection to Airport Deicing Suggested	Total Number of Studies
COD, BOD, DO, Nutrients			
COD or BOD	11	5	16
DO	10	10	20
Nutrients	8	9	17
Wildlife Impacts			
Fish Kill	8	10	18
Other Organisms	25	20	45
Human Health Impacts			
Health	4	4	8
Drinking Water	1	7	8
Aesthetic Impacts			
Foam	4	6	10
Odor	14	17	31
Color	11	9	20
Violations			
Permit Violations	17	10	27

Though EPA's literature search was extensive, it is unlikely that EPA located all available documentation of environmental impacts from airport deicing discharges. There are probably environmental impacts from airport deicing discharges that have not yet been documented and published because of the time and effort often required to detect, analyze, and document environmental impacts from industrial discharges.

An additional limitation on EPA's literature compilation is its ability to reflect current conditions at individual airports. Since the publication of articles describing environmental impacts from certain airports, some of those airports have installed collection and treatment systems or otherwise changed their deicing practices in order to reduce deicing pollutant discharges. *Table 3-6* summarizes a number of improvements airports have undertaken to reduce their environmental impact in recent years. A number of these efforts have improved conditions in receiving surface waters.

Table 3-6: Airport Deicing System Improvements for In-scope Airports

Airport	Environmental Impacts	Deicing System Improvements	Date Improvement Implemented
Baltimore/Washington International Airport	Odor, foam and color issues, fish impacts, Clean Water Act violation	Deicing pads and drains	By winter 1997-98
Cincinnati/Northern Kentucky International Airport	Anoxia, Sphaerotilus overgrowth, color and odor issues, "dead" stream, high BOD and ammonia levels	Discharge routing to POTW, recycling system	1994-2004
Cleveland Hopkins International Airport	High ammonia levels, fish kills, color and odor issues	Deicing pads and basins	By 2004
Detroit Metropolitan Wayne County Airport	Odor and color issues, permit violations, fish kills	Construct sewer line to route discharges to POTW	By 2010
Des Moines International Airport	Odor and color issues, state water quality standard violations	Stormwater detention facility	Long-term plan as of 1998
General Mitchell International Airport	Color issues, fish kills, high glycol and BOD levels	Redesigned storm sewers	Pre-2006
Louisville International Airport	High ammonia and BOD levels, low DO levels, fish kills	No longer using urea	Pre-2002
Minneapolis-St. Paul International Airport	Low DO levels, odor and color issues, high BOD and glycol levels, permit violations	Sewer system improvements and deicing pads	1998-2001
Port Columbus International Airport	High nutrient levels, low DO levels, fish kills, aquatic species diversity loss	No longer using urea, construction of containment system	By 2002-2003

Source: Information gathered during EPA's literature search completed in December of 2007.

Despite these limitations, the literature compilation provides a diverse profile of the types of environmental impacts associated with airport deicing discharges. As air traffic and deicing product usage levels continue to increase in the U.S. these types of impacts will either reappear at previously affected airports or newly appear at airports where they had not been previously detected, unless application, collection, and treatment practices change. Environmental impacts from deicing discharges continue to persist at some level at many of the airports listed in *Table 3-6*, despite the sometimes significant efforts made to address them.

Sections 3.4.1 to 3.4.5 provide additional information on documented environmental impacts. For additional information on individual articles EPA compiled during the literature review, see *Table C-1* in *Appendix C*. *Section 3.5* provides information on the potential current extent of environmental impacts from airport deicing discharges.

3.4.1 Chemical Oxygen Demand, Biochemical Oxygen Demand, Dissolved Oxygen, and Nutrient Impacts

3.4.1.1 Chemical Oxygen Demand and Biochemical Oxygen Demand

The primary ingredients in ADFs and pavement deicers are organic compounds that serve as freezing point depressants. These organic compounds degrade after release to the environment, creating high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) levels in surface waters. High COD and BOD levels in surface waters can lead to high levels of dissolved oxygen (DO) consumption as the organic matter degrades, potentially lowering DO concentrations below levels required for the health

and survival of aquatic organisms (see *Section 2.2.1.2*). EPA documented COD and BOD problems for 13 individual airports in 16 articles, 11 of which were classified as being definitively connected to airport deicing discharges. Many of the information sources were state government reports and published journal articles.

In a newspaper article on impacts from Minneapolis-St. Paul International Airport's deicing operations, the Minnesota Pollution Control Agency's water quality supervisor is quoted as stating that the airport's deicing discharges represent the largest source of organic pollutants to the Minnesota River (Meersman 1993). During the course of the 1992-1993 deicing season, approximately 2,400 tons of glycol were discharged to the Minnesota River. State officials suspected that these discharges lower DO levels in the Minnesota River.

In 1998, the Kentucky Department of Environmental Protection determined that the Cincinnati/Northern Kentucky International Airport was responsible for elevated glycol levels and BOD issues observed in surface waters receiving stormwater discharges from the airport. These problems continued to persist, even after the airport implemented remediation actions (Kentucky Department of Environmental Protection 1998).

3.4.1.2 *Dissolved Oxygen*

As organic material, BOD, and COD levels increase in airport deicing discharges increases, the amount of dissolved oxygen (DO) required by surface water microorganisms to digest the material also increases. Biodegradation of organic material lowers DO levels in surface waters and can ultimately make them uninhabitable for aquatic life. EPA compiled 20 articles describing DO impacts from deicing activities at 13 airports. The impacts in 10 articles could be definitively connected to airport deicing discharges. The articles describe low levels of DO and anoxia in receiving waters.

The Columbia Slough receives deicing pollutant discharges from Portland International Airport and is a well-documented case of deicing pollutants lowering DO levels in a receiving water. In a technical report prepared for the City of Portland, the airport's deicing discharges were documented as contributing 79% of all organic material discharging to the Columbia Slough (Wells 1997). Low DO levels clearly coincide with cold weather deicing activities. A separate report written by the Oregon Department of Environmental Quality (1998) specifically states that the airport's deicing pollutants have lowered DO in the Slough.

3.4.1.3 *Nutrients*

The pavement deicer urea decays and forms ammonia in surface waters. High concentrations of ammonia can be toxic to many aquatic organisms and plants can use the nitrogen in ammonia to fuel extra growth. Bacteria can also convert ammonia to other nitrogen-containing compounds that plants can absorb as nutrients. Nitrogen in airport deicing discharges can encourage algal blooms and other biological overgrowths, followed by low DO levels or anoxia as the overgrowths die and decay. EPA found nutrient impact complaints in 17 articles, 8 of which EPA classified as definitively connected to airport deicing discharges. The 17 articles discuss 12 different airports. Most of the articles describe impacts from algal blooms and elevated surface water levels of ammonia and nitrates.

Two articles describe nutrient enrichment in surface waters receiving deicing discharges from Port Columbus International Airport (State of Ohio Environmental Protection Agency 1998, State of Ohio Environmental Protection Agency 2004). A third report, another Ohio Environmental Protection Agency publication, describes high ammonia and nitrate concentrations in receiving waters downstream of the

airport and the discharge of significant quantities of glycol (State of Ohio Environmental Protection Agency 2003).

3.4.2 Wildlife Impacts

3.4.2.1 Fish Kills

As described in *Chapter 2*, ADFs and pavement deicers have toxic components that can harm or kill aquatic organisms when discharged in sufficient quantities to surface waters. As described in *Section 3.4.1*, ADFs and pavement deicers also contain high levels of organic matter and nutrients that, during degradation in surface waters, can lower DO concentrations to harmful or uninhabitable levels for aquatic life. Either of these pathways can result in acute fish death events known as fish kills. Eighteen of the articles documented in the literature review discussed fish kills. EPA classified impacts in 8 articles as definitively linked to airport deicing discharges. The 18 articles discussed fish kills downstream of 13 different airports and included newspaper articles, journal articles, and state government reports.

For example, in May 2001 at Detroit Metropolitan Wayne County Airport a stormwater collection pond primarily containing stormwater contaminated with ethylene and propylene glycol from deicing activities breached and discharged to the Frank and Poet Drain (Lochner 2006). Two days later, a fish kill was observed at the location where the Drain discharges to the Detroit River. EPA and the Federal Bureau of Investigation investigated the incident and charged the airport with violating the Clean Water Act after failing to report the discharge.

3.4.2.2 Other Organism Impacts

In addition to fish kills, airport deicing discharges have been linked to the death of other types of aquatic organisms and have been implicated in the sickening or deaths of other wildlife and pets that have come in contact with contaminated surface waters. Of the 45 articles EPA compiled in this category, 25 are definitively connected to airport deicing discharges. The 45 articles discuss 26 different airports. The following airports are discussed in 3 or more articles:

- Cincinnati/Northern Kentucky International Airport (6 articles);
- Baltimore/Washington International Airport (3 articles);
- Denver International Airport (3 articles); and
- General Mitchell International Airport (3 articles).

At Cincinnati/Northern Kentucky International Airport, Denver International Airport, and Buffalo-Niagara International Airport waters receiving deicing discharges are described as lifeless (Sierra Club 2004, Scanlon 1997, and Dawson 1994).

A number of studies conducted on the receiving waters located downstream from deicing outfalls at Baltimore/Washington International Airport report glycol concentrations high enough to kill daphnids and minnows (Hartwell et al. 1993, Fisher et al. 1995, Pelton 1997a).

3.4.3 Human Health, Aesthetic, and Other Aquatic Resource Use Impacts

3.4.3.1 Human Health

As discussed in *Chapter 2*, some ADF and pavement deicer components can be harmful to human beings exposed to sufficient quantities. Some people claim to have been sickened by strong chemical odors

associated with some deicing-contaminated stormwaters. Human health impacts are documented for 6 airports in 8 articles. The articles include newspaper articles and reports from organizations. Impacts range from headaches and nausea due to odors to claims of kidney and other health problems, especially in children. The Alliance of Residents Concerning O'Hare (1997), a nonprofit organization of citizens residing nearby Chicago O'Hare International Airport, documented vomiting and other illness due to fumes from airport deicing discharges on a number of separate occasions. Residents state that, at times, streams in residential neighborhoods receiving airport deicing discharges have unnatural colors and emit odors that cause illness.

3.4.3.2 *Drinking Water Contamination*

EPA compiled 8 articles that discuss drinking water impacts from 5 airports. One article definitively connected impacts to airport deicing discharges and the other articles are suggestive of a connection.

Three of the articles discussed drinking water contamination issues near Baltimore Washington International Airport but did not definitively connect these impacts to airport deicing discharges.

At Hartsfield-Jackson Atlanta International Airport, 10 days after an ADF spill into a major source of drinking water, consumers complained of a sickeningly sweet taste and smell in their drinking water. Testing of samples taken three days after the complaints started did not indicate deicing fluid contamination. However, sampling immediately following the spill indicated that water flowing from the airport into the river that serves as the drinking water source contained 1,600 ppm of glycol.

3.4.3.3 *Foam*

Deicing chemicals can form visible foam in surface waters. EPA's compiled 10 articles that describe foam in surface waters downstream of 7 airports. The articles include journal articles, newspaper articles, and reports from organizations. Four articles definitively connect the presence of foam to airport deicing discharges. Foam complaints frequently co-occur with odor and color complaints. High levels of glycols were also typically found in surface waters containing visible foam.

At Baltimore/Washington International Airport, levels of ethylene glycol as high as 4,800 mg/L were detected in the Muddy Bridge Branch where foam had been frequently sighted (McDowell 1997). In 1997, the airport applied nearly 200,000 gallons of ADF to planes and it is estimated that as much as 68% may have entered nearby creeks (Pelton 1998). This discharge coincided with numerous complaints about pinkish foam present on downstream surface waters.

3.4.3.4 *Odor*

Deicing-contaminated surface waters are frequently described as having a sickeningly sweet chemical smell. EPA compiled 31 articles describing complaints of odors from surface waters located downstream from airport deicing outfalls. Of the 31 articles, EPA classified 14 as describing a definitive connection between airport deicing discharges and odor. The 31 articles describe 16 different airports. Several airports are described in multiple articles:

- Cincinnati/Northern Kentucky International Airport (5 articles);
- Baltimore/Washington International Airport (4 articles); and
- Cleveland Hopkins International Airport (3 articles).

Odor complaints are frequently associated with additional impacts such as organism human health, and aesthetic impacts. For example, all articles describing the odor complaints from Baltimore/Washington International Airport discharges also described visible foam, human illness complaints, and fish impacts

(McDowell 1997, Pelton 1997b, Pelton 1998). At Cincinnati/Northern Kentucky International Airport, allegations of discharge violations involving Elijah Creek coincided with unpleasant odors, surface water discoloration, and pollutant concentrations high enough to harm aquatic life (Klepal 2004, Sierra Club 2004). Residents also complained about chemical smells and discolored water in Gunpowder Creek, which also receives airport deicing discharges. Glycol levels in Gunpowder Creek were found to be up to 3.5 times higher than allowed by the airport's wastewater discharge permit (Kelly 2004).

3.4.3.5 Color

Manufacturers add dye to ADFs to help ADF users track their presence on aircraft and airfield surfaces and to help them distinguish Type I from Type IV fluids. Sufficient levels of dye can discolor surface waters. In addition, as described above, degradation of organic material associated with airport deicing discharges can lower DO levels in surface waters. Under anoxic conditions, reduction of iron and manganese ions to more soluble species can color surface waters (Zitomer 2001)

EPA found 20 articles describing 11 airports with unnatural colored surface waters downstream of airport deicing stormwater outfalls. EPA classified 11 of the articles as describing impacts definitively connected to airport deicing discharges. Five articles described impacts from Cincinnati/Northern Kentucky International Airport and 3 articles describe impacts from Baltimore/Washington International Airport. Color complaints frequently coincided with odor complaints.

At Des Moines International Airport, color and odor issues are discussed in documents describing Total Maximum Daily Loads (TMDLs) for receiving waters as well as in materials provided to local city council members (Iowa Department of Natural Resources 2005, Flannery 1998). The TMDL document describes ethylene glycol concentrations of 65 to 120 mg/L and propylene glycol concentrations of 210 to 490 mg/L near the airport outfall to Yeader Creek. These high glycol concentrations coincided with a greenish color and sweet sewage odor in Yeader Creek. Yeader Creek was determined to be severely polluted and in violation of Iowa Water Quality Standards. Local residents who live near the creek have lodged complaints with the Iowa Department of Natural Resources about the surface water's discoloration and odor.

3.4.4 Permit Violations

Permit violations were frequently described in articles compiled by EPA. Permit violations provide additional information on large quantities of airport deicing pollutants discharging to surface waters. EPA compiled 27 articles that describe discharge permit violations at 12 different airports. Several airports, including Cleveland Hopkins International Airport, Cincinnati/Northern Kentucky International Airport, and Baltimore/Washington International Airport were discussed in multiple articles. Seventeen articles describe direct discharge violations. Other articles describe unspecified violations or administrative violations such as failure to report an unauthorized discharge.

3.5 Potential Current Impacts to Impaired Waters and Other Resources

EPA evaluated the potential for airport deicing discharges to impact surface waters listed as impaired under Section 303(d) of the Clean Water Act as well as other aquatic resources located downstream of airport deicing stormwater outfalls. Listing of a surface water as impaired under Section 303(d) of the Clean Water Act is an official determination that a waterbody is unable to serve one or more of its designated uses such as drinking water supply, recreation, wildlife habitat, etc. because of pollution or other modifications. It is an indicator of a stressed ecosystem.

EPA examined the listing status of surface waters receiving airport deicing discharges for two reasons. First, to determine the extent to which airport deicing pollutants are being discharged to already stressed aquatic ecosystems and potentially contributing additional stress. Second, to determine which listed waterbodies may be impaired as a direct result of receiving airport deicing discharges.

EPA's analysis used a geographical information system (GIS) analysis of surface waters to which airports directly discharge deicing pollutants. EPA used this information to identify 303(d)-listed waters and aquatic resources that could potentially be affected by deicing discharges. EPA also examined existing Total Maximum Daily Load (TMDL) documents in order to identify airports that have officially been determined to be point sources contributing to surface water impairment.

3.5.1 303(d)-Listed Waters Receiving Airport Deicing Discharges

Based on airport outfall location information provided in response to EPA's Airport Deicing Questionnaire (US EPA 2006c), EPA indexed deicing outfall locations to the National Hydrography Dataset (NHD) Plus stream network. EPA used NHD Plus tools to determine surface waters within 10 miles downstream of airport outfalls. Once downstream waters were identified in NHD Plus, EPA overlaid their location information with the 2002 national GIS coverage of 303(d)-listed waters (<http://www.epa.gov/waters/data/downloads.html#303d>, accessed September 24, 2007) in order to determine whether any of the downstream waters are listed as impaired. EPA then linked identified impaired streams to EPA's Watershed Assessment, Tracking, and Environmental Results (WATERS) database (<http://www.epa.gov/waters/data/index.html>, accessed September 24, 2007) in order to determine the nature of the impairment. Of the 93 airports for which EPA has sufficient outfall location information to conduct this analysis, 36 discharge directly to a freshwater waterbody that is listed as impaired. *Table 3-7* summarizes the results of this analysis.

Table 3-7: 303(d) Impairment Categories for Fresh Waters Receiving Direct Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

303(d) Impairment Category	Number of Airports with Impairment	Airport Deicing Pollutant Potentially Contributing to Impairment
Algal Growth	1	Yes
Ammonia	5	Yes
Cause Unknown	4	Yes
Cause Unknown - Impaired Biota	4	Yes
Chlorine	2	
Dioxins	2	
Fish Consumption Advisory - Pollutant Unspecified	1	Yes
Flow Alteration	4	
Habitat Alteration	6	
Mercury	2	
Metals (Other Than Mercury)	4	
Nutrients	7	Yes
Oil And Grease	1	
Organic Enrichment/Oxygen Depletion	12	Yes
Pathogens	18	
PCBs	6	
Pesticides	6	
pH	4	
Salinity/TDS/Sulfates/Chlorides	2	Yes
Sediment	6	
Temperature	2	
Total Toxicity	4	Yes
Toxic Organics	5	Yes
Turbidity	5	

Of the 28 in-scope airports directly discharging to impaired freshwater waterbodies, 21 discharge to waterbodies impaired by pollutants associated with airport deicing discharges. Because EPA had sufficient information for only 93 airports to conduct this analysis, additional airports could be discharging deicing pollutants to impaired waters.

Because NHD Plus does not provide information on marine waters, airport outfalls discharging directly to marine waters were not included in the GIS analysis described above. To assess whether any of the marine waters directly receiving airport deicing discharges are listed as impaired, EPA used information on receiving waters designated as marine from responses to EPA's Airport Deicing Questionnaire (US EPA 2006c) to search the WATERS database. *Table 3-8* summarizes the results of this analysis.

Table 3-8: 303(d) Impairment Categories for Marine Waters Receiving Direct Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

303(d) Impairment Category	Number of Airports with Impairment	Airport Deicing Pollutant Potentially Contributing to Impairment
Aesthetically impaired waters	2	Yes
Dioxin	1	
Organic Enrichment/Oxygen Depletion	2	Yes
Floatables	1	
Mercury	1	
Metals (Other Than Mercury)	1	
Nutrients	2	Yes
Pathogens	5	
PCBs	2	
Pesticides	1	
pH	1	
Toxic Organics	3	Yes

Of the 6 in-scope airports discharging to impaired marine waters, 5 discharge to waters impaired for pollutants associated with airport deicing discharges. Because EPA had sufficient information for only 93 airports to conduct this analysis, additional airports could be discharging deicing pollutants to impaired marine waters.

Because states have not assessed all surface waters receiving deicing pollutant discharges from airports for impairment, additional waters beyond those described here could be impaired.

Several of the 303(d) impairment categories EPA identified during the analysis can derive from airport deicing pollutants. These categories include “aesthetically impaired waters,” “algal growth,” “ammonia,” “cause unknown,” “cause unknown-impaired biota,” “fish consumption advisory – pollutant unspecified,” “nutrients,” “organic enrichment/oxygen depletion,” “salinity/TDS/sulfates/chlorides,” “total toxicity,” and “toxic organics.” A 303(d) listing alone does not mean that airport deicing discharges are the cause of the waterbody impairments. However, 26 of the 34 in-scope airports discharging to impaired waters are discharging to waters impaired in a manner potentially associated with airport deicing pollutants. Even if these airports are not the root cause of the identified impairment, they contribute additional loadings of those pollutants by which the surface waters are already impaired.

Table 3-9 provides additional information on airports discharging directly to 303(d)-listed waters and associated impairments.

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Austin Straubel International Airport	FW	Dutchman Creek	Ammonia	X
	FW	Dutchman Creek	Nutrients	X
	FW	Dutchman Creek	Nutrients (Phosphorus)	X
	FW	Dutchman Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Dutchman Creek	Total Toxicity	X
Austin-Bergstrom International	FW	Colorado River Below Town Lake	Pathogens	
	FW	Onion Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Onion Creek	Total Dissolved Solids	X
	FW	Onion Creek	Pathogens	
Birmingham International	FW	Village Creek	Ammonia	X
	FW	Village Creek	Nutrients	X
	FW	Village Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Village Creek	Toxic Organics	X
	FW	Village Creek	Flow Alteration	
	FW	Village Creek	Metals (Other Than Mercury)	
	FW	Village Creek	pH	
	FW	Village Creek	Sediment	
	FW	Village Creek	Temperature	
Boeing Field/King County International	FW	Duwamish River	pH	
Bradley International	FW	Farmington River	Pathogens	
	FW	Stony Brook	Cause Unknown	X
Cincinnati/Northern Kentucky International	FW	Elijahs Creek	Toxic Organics	X
	FW	Elijahs Creek	Ammonia	X
	FW	Elijahs Creek	Dissolved Oxygen	X
	FW	Gunpowder Creek	Ammonia	X
	FW	Gunpowder Creek	Dissolved Oxygen	X

¹FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Cleveland-Hopkins International	FW	Rocky River	Ammonia	X
	FW	Rocky River	Nutrients	X
	FW	Rocky River	Organic Enrichment/Oxygen Depletion	X
	FW	Rocky River	Chlorine	
	FW	Rocky River	Flow Alteration	
	FW	Rocky River	Habitat Alteration	
	FW	Rocky River	Pathogens	
	FW	Rocky River	PCBs	
	FW	Rocky River	Sediment	
Des Moines International	FW	Yeader Creek	Salinity/TDS/Sulfates/Chlorides	X
	FW	Yeader Creek	Toxic Organics	X
	FW	Easter Lake	Nutrients (Phosphorus)	X
Detroit Metropolitan Wayne County	FW	Frank And Poet Drain	Cause Unknown - Impaired Biota	X
Eppley Airfield	FW	Missouri River	Pathogens	
	FW	Missouri River	PCBs	
	FW	Missouri River	Pesticides	
General Edward Lawrence	MW	Boston Inner Harbor	Toxic Organics	X
Logan International	MW	Boston Inner Harbor	Pathogens	
Hartsfield - Jackson Atlanta International	FW	Flint River	Pathogens	
Indianapolis International	FW	East Fork White Lick Creek	Cause Unknown - Impaired Biota	X
	FW	East Fork White Lick Creek	Pathogens	
	FW	East Fork White Lick Creek	PCBs	
	FW	State Ditch	Cause Unknown - Impaired Biota	X
	FW	State Ditch	Pathogens	
James M Cox Dayton International	FW	Stillwater River	Ammonia	X
	FW	Stillwater River	Nutrients	X
	FW	Stillwater River	Organic Enrichment/Oxygen Depletion	X
	FW	Stillwater River	Habitat Alteration	
	FW	Stillwater River	Pathogens	

¹FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
John F Kennedy International	MW	Bergen Basin	Aesthetics	X
	MW	Bergen Basin	Dissolved Oxygen	X
	MW	Bergen Basin	Pathogens	
	MW	Jamaica Bay	Nutrients	X
	MW	Jamaica Bay	Dissolved Oxygen	X
	MW	Jamaica Bay	Pathogens	
	MW	Thurston Basin	Dissolved Oxygen	X
La Guardia	MW	Bowery Bay	Dissolved Oxygen	X
	MW	Bowery Bay	Pathogens	
	MW	Bowery Bay	PCBs	
	MW	Flushing Bay	Aesthetics	X
	MW	Flushing Bay	Dissolved Oxygen	X
	MW	Flushing Bay	PCBs	
	MW	Rikers Island Channel	Dissolved Oxygen	X
	MW	Rikers Island Channel	Pathogens	
Lafayette Regional	MW	Rikers Island Channel	PCBs	
	FW	Vermilion River	Nutrients	X
	FW	Vermilion River	Organic Enrichment/Oxygen Depletion	X
	FW	Vermilion River	Pathogens	
	FW	Vermilion River	Pesticides	
Louisville International- Standiford Field	FW	Vermilion River	Turbidity	
	FW	Southern Ditch	Organic Enrichment/Oxygen Depletion	X
Minneapolis-St Paul International/Wold-Chamberlain	FW	Southern Ditch	Pathogens	
	FW	Minnesota River	Organic Enrichment/Oxygen Depletion	X
	FW	Minnesota River	Mercury	
	FW	Minnesota River	Pathogens	
	FW	Minnesota River	PCBs	
	FW	Minnesota River	Turbidity	

¹FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Newark Liberty International	MW	Elizabeth Channel	Toxic Organics	X
	MW	Elizabeth Channel	Dioxin	
	MW	Elizabeth Channel	Floatables	
	MW	Elizabeth Channel	Metals	
	MW	Elizabeth Channel	Pathogens	
	MW	Elizabeth Channel	PCBs	
	MW	Newark Channel	Toxic Organics	X
	MW	Newark Channel	Dioxin	
	MW	Newark Channel	Floatables	
	MW	Newark Channel	Metals	
	MW	Newark Channel	Pathogens	
	MW	Newark Channel	PCBs	
Norman Y. Mineta San Jose International	FW	Los Gatos Creek	Pesticides	
Ontario International	FW	Cucamonga Creek	Pathogens	
Phoenix Sky Harbor International	FW	Salt River	Pesticides (Chlordane)	
	FW	Salt River	Pesticides (DDT Metabolites)	
	FW	Salt River	Pesticides (Dieldrin)	
	FW	Salt River	Pesticides (Toxaphene)	
	FW	Salt River	pH	
Piedmont Triad International	FW	Brush Creek	Habitat Alteration	
	FW	East Fork Deep River	Habitat Alteration	
	FW	East Fork Deep River	Pathogens	
	FW	East Fork Deep River	Turbidity	
	FW	Horsepen Creek	Sediment	

¹FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Port Columbus International	FW	Big Walnut Creek	Ammonia	X
	FW	Big Walnut Creek	Cause Unknown	X
	FW	Big Walnut Creek	Nutrients	X
	FW	Big Walnut Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Big Walnut Creek	Total Toxicity	X
	FW	Big Walnut Creek	Toxic Organics	X
	FW	Big Walnut Creek	Flow Alteration	
	FW	Big Walnut Creek	Habitat Alteration	
	FW	Big Walnut Creek	Metals (Other Than Mercury) (Copper)	
	FW	Big Walnut Creek	Metals (Other Than Mercury)	
	FW	Big Walnut Creek	Pathogens	
	FW	Big Walnut Creek	Sediment	
	FW	Big Walnut Creek	Temperature	
	FW	Big Walnut Creek	Turbidity	
Portland International	FW	Columbia Slough	Algal Growth	X
	FW	Columbia Slough	Dioxins	
	FW	Columbia Slough	Metals (Other Than Mercury)	
	FW	Columbia Slough	Nutrients	X
	FW	Columbia Slough	Organic Enrichment/Oxygen Depletion	X
	FW	Columbia Slough	Pathogens	
	FW	Columbia Slough	PCBs	
	FW	Columbia Slough	Pesticides	
Rickenbacker International	FW	Columbia Slough	pH	
	FW	Walnut Creek	Cause Unknown	X
	FW	Walnut Creek	Fish Consumption Advisory - Pollutant Unspecified	X
	FW	Walnut Creek	Total Toxicity	X
	FW	Walnut Creek	Flow Alteration	
	FW	Walnut Creek	Habitat Alteration	
	FW	Walnut Creek	Pathogens	
	FW	Walnut Creek	PCBs	
	FW	Walnut Creek	Sediment	

¹FW – Freshwater
MW – Marine water

Table 3-9: 303(d) Listed Waters Receiving Direct Airport Deicing Discharges from Surveyed Airport within Scope of the Final Rule

Airport Name	Waterbody Type ¹	Waterbody Name	Parent Cause Description	Potentially Linked to Airport Deicing
Ronald Reagan Washington National	FW	Lower Anacostia River	Organic Enrichment/Oxygen Depletion	X
	FW	Lower Anacostia River	Toxic Organics (Bis(2-Ethylhexyl)Phthalate)	X
	FW	Lower Anacostia River	Toxic Organics (Chrysene)	X
	FW	Lower Anacostia River	Toxic Organics	X
	FW	Lower Anacostia River	Chlorine	
	FW	Lower Anacostia River	Dioxins	
	FW	Lower Anacostia River	Mercury	
	FW	Lower Anacostia River	Metals (Other Than Mercury) (Selenium)	
	FW	Lower Anacostia River	Metals (Other Than Mercury)	
	FW	Lower Anacostia River	Oil And Grease	
	FW	Lower Anacostia River	Pathogens	
	FW	Lower Anacostia River	Turbidity	
San Antonio International	FW	Salado Creek	Cause Unknown - Impaired Biota	X
	FW	Salado Creek	Organic Enrichment/Oxygen Depletion	X
	FW	Salado Creek	Pathogens	
	FW	Salado Creek	Pesticides	
Seattle-Tacoma International	MW	Puget Sound	Nutrients	X
	MW	Puget Sound	Toxic Organics	X
	MW	Puget Sound	Mercury	
	MW	Puget Sound	Pathogens	
	MW	Puget Sound	Pesticides	
	MW	Puget Sound	pH	
Theodore Francis Green State	FW	Buckeye Brook	Cause Unknown - Impaired Biota	X
	FW	Buckeye Brook	Pathogens	
Toledo Express	FW	Swan Creek	Total Toxicity	X
	FW	Swan Creek	Habitat Alteration	
	FW	Swan Creek	Sediment	
Wilkes-Barre/Scranton International	FW	Spring Brook	Cause Unknown	X

¹FW – Freshwater
MW – Marine water

3.5.2 Airport Deicing Discharges Listed as TMDL Point Sources

To identify TMDLs that list airport deicing discharges as a point source contributing to a receiving waterbody's impairment, EPA searched the online TMDL document database (http://iaspub.epa.gov/waters/text_search.tmdl_search_form, accessed August 2, 2007). The EPA TMDL document database tracks information on waters listed by states as impaired under Section 303(d) of the Clean Water Act. The database provides information such as the identity of the pollutant causing the impairment, the source of the impairment, and the status of TMDL development for the impaired water body.

To date, EPA has identified 4 TMDL documents officially listing airport deicing discharges as point sources contributing to surface water impairment:

- Total Maximum Daily Load for Priority Organics Yeader, Creek, Polk County, Iowa;
- Total Maximum Daily Loads for Nutrients and Siltation, Easter Lake, Polk County, Iowa;
- Impacts of Deicing Fluids on Elijahs and Gunpowder Creeks, Boone County, Kentucky; and
- Columbia Slough Total Maximum Daily Loads for Dissolved Oxygen.

The state of Iowa has listed Yeader Creek as impaired by excessive levels of "priority organics" (glycol compounds) and identified Des Moines International Airport as the primary source. The TMDL describes Yeader Creek as a small stream (2 to 3 cubic feet per second flow). Waters immediately downstream from airport deicing stormwater outfalls had a greenish color, a wastewater odor, and no fish or macroinvertebrates. In addition, exposed substrate was an unusual rust-orange color and embedded substrate was an unusual black color, suggesting anaerobic conditions. The Yeader Creek TMDL describes two additional locations downstream as having pools of water the same nonalgal green color and with the "same odor of sewage and sweetener" as the waters immediately downstream of the airport deicing stormwater outfalls. The Yeader Creek TMDL established discharge limits for ethylene glycol and propylene glycol for airport deicing outfalls and set a benthic macroinvertebrate distribution target for the river to assess stream recovery.

The state of Iowa has listed Easter Lake as impaired for nutrients (i.e., phosphorus) and sediment. Although the Des Moines International Airport was identified as a contributing point sources for nutrient impairment, the airport's stormwater phosphorus load (110 pounds per year) was considered to be minor in comparison to other potential phosphorus sources in the watershed and the airport was not assigned a waste load reduction goal. The TMDL analysis did not consider the Des Moines International Airport to be a significant source of sediment to Easter Lake.

Elijahs and Gunpower Creeks are located immediately downstream from the Cincinnati/Northern Kentucky International Airport. Since the early 1990s the Kentucky Division of Water has documented low dissolved oxygen levels, evidence of ammonia toxicity, and extensive growth of *Sphaerotilus* bacteria in the creeks. In 1996, both streams were listed on Kentucky's 303(d) list of impaired waters and ranked as a high priority for TMDL development. The results of the TMDL analysis established discharge limits for BOD₅ and ammonia and required the airport to develop a Best Management Practices plan and a Groundwater Protection Plan.

The Columbia Slough, located downstream from the Portland International Airport in Oregon, is listed as impaired for multiple water quality parameters including bacteria, pH, dissolved oxygen, phosphorus, temperature, lead, and several toxic organics. The TMDL identified a complex list of pollution sources

contributing to the Slough's impairment including combined sewer overflows, landfill leachate, airport deicing discharges, urban and industrial runoff, and other point sources in the watershed. Airport deicing discharges were identified as the primary pollution source for wintertime dissolved oxygen violations in the Slough. The TMDL established a range of BOD waste load allocations for airport deicing discharges to meet dissolved oxygen goals and also required the airport to perform additional waterbody monitoring.

3.5.3 Resources Located Downstream from Airport Deicing Discharge Outfalls

As a screening-level assessment, EPA evaluated the potential for airport deicing discharges to affect the following resources:

- Groundwater aquifers;
- Drinking water intakes from surface water sources;
- Federal lands;
- National, state, and local parks; and
- National Wildlife Refuge Areas (NWRAs).

EPA assessed the potential for airport deicing discharges to affect groundwater aquifers based on information provided in responses to EPA's *Airport Deicing Questionnaire* (US EPA 2006c). Individual airports' responses indicated whether or not airport grounds are located immediately above an aquifer, and whether or not the aquifer is a drinking water source. EPA assessed the remaining aquatic resources listed above for those surface waters located within 10 miles downstream of airport deicing outfalls, using the same GIS-based methodology described in *Section 3.5.1*. EPA overlaid the relevant NHD Plus stream segments over the following GIS coverages to determine whether downstream surface waters intersect with the GIS areas associated with each resource:

- Drinking water intake point file from EPA's Reach Address Database (RAD);
- National atlas of the U.S. federal land boundaries;
- Environmental Systems Research Institute (ESRI) U.S. Geographic Data Technology, Inc. (GDT) park landmarks (includes federal, state, and local parks in the U.S.); and
- U.S. Fish and Wildlife National Wildlife Refuge Area boundaries.

EPA analyzed aquatic resources within a distance of 10 miles downstream of airport deicing stormwater outfalls because, according to EPA's literature compilation, many documented impacts have taken place within this distance. Impacts could occur at distances beyond 10 miles downstream, but EPA has chosen 10 miles for this preliminary analysis.

Table 3-10 presents the results of the analysis for aquatic resources which could potentially be affected by airport deicing discharges. Because EPA has sufficient information to conduct this analysis for only airports EPA surveyed, the table below is not a complete list of airports discharging deicing pollutants to surface waters containing the resources listed above.

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

Airport Name	Airport City	Airport State	Airport Grounds Above an Aquifer	Within 10 Miles Downstream from Airport Deicing Outfall			
				Drinking Water Intakes	Federal Lands	Parks	NWRAs
Albany International	Albany	NY		Yes		Yes	
Albuquerque International Sunport	Albuquerque	NM	DW				
Aspen-Pitkin Co/Sardy Field	Aspen	CO			Yes		
Austin Straubel International	Green Bay	WI	DW				
Austin-Bergstrom International	Austin	TX	Yes				
Baltimore-Washington International	Baltimore	MD	DW			Yes	
Bethel	Bethel	AK					
Birmingham International	Birmingham	AL	Yes			Yes	
Bismarck Municipal	Bismarck	ND					
Boeing Field/King County International	Seattle	WA	Yes			Yes	
Bradley International	Windsor Locks	CT	Yes			Yes	
Buffalo Niagara International	Buffalo	NY	Yes			Yes	
Central Wisconsin	Mosinee	WI					
Charlotte/Douglas International	Charlotte	NC	Yes			Yes	
Chicago O'Hare International	Chicago	IL	Yes			Yes	
Cincinnati/Northern Kentucky International	Covington	KY	Yes			Yes	
City of Colorado Springs Municipal	Colorado Springs	CO					
Cleveland-Hopkins International	Cleveland	OH				Yes	
Dallas Love Field	Dallas	TX	DW			Yes	
Dallas/Fort Worth International	Dallas-Fort Worth	TX				Yes	
Denver International	Denver	CO	Yes				
Des Moines International	Des Moines	IA	Yes	Yes		Yes	
Detroit Metropolitan Wayne County	Detroit	MI				Yes	
Eppley Airfield	Omaha	NE	DW	Yes			
Evansville Regional	Evansville	IN					
Fairbanks International	Fairbanks	AK	DW				
Fort Wayne International	Fort Wayne	IN	DW	Yes			
General Edward Lawrence Logan International	Boston	MA	Yes				
General Mitchell International	Milwaukee	WI				Yes	
George Bush Intercontinental Airport/Houston	Houston	TX	DW			Yes	
Gerald R. Ford International	Grand Rapids	MI					
Glacier Park International	Kalispell	MT	DW		Yes		
Greater Rochester International	Rochester	NY	Yes			Yes	
Hartsfield - Jackson Atlanta International	Atlanta	GA	Yes			Yes	
Indianapolis International	Indianapolis	IN	Yes			Yes	
James M Cox Dayton International	Dayton	OH					
John F Kennedy International	New York	NY			Yes	Yes	
Juneau International	Juneau	AK					

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

Airport Name	Airport City	Airport State	Airport Grounds Above an Aquifer	Within 10 Miles Downstream from Airport Deicing Outfall			
				Drinking Water Intakes	Federal Lands	Parks	NWRAs
Kansas City International	Kansas City	MO		Yes			
La Guardia	New York	NY					
Lafayette Regional	Lafayette	LA	DW				
Lambert-St Louis International	St Louis	MO	Yes			Yes	
Louisville International- Standiford Field	Louisville	KY					
Lovell Field	Chattanooga	TN	Yes	Yes			
Manchester	Manchester	NH	Yes	Yes		Yes	
Mc Carran International	Las Vegas	NV	DW			Yes	
Memphis International	Memphis	TN	Yes				
Minneapolis-St Paul International/Wold-Chamberlain	Minneapolis	MN	Yes		Yes	Yes	
Montgomery Regional (Dannelly Field)	Montgomery	AL	Yes				
Nashville International	Nashville	TN		Yes		Yes	
Newark Liberty International	Newark	NJ	Yes				
Nome	Nome	AK	Yes				
Norfolk International	Norfolk	VA	Yes				
Norman Y. Mineta San Jose International	San Jose	CA			Yes	Yes	Yes
Northwest Arkansas Regional	Fayetteville/ Springdale	AR	Yes				
Ontario International	Ontario	CA					
Outagamie County Regional	Appleton	WI	DW				
Philadelphia International	Philadelphia	PA	DW				
Phoenix Sky Harbor International	Phoenix	AZ	DW				
Piedmont Triad International	Greensboro	NC	DW	Yes		Yes	
Pittsburgh International	Pittsburgh	PA		Yes			
Port Columbus International	Columbus	OH				Yes	
Portland International	Portland	OR	Yes				
Raleigh-Durham International	Raleigh/Durham	NC	DW			Yes	
Ralph Wien Memorial	Kotzebue	AK	Yes				
Rapid City Regional	Rapid City	SD	DW				
Redding Municipal	Redding	CA	DW			Yes	
Reno/Tahoe International	Reno	NV	DW				
Rickenbacker International	Columbus	OH	Yes				
Roanoke Regional/Woodrum Field	Roanoke	VA	Yes				
Rochester International	Rochester	MN	DW				
Ronald Reagan Washington National	Washington	DC	Yes		Yes	Yes	
Sacramento International	Sacramento	CA	DW	Yes		Yes	
Salt Lake City International	Salt Lake City	UT					
San Antonio International	San Antonio	TX				Yes	
Seattle-Tacoma International	Seattle	WA	DW			Yes	
Syracuse Hancock International	Syracuse	NY					

Table 3-10: Resources Potentially Impacted by Airport Deicing Discharges from Surveyed Airports within Scope of the Final Rule

Airport Name	Airport City	Airport State	Airport Grounds Above an Aquifer	Within 10 Miles Downstream from Airport Deicing Outfall			
				Drinking Water Intakes	Federal Lands	Parks	NWRAs
Ted Stevens Anchorage International	Anchorage	AK	Yes				
Theodore Francis Green State	Providence	RI	Yes			Yes	
Toledo Express	Toledo	OH	DW				
Tucson International	Tucson	AZ	Yes				
Washington Dulles International	Washington	DC	DW	Yes	Yes	Yes	
Wilkes-Barre/Scranton International	Wilkes-Barre/Scranton	PA	Yes				
Will Rogers World	Oklahoma City	OK	DW				
Wilmington International	Wilmington	NC	DW				
Yeager	Charleston	WV		Yes			

DW = Aquifer is known by airport to be used for drinking water.

4 Benefits of Final Regulatory Options

This chapter summarizes the final regulatory options EPA evaluated and the environmental benefits EPA anticipates will result from each option. The benefits of reduced airport deicing pollutant discharges may be classified in three broad categories: human health, ecological and economic productivity benefits. EPA was not able to monetize benefits of the final regulatory options because of an imperfect understanding of the link between discharge reductions and benefit categories, and how society values some of the benefit events.

This chapter presents a summary of EPA's regulatory options (*Section 4.1*), a discussion of individual airports likely to be affected by the final options and associated pollutant discharge reductions (*Sections 4.2 and 4.3*), and a qualitative assessment of expected ecological and human health and aquatic resource use benefits from reduced deicing pollutant discharges (*Section 4.4*).

4.1 Final Regulatory Options

EPA evaluated two different collection and treatment scenarios for aircraft deicing operation discharges from ADF application sites:

- **20% collection and treatment scenario** - uses glycol collection vehicles (GCVs) for deicing stormwater collection and anaerobic fluid bed (AFB) treatment for deicing stormwater treatment;
- **40% collection and treatment scenario** - uses GCVs in combination with plug-and-pump technology for deicing stormwater collection and AFB treatment for deicing stormwater treatment.

A complete description of these collection and treatment methods is available in EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

EPA also evaluated methods for control of deicing pollutant discharges from the airfield beyond ADF application sites. One approach EPA evaluated is to eliminate the use of urea as a pavement deicer and replace it with other, less environmentally harmful products. Other, less harmful products (e.g., potassium acetate, sodium acetate, and sodium formate) are available for substitution.

Table 4-1 provides a brief description of each of EPA's final regulatory options.

Table 4-1: Regulatory Options Evaluated for the Airport Deicing Category

Option	Option Description	Number of Airports Subject to Option
1	40 percent ADF collection requirement for large and medium ADF users (based on plug and pump with GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment)	198
2	40 percent ADF collection requirement for the large ADF users (based on plug and pump with GCVs) and 20 percent ADF collection requirement for medium ADF users (based on GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment)	198
3	Site-Specific Aircraft Deicing Discharge Controls	198

A complete description of how EPA constructed these regulatory options is available in the *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

4.2 Airports Affected by the Final Regulatory Options

EPA's survey collected data, for use in evaluating the airport deicing category, at all large and medium hub primary commercial airports, and a statistical subsample of small and nonhub primary commercial airports. To determine the airports within scope of the final regulatory options, EPA evaluated those airports for which survey information is available and then scaled up the resulting data using statistical weighting factors to represent conditions for the entire category. For additional information on the use of survey data and associated statistical weighting factors, see EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

For each regulatory option, EPA determined which individual airports are likely to fall within scope of the option. EPA then determined which surveyed airports are already in compliance with the option and which airports would likely need to take action to comply with the option.

For airports EPA surveyed, *Table 4-2* summarizes which options would likely require an airport to take action to address deicing discharges. For example, Albuquerque International Sunport falls within scope of Option 1 but, based on EPA's survey data, is believed to be already in compliance with both the 20% ADF collection and treatment and the urea restriction requirement. Therefore, for this airport under Option 1, EPA did not estimate additional technology requirements, compliance costs, or pollutant discharge reductions. Conversely, Charlotte-Douglas International Airport falls within scope of Option 1 and, based on EPA's survey information, is not believed to be in compliance with either the 20% ADF collection and treatment or the urea restriction requirement. For this airport, EPA evaluated GRV use and pavement deicer product substitution to reach compliance with Option 1's requirements. EPA also calculated associated compliance costs and pollutant discharge reductions.

Table 4-2: Surveyed Airports Affected by Final Regulatory Options

Airport Name	Option 1	Option 2	Option 3
Albuquerque Intl Sunport	X		
Austin Straubel International	X	X	X
Bethel	X	X	X
Boise Air Terminal/Gowen Fld	X	X	X
Bradley Intl	X	X	X
Central Wisconsin	X	X	X
Charlotte/Douglas Intl	X	X	X
Eppley Airfield	X	X	
Fairbanks Intl	X	X	X
Fort Wayne International	X	X	X
General Edward Lawrence Logan Intl	X	X	X
Glacier Park Intl	X	X	X
John F Kennedy Intl	X	X	
Juneau Intl	X	X	X
La Guardia	X	X	
Manchester	X	X	X
Memphis Intl	X	X	
Newark Liberty Intl	X	X	
Northwest Arkansas Regional	X	X	X
Piedmont Triad International	X	X	X
Port Columbus Intl	X	X	
Portland Intl	X		
Raleigh-Durham Intl	X	X	X
Ralph Wien Memorial	X	X	X
Reno/Tahoe International	X	X	X
Ronald Reagan Washington National	X	X	X
Salt Lake City Intl	X	X	X
Seattle-Tacoma Intl	X	X	
South Bend Regional	X	X	X
Spokane Intl	X	X	X
Stewart Intl	X	X	X
Ted Stevens Anchorage Intl	X	X	X
Yeager	X	X	X

Although EPA has insufficient information to determine what would happen under each regulatory option at each airport that was not surveyed, EPA was able to use statistical techniques to estimate the level to which each regulatory option would require airport deicing operation changes for the airport population determined to be within scope of the rule.

EPA's estimate of actions taken by individual airports under each regulatory option is based on data from EPA's Airport Deicing Questionnaire (2006c) and other publicly available data sources. Although current conditions at some individual airports may have changed since the survey was conducted, the overall results of the analysis provide a useful estimate of the level of action required by each regulatory option.

4.3 Environmental Benefits Anticipated under Final Regulatory Options

EPA expects that environmental benefits associated with each final regulatory option will accrue to society in several broad categories, including improved environmental quality, enhanced aquatic resource value for human use, reduced human health risks, and increased productivity in economic activities that are adversely affected by airport deicing pollutants discharges. This section provides a qualitative and quantitative discussion of benefits associated with the final regulatory options.

4.3.1 *Airport Actions and Benefits under Final Regulatory Options*

In assessing potential benefits from reducing airport deicing pollutant discharges, EPA used information on deicing pollutant environmental behavior, pollutant effects on the aquatic environment, human use of aquatic resources, and human health; deicing pollutant discharge levels under current conditions and under each final regulatory option; and characteristics of surface and ground water resources potentially affected by deicing pollutant discharges.

Table 4-3 and *Table 4-4* list the airports addressed by each regulatory option along with the following information:

- EPA's estimates of ammonia and COD discharge reductions associated with each airports ADF collection and treatment and pavement deicer substitution actions;
- Whether the airport discharges deicing pollutants directly to a water body listed as impaired under Section 303(d) of the Clean Water Act;
- Whether the airport property is above a groundwater aquifer and if that aquifer supplies drinking water (US EPA 2006c); and
- Information on aquatic resources (drinking water intakes, federal lands, and park lands) within 10 miles downstream of airport outfalls.³

³ Source files include the drinking water intake point file from EPA's Reach Address Database (RAD); national atlas of the U.S. federal land boundaries; ESRI U.S. GDT park landmarks (includes U.S. national, state, and local parks); and U.S. Fish and Wildlife NWRA boundaries.

Table 4-3. Option 1 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall ¹	Above an Aquifer ²	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Albuquerque Intl Sunport	0	119,915	0		DW			
Austin Straubel International	25,387	0	69,240	P	DW			
Bethel	38,105	0	103,927					
Boise Air Terminal/Gowen Field	152,740	0	416,584		DW			
Bradley International	9,478	0	25,849	P	X			X
Central Wisconsin	69,856	0	190,526					
Charlotte/Douglas International	84,821	510,138	231,340		X			X
Eppley Airfield	0	412,933	0	X	DW	X		
Fairbanks International	187,883	0	512,432		DW			
Fort Wayne International	161,593	0	440,728		DW	X		
General Edward Lawrence Logan International	5,782	3,567,358	15,769	P	X			
Glacier Park International	189	0	514		DW		X	
John F Kennedy International	0	2,010,543	0	P			X	X
Juneau International	270,506	0	737,779					
La Guardia	0	1,644,524	0	P				
Manchester	20,844	669,225	56,851		X	X		X
Memphis International	0	759,100	0	X	X			
Newark Liberty International	0	4,197,448	0	P	X			
Northwest Arkansas Regional	10,186	0	27,782		X			
Piedmont Triad International	52,441	255,757	143,028	X	DW	X		X
Port Columbus International	0	1,141,588	0	P				X
Portland Intl	0	208,513	0		X			
Raleigh-Durham International	35,841	381,179	97,753		DW			X
Ralph Wien Memorial	5,659	0	15,435		X			
Reno/Tahoe International	6,330	138,835	17,265		DW			
Ronald Reagan Washington National	44,141	0	120,391	P	X		X	X
Salt Lake City International	634,519	0	1,730,588					
Seattle-Tacoma Intl	0	585,861	0		DW			X
South Bend Regional	18,358	0	50,070		DW			

¹ P = Impairment potentially linked to airport deicing.

² DW = Airport located above an aquifer used for drinking water.

Table 4-3. Option 1 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall ¹	Above an Aquifer ²	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Spokane International	281,824	0	768,648		X			
Stewart International	85,905	0	234,299					
Ted Stevens Anchorage International	1,423,212	0	3,881,674		X			
Yeager	15,572	0	42,471			X		

¹ P = Impairment potentially linked to airport deicing.

² DW = Airport located above an aquifer used for drinking water.

Table 4-4. Option 2 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	COD Discharge Reduction (pounds)		303(d) Listed Waters at the Outfall ¹	Above an Aquifer ²	Within 10 Miles Downstream of Airport Outfall(s)		
		Aircraft Deicing Fluids	Pavement Deicers			Drinking Water Intake	Federal Lands	Park Lands
Austin Straubel International	25,387	0	69,240	P	DW			
Bethel	38,105	0	103,927					
Boise Air Terminal/Gowen Field	152,740	0	416,584		DW			
Bradley International	9,478	0	25,849	P	X			X
Central Wisconsin	69,856	0	190,526					
Charlotte/Douglas International	84,821	255,069	231,340		X			X
Eppler Airfield	0	206,466	0	X	DW	X		
Fairbanks International	187,883	0	512,432		DW			
Fort Wayne International	161,593	0	440,728		DW	X		
General Edward Lawrence Logan International	5,782	1,783,679	15,769	P	X			
Glacier Park International	189	0	514		DW		X	
John F Kennedy International	0	1,005,272	0	P			X	X
Juneau International	270,506	0	737,779					
La Guardia	0	822,262	0	P				
Manchester	20,844	334,613	56,851		X	X		X
Memphis International	0	379,550	0	X	X			
Newark Liberty International	0	2,098,724	0	P	X			
Northwest Arkansas Regional	10,186	0	27,782		X			
Piedmont Triad International	52,441	127,879	143,028	X	DW	X		X
Port Columbus International		570,794	0	P				X
Raleigh-Durham International	35,841	190,589	97,753		DW			X
Ralph Wien Memorial	5,659	0	15,435		X			
Reno/Tahoe International	6,330	0	17,265		DW			
Ronald Reagan Washington National	44,141	0	120,391	P	X		X	X
Salt Lake City International	634,519	0	1,730,588					
Seattle-Tacoma Intl	0	292,931	0		DW			X
South Bend Regional	18,358	0	50,070		DW			
Spokane International	281,824	0	768,648		X			
Stewart International	85,905	0	234,299					
Ted Stevens Anchorage International	1,423,212	0	3,881,674		X			
Yeager	15,572	0	42,471			X		

¹ P = Impairment potentially linked to airport deicing.

² DW = Airport located above an aquifer used for drinking water.

Table 4-5. Option 3 – Airport Load Reductions and Environmental Benefits

Airport Name	Pavement Deicer Ammonia (pounds)	Pavement Deicers COD Discharge Reduction (pounds)	303(d) Listed Waters at the Outfall ¹	Above an Aquifer ²	Within 10 Miles Downstream of Airport Outfall(s)		
					Drinking Water Intake	Federal Lands	Park Lands
Austin Straubel International	25,387	69,240	P	DW			
Bethel	38,105	103,927					
Boise Air Terminal/Gowen Field	152,740	416,584		DW			
Bradley International	9,478	25,849	P	X			X
Central Wisconsin	69,856	190,526					
Charlotte/Douglas International	84,821	231,340		X			X
Fairbanks International	187,883	512,432		DW			
Fort Wayne International	161,593	440,728		DW	X		
General Edward Lawrence Logan International	5,782	15,769	P	X			
Glacier Park International	189	514		DW		X	
Juneau International	270,506	737,779					
Manchester	20,844	56,851		X	X		X
Northwest Arkansas Regional	10,186	27,782		X			
Piedmont Triad International	52,441	143,028	X	DW	X		X
Raleigh-Durham International	35,841	97,753		DW			X
Ralph Wien Memorial	5,659	15,435		X			
Reno/Tahoe International	6,330	17,265		DW			
Ronald Reagan Washington National	44,141	120,391	P	X		X	X
Salt Lake City International	634,519	1,730,588					
South Bend Regional	18,358	50,070		DW			
Spokane International	281,824	768,648		X			
Stewart International	85,905	234,299					
Ted Stevens Anchorage International	1,423,212	3,881,674		X			
Yeager	15,572	42,471			X		

¹ P = Impairment potentially linked to airport deicing.

² DW = Airport located above an aquifer used for drinking water.

Table 4-6 presents the total COD and ammonia discharge reductions associated with each of the regulatory options.

Table 4-6: Annual Pollutant Discharge Reductions under Regulatory Options			
Regulatory Option	ADF COD (million pounds)	Pavement Deicer COD (million pounds)	Pavement Deicer Ammonia (million pounds)
Option 1	16.6	12.0	4.4
Option 2	13.8	12.0	4.4
Option 3	0	12.0	4.4

The totals for each regulatory option in Table 4-6 are greater than the sum of the reductions presented for individual airports in Table 4-3 and Table 4-4. This is because the totals in Table 4-6 reflect discharge reductions associated with all airports in scope of the final regulatory options, whereas Table 4-3 and Table 4-4 present reductions associated only with airports EPA surveyed. EPA calculated the discharge reductions associated with these airports by using statistical weighting factors associated with EPA's Airport Deicing Questionnaire (US EPA 2006c). For additional information on the calculation of discharge reductions associated with each regulatory option, see EPA's *Technical Development Document for the Final Effluent Limitation Guidelines and Standards for the Airport Deicing Category* (US EPA 2010).

Table 4-6 presents discharge reductions only for COD and ammonia. The final regulatory options will reduce discharges of other pollutants, as well (see Chapter 2), but EPA does not have sufficient information at this time to quantify those reductions.

4.4 Expected Ecological, Human Aquatic Resource Use, and Human Health Benefits

The final regulatory options will reduce discharges of chemical oxygen demand (COD), ammonia from urea pavement deicers, and other airport deicing product chemicals from selected airports. EPA anticipates that these discharge reductions will improve receiving water characteristics, including pollutant levels, aesthetic problems, aquatic community health, and utility for human needs and health.

4.4.1 Ecological Benefits

Ecological benefits from the regulation include protection of fresh- and saltwater plants, invertebrates, fish, and amphibians, and other aquatic organisms, as well as terrestrial wildlife and birds that prey on aquatic organisms exposed to airport deicing pollutants. The final regulation will reduce the presence and discharge of various pollutants to aquatic ecosystems currently under stress (e.g., 303(d) listed water bodies). The drop in pollutant discharges would help reestablish productive ecosystems in damaged waterways, protect resident species, including threatened and endangered species where present, and reduce the severity and frequency of fish kill events.

4.4.2 Human Health Benefits

As discussed in Chapters 2 and 3 of this document, EPA identified several possible health risks and incidents of complaint by members of the public associated with certain ADF and pavement deicer components. To the extent current discharges contribute to human health risk, reducing airport deicing

pollutant discharges to the nation's waterways will generate human health benefits by reducing risk of non-cancer and cancer toxic effects from fish and water consumption and contact.

Human health benefits are typically analyzed by estimating the change in the expected number of adverse human health events in the exposed population resulting from a reduction in effluent discharges. EPA, however, did not quantify changes in human health risk resulting from the final regulatory options due to unavailability of dose-response functions for many chemicals of potential concern and the complexity of many chemical's environmental behavior.

In concept, the value of these health effects to society is the monetary value that society is willing to pay to avoid the health effects, or the amount that society would need to be compensated to accept increases in the number of adverse health events. Willingness to pay (WTP) values are generally considered to provide a fairly comprehensive measure of society's valuation of the human and financial costs of illness associated with the costs of health care, losses in income, and pain and suffering of affected individuals and of their family and friends. Another measure that is typically used in assessing human health benefits is the cost of an illness. Cost of an illness is the direct medical costs of treating a health condition (e.g., reproductive problems), and can be used to value changes in health risk from reduced exposure to pollutants such as ethylene glycol.

4.4.3 Human Use of Aquatic Resource Benefits

Improvements in ecosystems and habitats and enhanced aesthetic quality of surface waters enhance human use and enjoyment of these areas. In particular, reducing instances of objectionable odors, colors, and foaming that have been frequently reported in surface waters affected by ADFs and pavement deicers is expected to enhance a broad range of recreational uses of the affected waterbodies, including swimming, boating, fishing, water skiing, and use of park lands adjacent to affected waterbodies. Improvements will also enhance quality of life for people who live near affected waterbodies. The regulation will also augment nonuse values (e.g., option, existence, and bequest values) of the affected water resources.

EPA's review of 45 surface water valuation studies conducted between 1981 and 2002 demonstrates that society places a significant value on improving and/or protecting its water resources. Total WTP (including use and non-use values) for water quality improvements over the sample of 45 studies ranged from \$8.72 to \$525.91, with a mean value of \$120.54 (US EPA 2008c). WTP values from published studies vary widely depending on the study (e.g., methodology and sample size) and resource characteristics (e.g., water body characteristics, the magnitude of water quality improvements, the geographic scope of improvement). For example, WTP for reducing nutrient pollution and eutrophication impacts estimated by Shrestha and Alavapati (2004) ranges from \$84.15 to \$106.71 (2008\$, annualized). A study by Lindsey (1994) found that WTP to meet nutrient pollution reduction goals in the Chesapeake Bay ranged from \$34.90 to \$106.78 (2008\$), depending upon the choice of outliers and protest bids excluded. Values for oil and toxic materials reductions were also available in the same review. A study by Phaneuf et al. (1998) found that WTP for a 20% reduction in toxins at fishery sites in North Carolina's Tar-Pamlico basin ranges from \$14.59 to \$193.46 (2008\$), depending upon the models utilized. Based on the evidence from the published literature, EPA estimates that nonmarket benefits from water quality improvements resulting from reduced deicing pollutant discharges are likely to be substantial.

Reduced airport deicing discharges should improve groundwater and drinking water sources located under or near airports subject to regulation. Drinking water contaminated by deicing pollutants may pose

health risks or have an unpleasant taste and odor which may cause concerns regarding potential adverse health effects. Protection of groundwater sources from contamination by airport deicing pollutants is of particular concern because households that use private wells usually do not treat or regularly test their drinking water for contamination.

The appropriate measure of the economic value of clean groundwater achieved through a ban on MTBE use in gasoline is option price. This measure is commonly used when uncertainty is present in the analysis. Option price is defined as an individual's maximum WTP to secure the option to use a resource or commodity in the future (Desvousges et al. 1987 and Freeman 2003). Option price is a measure of the total economic value an individual places on protecting groundwater quality. Protecting groundwater quality provides a number of services to groundwater users, including avoidance of higher drinking water costs (e.g., avoided treatment or replacement costs), elimination of potential health concerns associated with consumption of bad tasting water, general aesthetic enjoyment derived from a clean environment, and any nonuse values associated with protecting groundwater quality (e.g., bequest value, existence value).

Based on the meta-analysis of groundwater valuation studies, WTP values for protection of groundwater from contamination by pollutants other than nitrates and pesticides (i.e., "Other" pollutants) range from \$154.74 to \$235.25 for residential wells. For small public water supply systems, household WTP values range from \$78 to \$122.03, and for public water supply systems, household WTP values range from \$78 to \$233.99 (2008\$) (US EPA 2001). All are annual values.

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Appendix A: Detailed Characterization of Airport Deicing Products

Table A-1: Surveyed U.S. Commercial Airports- Chemical Pavement Deicer Usage

Pavement Deicer Chemical	2002/2003 Total Surveyed Airport Usage (tons/year)	2003/2004 Total Surveyed Airport Usage (tons/year)	2004/2005 Total Surveyed Airport Usage (tons/year)	Average Total Surveyed Airport Usage (tons/year) [†]	Percentage of Chemical Usage
Potassium acetate	22,803	20,267	20,029	21,185	65
Propylene glycol-based fluids	3,317	4,147	2,884	3,089	9
Urea (airside)	3,015	3,804	4,031	3,620	11
Sodium acetate	2,815	3,195	2,663	2,888	9
Sodium formate	1,663	694	1,359	1,290	4
Ethylene glycol-based fluids	1,038	465	691	731	2

[†] Based on the 90 airports reporting airfield deicing chemical use. The 3 year average is not a straight average of the total annual amounts; the average for each airport was evaluated and calculated separately.

Source: EPA Airport Deicing Questionnaire (2006c). For additional details, see EPA (2010).

Table A-2: Chelating Agents

Characteristics	Ethylene diamine tetra acetic acid (EDTA)	Diethylene triamine penta acetic acid (DTPA , DTAA)
CASRN	60-00-4	67-43-6
Formula	$C_{10}H_{16}N_2O_8$	$C_{14}H_{23}N_3O_{10}$
Water solubility, g/L	1.0	4.8
Log K_{OW}	-3.86	-4.91
Log K_{OC}	1.99	
Henry's Law constant (atm-m ³ /mole)	7.69×10^{-16}	
Vapor pressure (mm Hg)	2×10^{-12}	
Environmental partitioning summary	Both volatilization and adsorption to soils and particulates are expected to be negligible.	
Degradation summary	Both aerobic and anaerobic biodegradation are negligible for un-complexed EDTA. Photolysis of EDTA complexed with Fe(III) is likely to be the primary route of degradation, but only where exposed to bright light. Otherwise, degradation appears to be minimal. ^a	Relatively resistant to biodegradation, especially where the microbial community is unacclimated.
Degradation products		
Half-life	In the upper layer of surface water directly exposed to the sun, the half-life of EDTA*Fe(III) was approximately 11 minutes.	
Transport rate summary	EDTA is highly mobile in soil, sediment, and water.	DTPA is expected to be highly mobile in soil, sediment, and water.
Mixture effects	Both of these substances can increase the mobility of potentially toxic metals. They readily form complexes with metal ions, bringing them into the soluble phase in soils, sediments, and water. This property is being investigated and exploited for extracting and phytoremediating toxic metals. ^a	
Additional notes	Degradation of uncomplexed EDTA appears to be minimal; photolysis of metal-complexed EDTA could be rapid in the presence of direct sunlight, and this may be the primary route of degradation. EDTA is commonly detected in surface water; it is not removed by standard wastewater or drinking water treatment processes, but may be degraded by UV treatment of drinking water. ^a Most characteristics of these compounds are expected to be similar.	

Source: Oviedo and Rodriguez (2003).

Blank cells indicate information not readily available to EPA at this time.

Table A-3: Freezing Point Depressants: Sugars

Characteristics	Dulcitol	Mannitol	Sorbitol
CASRN	608-66-2	69-65-8	50-70-4
Formula	C ₆ H ₁₄ O ₆	C ₆ H ₁₄ O ₆	C ₆ H ₁₄ O ₆
Water solubility, g/L	31		Freely soluble up to 83%
Log K _{OW}			-2.2
Log K _{OC}			0.30
Henry's Law constant (atm-m ³ /mole)			7.3x10 ⁻¹³
Vapor pressure (mm Hg)			4.9x10 ⁻⁹
Environmental partitioning summary	Not expected to volatilize or to adsorb to soils or particulates.		
Half-life			
Degradation summary	Biodegradation, the primary route of degradation, is expected to be very rapid. Hydrolysis and photolysis are not expected.		
Degradation products	Carbon dioxide, water, and microbial biomass.		
Transport rate summary	All of these substances may be highly mobile in water and soil, but biodegradation is likely to limit the distance of transport in surface water, groundwater, and soil.		
Mixture effects			
Degradation products	CO ₂		
Additional notes	Characteristics of these sugar alcohols are likely to be relatively similar.		
Blank cells indicate information not readily available to EPA at this time.			

Table A-4: Freezing Point Depressants: Acetates

Characteristics	Potassium acetate	Sodium acetate
CASRN	127-08-2	127-09-3 (anhydrous)
Formula	C ₂ H ₃ KO ₂	C ₂ H ₃ NaO ₂
Water solubility, g/L		1,190 at 0° C
Log K _{OW}		
Log K _{OC}	-3.72	
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		7.08x10 ⁻⁷
Environmental partitioning summary	These substances are not expected to volatilize. They are quite soluble in water. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents, but may also remain dissolved in surface water and groundwater. Acetate should be rapidly biodegraded under aerobic conditions in surface water, groundwater, and soil.	
Half-life		
Degradation summary		
Degradation products	The cations calcium, magnesium, potassium, and sodium are liberated, and acetate degradation produces bicarbonate, carbon dioxide, and water ^a .	
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.	
Mixture effects	Formate can decrease the breakdown of acetate in anaerobic environments.	
Additional notes		

Source: D'Itri (1992).

Blank cells indicate information not readily available to EPA at this time.

Table A-5: Freezing Point Depressants: Formates and Lactates

Characteristics	Potassium formate	Sodium formate	Ethyl lactate	Sodium lactate
CASRN	590-29-4	141-53-7	97-64-3	72-17-3
Formula	CH ₂ O ₂ .K	CH ₂ O ₂ .Na	C ₅ H ₁₀ O ₃	C ₃ H ₆ O ₃ .Na
Water solubility, g/L	3,310 at 18° C	972 at 20° C	Miscible with water	1,000
Log K _{OW}			-0.18	
Log K _{OC}			1	
Henry's Law constant (atm-m ³ /mole)			5.8x10 ⁻⁷	
Vapor pressure (mm Hg)			3.75	
Environmental partitioning summary	These substances are not expected to volatilize. They are quite soluble in water, and may be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents but may also remain dissolved in surface water and groundwater.			
Half-life			In water: hydrolysis: 72 days at pH 7; 7 days at pH 8.	
Degradation summary	Formate is slowly hydrolyzed in water, and can be anaerobically degraded by methanogens.		Hydrolysis to ethanol and lactate in surface waters may be an important degradation pathway.	
Degradation products	Release of potassium and sodium cations and microbial biomass.			
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.			
Mixture effects	60% ethyl lactate has a strong cosolvency effect and can increase the solubility of dense non-aqueous phase liquid (DNAPL) compounds by orders of magnitude.			
Additional notes				

Redox Tech (2008) and US NLM (2008).

Schauer et al. (1982) and Redox Tech (2008).

Blank cells indicate information not readily available to EPA at this time.

Table A-6: Freezing Point Depressants: Other

Characteristics	Sodium pyrrolidone carboxylate	Glycerol	Isopropanol	Proline	Erythritol	Pentaerythritol
CASRN	54571-67-4	56-81-5	67-63-0	147-85-3	149-32-6	115-77-5
Formula	C ₅ H ₇ NO ₃ .Na	C ₃ H ₈ O ₃	C ₃ H ₈ O	C ₅ H ₉ NO ₂	C ₄ H ₁₀ O ₄	C ₅ H ₁₂ O ₄
Water solubility, g/L		Freely soluble	1000	1620	610	72.3
Log K _{OW}		-1.76	0.05	-2.54	-2.29	-1.69
Log K _{OC}			1.4			
Henry's Law constant (atm-m ³ /mole)		1.73x10 ⁻⁸	8.10x10 ⁻⁶	1.92x10 ⁻⁹		4.1x10 ⁻¹⁰
Vapor pressure (mm Hg)		1.58X10 ⁻⁴	45.4	3.77x10 ⁻⁹		15.1
Environmental partitioning summary		Volatilizes more slowly than water. Should not adsorb to soil or particulates.	Volatilization is expected to be an important route of removal from soil and water. Should not adsorb to soil or particulates.			Readily forms complexes with metal ions; this is likely to retard its mobility in soils and sediments.
Half-lives		Atmospheric degradation: 33 h to 3.2 d.	Volatilization from river: 57 h; from lake: 29 d. Aerobic degradation in sludge: <1 d to 48 d.			
Degradation summary		Rapid, both aerobic and anaerobic.	Rapid, both aerobic and anaerobic.			3 to 15 days lag time before significant degradation begins.
Degradation products						
Transport rate summary		Should move very rapidly through soil and water, but range may be limited by rapid degradation.				
Mixture effects						
Additional notes	With the exception of the erythritols, these chemicals are not expected to share similar properties.					

Blank cells indicate information not readily available to EPA at this time.

Table A-7: Freezing Point Depressants: Ethylene Glycols

Characteristics	Poly-ethylene glycol, molecular weight from 62 to 106	Ethylene glycol	Diethylene glycol ^a	Triethylene glycol
CASRN	25322-68-3	107-21-1	111-46-6	112-27-6
Formula	(C ₂ H ₄ O) _n .(H ₂ O) _n	C ₂ H ₆ O ₂	C ₄ H ₁₀ O ₃	C ₆ H ₁₄ O ₄
Water solubility, g/L	Freely soluble	Freely soluble	Freely soluble	Freely soluble
Log K _{OW}		-1.36	1.47	-1.98
Log K _{OC}		1 (K _{OC})	1 (K _{OC})	1
Henry's Law constant (atm-cu m ³ /mole)		6.00x10 ⁻⁸	2x10 ⁻⁹	3.2x10 ⁻¹¹
Vapor pressure (mm Hg)		0.092	1	1.32x10 ⁻³
Environmental partitioning summary	Volatilization is not expected to be an important pathway for these glycols. Very high mobility is expected for all glycols in soil, sediment, and water. Experimentally determined adsorption of ethylene glycol to four soils (two clay, two sandy clay) ranged from 0-0.5%. Tracer experiments have shown that ethylene glycol moves through soil with water.			
Half-lives		Atmospheric half-life: 50 h at 25° C.	Atmospheric half-life: 13 h.	
Degradation summary		Very rapid degradation rates in soil, sediment, and water. Soils: 90 to 100% degradation of ethylene glycol was observed in various field soils in 2 to 12 days (temperatures not known); ethylene glycol in aircraft deicing or anti-icing fluid formulation was completely degraded in runway-side soils within 29 days at 8° C. Water: Hydrolysis and photolysis are not expected to be significant. Ethylene glycol in river water degraded completely in three days at 20° C and in 5 to 14 days at 8° C. Aerobic degradation of ethylene glycol may be essentially complete in less than one to four days under optimal conditions in water or treatment systems, but the impact of the full theoretical biological oxygen demand may not be observed for several weeks.	Water: Diethylene glycol in aerobic river water showed little degradation during winter.	Soils: Triethylene glycol in aerobic soil was completely degraded within 7 to 11 days.
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.			
Transport rate summary	Expected to have very high mobility in soil, sediment, and water.			
Mixture effects	Triazoles decrease the degradation rate of glycols. Low temperatures may also greatly decrease the degradation rates of glycols.			

Table A-7: Freezing Point Depressants: Ethylene Glycols

Characteristics	Poly-ethylene glycol, molecular weight from 62 to 106	Ethylene glycol	Diethylene glycol ^a	Triethylene glycol
Additional notes	Ethylene glycols are expected to share somewhat similar properties, except for polyethylene glycols. Formulated polyethylene glycol products contain different mixtures of polymers, and the properties of the products will vary based on the size and shape of the polymers they contain. All of these substances are expected to be rapidly degraded under aerobic and anaerobic conditions.			

a. Not currently used in the U.S.

Blank cells indicate information not readily available to EPA at this time.

Table A-8: Freezing Point Depressants: Propylene Glycols

Characteristics	Propylene glycol	1,3-Propylene glycol	1, 1'-oxybis-2-propanol (dipropylene glycol)
CASRN	57-55-6	504-63-2	25265-71-8
Formula	C ₃ H ₈ O ₂		C ₆ H ₁₄ O ₃
Water solubility, g/L	Freely soluble	Freely soluble	Freely soluble
Log K _{OW}	-0.92	-1.04	-1.486
Log K _{OC}	0.90		1 (K _{OC})
Henry's Law constant (atm-m ³ /mole)	1.3x10 ⁻⁸	1.74x10 ⁻⁷	5.6x10 ⁻⁹
Vapor pressure (mm Hg)	0.13	0.0441	0.032
Environmental partitioning summary	Very high mobility in soils, sediments, and water. Not expected to volatilize readily.		
Half-lives			
Degradation summary	Propylene glycol was not observed to degrade at 4° C, and only degraded at 20 C in soil that was rich in organic matter ^a .		
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.		
Transport rate summary			
Mixture effects			
Additional notes			

Source: Jaesche et al. (2006).

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Table A-9: Freezing Point Depressants: Urea and Metabolites

Characteristics	Urea	Ammonia
CASRN	57-13-6	7664-41-7
Formula	CH ₄ N ₂ O	H ₃ N
Water solubility, g/L	545	“31%”
Log K _{OW}	-2.11	0.23
Log K _{OC}	0.903	
Henry’s Law constant (atm-m ³ /mole)		1.61x10 ⁻⁵
Vapor pressure (mm Hg)	1.2x10 ⁻⁵	7.51x10 ³
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-10: Thickeners: Acrylic Acid Polymers

Characteristics	Carbomer	Carbopol 672	Carbopol 934	Carbopol 1610	Carbopol 1621	Carbopol 1622	Polymer of acrylic acid
CASRN	Trade name	Trade name	9007-16-3	Trade name	Trade name	Trade name	79-10-7
Formula	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid	polymer of acrylic acid
Water solubility, g/L							1x10 ³
Log K _{OW}							0.35
Log K _{OC}							1.63
Henry's Law constant (atm-m ³ /mole)							3.2x10 ⁻⁷
Vapor pressure (mm Hg)							3.97
Environmental partitioning summary	Not expected to volatilize from water or moist soil. Slow volatilization from dry soil is possible. Not expected to adsorb to soils or particulates; potential for transport in soil is high.						
Half-lives							
Degradation summary	Non-polymerized (monomeric) acrylic acid readily biodegrades both aerobically and anaerobically; it reached 68% of its theoretical BOD in 2 weeks using an activated sludge inoculum, and in a 42-day anaerobic screening study using a sewage seed inoculum, 71% of acrylic acid was degraded. However, biodegradability decreases with increasing number of polymerized units and increasing formula molecular weight, dropping off sharply between MWs 700 and 1,000, and for polymers with more than seven units ^a . It appears that monomers and dimers of acrylic acid are completely biodegradable, but there are indications polymers of three to seven units are incompletely biodegraded ^a .						
Degradation lag time							
Transport rate summary							
Mixture effects							
Additional notes	May be contaminated by low-ppm levels of metals.						

Source: Larson et al. (1997).

Blank cells indicate information not readily available to EPA at this time.

Table A-11: Thickeners: Natural Gums

Characteristics	Kappa-carrageenan	Iota-carrageenan	Welan gum	Xanthan gum
CASRN	Mixture	9062-07-1	Mixture	11138-66-2
Formula				
Water solubility, g/L	10			
Log K _{OW}				
Log K _{OC}				
Henry's Law constant (atm-m ³ /mole)				
Vapor pressure (mm Hg)				
Environmental partitioning summary				
Half-lives				
Degradation summary				
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes	Naturally-derived high-molecular-weight polysaccharide gums. Tend to be highly water soluble, and are expected to be biodegradable, although biodegradation information was not available.			

Blank cells indicate information not readily available to EPA at this time.

Table A-12: Thickeners: Other

Characteristics	Hydroxyethylcellulose
CASRN	9004-62-0
Formula	C ₂ -H ₆ -O ₂ .x-Unspecified
Water solubility g/L	Freely soluble
Log KOW	
Log KOC	
Henry's Law constant (atm-m ³ /mole)	
Vapor pressure (mm Hg)	
Environmental partitioning summary	
Half-lives	
Degradation summary	Cellulose gums are generally slowly biodegraded. Reported values for the biological oxygen demand of two samples of hydroxyethyl cellulose are 7,000 & 18,000 ppm, respectively, after 5 days of incubation.
Degradation lag time	
Transport rate summary	
Mixture effects	
Additional notes	

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Table A-13: Surfactants: Alcohol Ethoxylates

Characteristics	Decyl alcohol ethoxylate	Lauryl alcohol ethoxylate	Lauryl alcohol phosphoric acid - ester ethoxylate
CASRN	26183-52-8	Category	-
Formula	$\text{CH}_3(\text{CH}_2)_n(\text{OCH}_2\text{CH}_2)_y\text{OH}^a$	$\text{CH}_3(\text{CH}_2)_n(\text{OCH}_2\text{CH}_2)_y\text{OH}^a$	$\text{CH}_3(\text{CH}_2)_n(\text{OCH}_2\text{CH}_2)_y\text{OH}^a$
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}	In general, log K_d is a better predictor of behavior than K_{OW} for these substances^a. Log K_d, as with the other physicochemical parameters, varies by ethoximer. The formula below, as given by Belanger et al. (2006) permits the calculation of an estimated log K_d. $\log K_d = 0.331 * (\text{alkyl chain length}) - 0.009 * (\text{ethoxylate chain length}) - 1.126$		
Henry's Law constant (atm-m ³ /mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary	Sorption may be important, and is likely to vary by ethoximer.		
Half-lives			
Degradation summary	Aerobic degradation may be rapid.		
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Source: Belanger et al. (2006).

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Table A-14: Surfactants: Alkylbenzene Sulfonates

Characteristics	Sodium alkylbenzene sulfonate	Siponate A-2466, sodium dodecylbenzene sulfonate	Siponate DDB-40, sodium dodecylbenzene sulfonate	Siponate DS, sodium dodecylbenzene sulfonate	Sandocorin 8132, sodium dodecylbenzene sulfonate
CASRN	68411-30-3	Trade name	Trade name	Trade name	Trade name
Formula					
Water solubility, g/L					
Log K _{OW}					
Log K _{OC}					
Henry's Law constant (atm-m ³ /mole)					
Vapor pressure (mm Hg)					
Environmental partitioning summary					
Half-lives					
Degradation summary					
Degradation lag time					
Transport rate summary					
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-15: Surfactants: Alcohol Ethoxylates

Characteristics	Alcohol ethoxylates	Tergitol TMN-10, branched secondary alcohol ethoxylate	Aliphatic alcohol ethoxylates
CASRN	Category	Trade name	Category
Formula			
Water solubility, g/L			
Log K _{OW}			
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

Table A-16: Surfactants: Alkylphenol Ethoxylates

Characteristics	Alkylphenol ethoxylates	Octylphenol ethoxylates	Nonylphenol ethoxylates
CASRN	Category	Category	Category
Formula			C ₉ H ₁₉ - C ₆ H ₄ O(CH ₂ CH ₂ O) _n H ^a
Water solubility, g/L	All are highly soluble in water, but solubility varies by ethoxymers ^a .		
Log K _{OW}			
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary	Not expected to volatilize. Likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymers, and migration through the soil has been observed. In water, as in soil, may sorb to organic matter or particulates ^a .		
Half-lives	3-26 d under ideal aerobic conditions with acclimated community ^b		
Degradation summary	Degradation varies by ethoxymers, and tends to produce some recalcitrant compounds ^a .		
Degradation lag time			
Transport rate summary			
Mixture effects	Surfactants can increase the solubility and transport of less soluble substances.		
Additional notes	These are all categories; therefore, the specific physical properties vary by ethoxymers. Alkylphenol ethoxylates are antifoaming agents ^c . Degradation of these compounds can produce more persistent octyl- and nonylphenols.		

Blank cells indicate information not readily available to EPA at this time.

a. Environment Canada (2002).

b. Staples et al. (2001).

c. Bennie et al. (1997).

Table A-17: Surfactant Breakdown Products: Alkylphenols

Characteristics	Octylphenol	Nonylphenol
CASRN	Category	25154-52-3 (category)
Formula	C ₁₄ H ₂₂ O	
Water solubility, g/L		5.43x10 ^{-3a}
Log K _{OW}	4.12 ^b	4.1-4.7 ^a
Log K _{OC}	4.01 to 4.65 ^b	
Henry's Law constant (atm-m ³ /mole)		1.09x10 ^{-4a}
Vapor pressure (mm Hg)		3.4x10 ^{-5a}
Environmental partitioning summary	Unlikely to volatilize from soils. Likely to partition to sediments and soil minerals ^b .	Although volatility is low, can volatilize from water and result in high atmospheric concentrations. Unlikely to volatilize from soils. Likely to partition to sediments and mineral particles in water and soil, but can still leach through soils ^a .
Half-lives	7-50 d in river water ^c .	2.4 hours to 0.74 d in water. Photolytic half- life in upper layer of surface water is 10-15 hours; in deeper layers, it is much slower. In a sediment mesocosm, a half-life of 66 days was observed ^a .
Degradation summary	Relatively rapid degradation in aerobic river water ^c . Highly recalcitrant to anaerobic degradation in sediments ^c .	A biphasic degradation profile has been observed in soils, with relatively rapid initial degradation of 30-50% of applied nonylphenol degrading in the first several weeks, and the remainder degrading with a half-life of approximately 90 days ^a .
Degradation lag time		
Transport rate summary	Can leach through soils ^b .	Can leach through soils ^a .
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

a. Environment Canada (2002).

b. Isobe et al. (2001).

c. Christiansen et al. (2002).

Table A-18: Surfactants: Diamines

Characteristics	Oleic acid diamine	Oleyl propylene diamine	Palmitic acid diamine
CASRN	Category	Category	Category
Formula			
Water solubility, g/L			
Log K _{OW}			
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

Table A-19: Surfactants: Polyethylene Oxide Monomer and Polymer

Characteristics	Ethylene oxide	Ethylene oxide / propylene oxide block copolymers
CASRN	75-21-8	Category
Formula	C ₂ H ₄ O	
Water solubility, g/L	Miscible with water	
Log K _{OW}	-0.3	
Log K _{OC}	n/a	
Henry's Law constant (atm-m ³ /mole)	1.48X10 ⁻⁴	
Vapor pressure (mm Hg)	1314	
Environmental partitioning summary	Expected to volatilize rapidly from soil. It does not adsorb well to soil, and would be expected to leach readily. In water, volatilization will occur in hours to days.	
Half-lives	Atmospheric half-life estimated at 211 days. The volatilization half-lives of ethylene oxide in a model river and lake are 5.9 hr and 3.8 days, respectively. The half-life for hydrolysis is 9-14 days. In a river die-away test, the rate of degradation was not significantly different than for hydrolysis.	
Degradation summary	Hydrolysis may also be an important mechanism of removal from water. Biodegradation appears to occur more slowly than volatilization, but data are extremely limited. Expected to degrade by hydrolysis in groundwater. Products of degradation by hydrolysis are biodegradable (ethylene glycol and ethylene chlorohydrin).	
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

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Table A-20: Surfactants: Other Nonionic Detergents

Characteristics	Emerest 2660 (OEG-12 oleate) (=Polyoxyethylene monoleate)	Emsorb 6900 (peg-20 sorbitan oleate) (=glycol (polysorbate 80))
CASRN	9004-96-0	9005-65-6
Formula	(C ₂ H ₄ O) multi-C ₁₈ H ₃₄ O ₂	
Water solubility, g/L	Very soluble	Highly soluble
Log K _{OW}		
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-21: Corrosion Inhibitors and Flame Retardants: Tolyltriazoles

Characteristics	Tolyltriazole	Cobratec TT-50S, tolyltriazole solution
CASRN	29385-43-1	Trade name
Formula	C ₇ H ₇ N ₃	
Water solubility, g/L		
Log K _{OW}		
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary	Mobile in groundwater.	
Half-lives		
Degradation summary	Unlikely to be readily degradable.	
Degradation lag time		
Transport rate summary		
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.	
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-22: Corrosion Inhibitors and Flame Retardants: Other Triazoles

Characteristics	Triazoles	Benzyltriazole	Benzotriazole	5-Methyl-1H-Benzotriazole	4-methyl-1H-benzotriazole
CASRN	37306-44-8	-	95-14-7	136-85-6	29878-31-7
Formula	C ₂ H ₃ N ₃		C ₆ H ₅ N ₃	C ₇ H ₇ N ₃	C ₇ H ₇ N ₃
Water solubility, g/L			19.8		
Log K _{OW}			1.44		
Log K _{OC}					
Henry's Law constant (atm-m ³ /mole)			3.17x10 ⁻⁷		
Vapor pressure (mm Hg)			4.0x10 ⁻²		
Environmental partitioning summary			Expected to be highly mobile in soil. Also, it may protonate in some environmental matrices, and the cationic form should bind to organic material and clays. Volatilization is not expected.		
Half-lives			Half-life for atmospheric degradation by reaction with hydroxyl radicals is estimated at 16 days. May also be subject to direct photolysis.		
Degradation summary			Persists in the environment; apparently not biodegradable.	5-tolyltriazole is much better (aerobically) degradable than the 4-tolyltriazole isomer (in river water samples). ^b	
Degradation lag time					
Transport rate summary					
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.				
Additional notes	Benzotriazole and methylbenzotriazole have been detected in groundwater near an airport, at concentrations in excess of those known to be toxic to microbiota, fish, and invertebrates. ^a				

Blank cells indicate information not readily available to EPA at this time.

a. Cancilla et al. (1998)

b. Weiss and Reemtsma (2005).

Table A-23: Corrosion Inhibitors: Alcohols

Characteristics	Propargyl alcohol
CASRN	107-19-7
Formula	C ₃ H ₄ O
Water solubility, g/L	Miscible with water
Log K _{OW}	-0.38
Log K _{OC}	
Henry's Law constant (atm-m ³ /mole)	1.1x10 ⁻⁶
Vapor pressure (mm Hg)	15.6
Environmental partitioning summary	Should be highly mobile in soil, and volatilize readily from both moist and dry soils. In water, propargyl alcohol is not expected to adsorb to sediments or suspended solids. Volatilization from the water's surface is expected.
Half-lives	The half-life of propargyl alcohol in an alkaline sandy silt loam (61.5% sand, 31.1% silt, 7.4% clay, pH 7.8, 3.25% organic carbon) was 12.6 days. The half-life in an acidic sandy loam (68% sand, 23.4% silt, 8.6% clay, pH 4.8, 0.94% organic carbon) was 13 days. Modeled volatilization half-lives for a river and lake are 16 and 176 days, respectively. The modeled atmospheric half-life due to degradation by hydroxyl radicals is 37 hours.
Degradation summary	Aerobic degradation in soils is expected, based on the results above, and is also likely in water.
Degradation lag time	
Transport rate summary	
Mixture effects	
Additional notes	

Blank cells indicate information not readily available to EPA at this time.

Table A-24: Corrosion Inhibitors: Nitrite, Nitrate, and Silicate Salts

Characteristics	Sodium nitrate	Sodium nitrite	Sodium silicate	Potassium silicate
CASRN	7631-99-4	7632-00-0	13870-28-5	10006-28-7
Formula	HNO ₃ .Na	HNO ₂ .Na		K ₂ SiO ₃
Water solubility, g/L	912	848	Almost insoluble in cold water; soluble in water with heat and pressure	
Log K _{OW}				
Log K _{OC}				
Henry's Law constant (atm-m ³ /mole)				
Vapor pressure (mm Hg)				
Environmental partitioning summary	Nitrite does not volatilize from soil or water.	Nitrate does not volatilize from soil or water.		
Half-lives				
Degradation summary	Aerobically degraded to nitrate.			
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes				

Blank cells indicate information not readily available to EPA at this time.

Table A-25: Corrosion Inhibitors: Other Inorganics

Characteristics	Potassium phosphate	Borax
CASRN	7778-53-2	1303-96-4
Formula	H ₃ O ₄ P.3K	B ₄ Na ₂ O ₇ .10H ₂ O
Water solubility, g/L		593
Log K _{OW}		
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		Approximately zero.
Environmental partitioning summary		Not expected to volatilize from soils or water.
Half-lives		
Degradation summary		Persists in soil for a year or more, depending on soil type and rainfall.
Degradation lag time		
Transport rate summary		High mobility in soil with high rainfall; otherwise, sorbs to minerals in soils.
Mixture effects		Biostatic and antiseptic; biodegradation not reported. May inhibit degradation of other substances in mixtures due to antimicrobial activity.
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-26: Corrosion Inhibitors: Other Organics

Characteristics	Sodium benzoate	Phosphate esters	Thiourea
CASRN	532-32-1	Category	62-56-6
Formula	C ₇ H ₅ NaO ₂		CH ₄ N ₂ S
Water solubility, g/L	556		
Log K _{OW}			-1.08
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)			1.98x10 ⁻⁹
Vapor pressure (mm Hg)	3.67x10 ⁻⁹		
Environmental partitioning summary			Is not expected to adsorb to suspended solids and sediment in water. Not expected to volatilize from any medium.
Half-lives			
Degradation summary			Thiourea can degrade in soil by both chemical and microbial degradation, although high levels of thiourea may suppress microbial activity for extended periods of time. In one soil degradation study, thiourea persisted in excess of 15 weeks.
Degradation lag time			
Transport rate summary			Expected to be highly mobile in soils.
Mixture effects			May delay degradation of other components of mixtures due to antimicrobial activity.
Additional notes		((RO) ₃ PO) Phosphoric acids with alkyl or aryl alcohols.	

Blank cells indicate information not readily available to EPA at this time.

Table A-27: Corrosion Inhibitors: Ethanolamines

Characteristics	Monoethanolamine	Diethanolamine	Triethanolamine
CASRN	141-43-5	111-42-2	102-71-6
Formula	C ₂ H ₇ NO	C ₄ H ₁₁ NO ₂	C ₆ H ₁₅ NO ₃
Water solubility, g/L	1x10 ³	Freely soluble	Freely soluble
Log K _{OW}	-1.31	-1.43	-1
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)	3.25x10 ⁻⁸	3.9x10 ⁻¹¹	7.1x10 ⁻¹³
Vapor pressure (mm Hg)	0.404	1.4x10 ⁻⁴	3.59x10 ⁻⁶
Environmental partitioning summary	Expected to ionize under most environmental conditions (pH 5 to 9), which would favor adsorption to clays and organic matter. Not expected to volatilize from soils or water.		
Half-lives		Days to weeks	
Degradation summary	Biodegradation may be an important pathway of degradation.	Rapid biodegradation expected, following lag time. Aerobic degradation observed.	Aerobic degradation observed.
Degradation lag time	5 d		15 d
Transport rate summary	Binding to clays and organic matter should restrict mobility of ionized ethanolamines in soil. Unionized forms are predicted to be very mobile in soils. In water, they may be transported with particulates.		
Mixture effects			
Additional notes	Degrades to nitrogen dioxide and ammonia.	N-Nitrosodiethanolamine is a degradation product	

Blank cells indicate information not readily available to EPA at this time.

Table A-28: pH Buffers, Phosphate-Based

Characteristics	Dipotassium phosphate	Disodium phosphate (Sodium hydrogen phosphate)
CASRN	7758-11-4	7558-79-4
Formula	H ₃ O ₄ P.2K	H ₃ O ₄ P.2Na
Water solubility, g/L	Freely soluble	Freely soluble
Log K _{OW}		
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-29: pH Reducers

Characteristics	Potassium hydroxide	Sodium hydroxide
CASRN	1310-58-3	1310-73-2
Formula	HKO	HNaO
Water solubility, g/L	Freely soluble	Freely soluble
Log K _{OW}		Too low to be measured
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes		

Blank cells indicate information not readily available to EPA at this time.

Table A-30: Antifoamers: Silicones

Characteristics	DC 1520, silicone antifoam	Foamban	SAG 1000	SAG 7133
CASRN	Trade name	Category	Trade name	Trade name
Formula				
Water solubility, g/L				
Log K _{OW}				
Log K _{OC}				
Henry's Law constant (atm-m ³ /mole)				
Vapor pressure (mm Hg)				
Environmental partitioning summary				
Half-lives				
Degradation summary				
Degradation lag time				
Transport rate summary				
Mixture effects				
Additional notes				

Blank cells indicate information not readily available to EPA at this time.

Table A-31: Antifoamers: Silicones and Other Substances

Characteristics	Siltech E-2202	Dimethyl polysiloxane	AF-9020, polydimethylsiloxane	1-dodecanol
CASRN	Trade name	9016-00-6	63148-62-9	112-53-8
Formula		(C ₂ H ₆ OSi) _x -	(C ₂ H ₆ OSi) _n	C ₁₂ H ₂₆ O
Water solubility, g/L				0.004
Log K _{OW}				5.13
Log K _{OC}				1.5x10 ⁺⁴ (K _{OC})
Henry's Law constant (atm-m ³ /mole)				2.22x10 ⁻⁵
Vapor pressure (mm Hg)				8.48x10 ⁻⁴
Environmental partitioning summary				Expected to have slight mobility in soil and volatilize from wet soils; not expected to volatilize from dry soils. Likely to adsorb to suspended solids and sediment and volatilize from water surfaces. Should exist as a vapor in the atmosphere.
Half-lives				Vapor-phase 1-dodecanol is degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 21 hours.
Degradation summary				Does not degrade anaerobically. Atmospheric degradation via hydroxyl radicals. No environmental hydrolysis.
Degradation lag time				
Transport rate summary				Immobile in soil.
Mixture effects				
Additional notes				

Blank cells indicate information not readily available to EPA at this time.

Table A-32: Dyes

Characteristics	Eosin orange, tetrabromofluorescein	FD&C blue #1, alphazurine
CASRN	17372-87-1	3844-45-9
Formula	C ₂₀ H ₈ Br ₄ O ₅ .2Na	
Water solubility, g/L		
Log K _{OW}	4.8	
Log K _{OC}		
Henry's Law constant (atm-m ³ /mole)		
Vapor pressure (mm Hg)		
Environmental partitioning summary		
Half-lives		
Degradation summary		
Degradation lag time		
Transport rate summary		
Mixture effects		
Additional notes	May discolor receiving waters.	

Blank cells indicate information not readily available to EPA at this time.

Table A-33: Additional Dyes

Characteristics	FD&C yellow #5, tartrazine	Malonyl green, C.I. Pigment Yellow 34	Shilling green
CASRN	1934-21-0	Trade name	Trade name
Formula	$C_{16}H_9N_4Na_3O_9S_2$		
Water solubility, g/L			
Log K_{OW}			
Log K_{OC}			
Henry's Law constant (atm- $m^3/mole$)			
Vapor pressure (mm Hg)			
Environmental partitioning summary			
Half-lives			
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

Table A-34: Hydrophobic Agents

Characteristics	N-Dodecane ^a	Mineral oil	White mineral oil (10 cSt)
CASRN	112-40-3 ^a	Mixture	Mixture
Formula			
Water solubility, g/L		Insoluble in water	
Log K _{OW}		n/a	
Log K _{OC}			
Henry's Law constant (atm-m ³ /mole)			
Vapor pressure (mm Hg)	1.3x10 ^{-1a}		
Environmental partitioning summary			
Half-lives	1.1 days in the atmosphere; degraded via gas-phase reaction with hydroxyl radicals ^a		
Degradation summary			
Degradation lag time			
Transport rate summary			
Mixture effects			
Additional notes			

Blank cells indicate information not readily available to EPA at this time.

a. Chemfate database (2008).

Table A-35: Solvents

Characteristics	Ethylbenzene	Toluene	M- and P-Xylene	Trichloroethylene	Methyl ethyl ketone
CASRN	100-41-4	108-88-3	108-38-3	79-01-6	78-93-3
Formula	C ₈ H ₁₀	C ₇ H ₈	C ₈ H ₁₀	C ₂ HC ₁₃	C ₄ H ₈ O
Water solubility, g/L	0.0014 @ 15 degrees C		Insoluble in water	1.280	353 @ 10 Deg C
Log K _{OW}	3.15		3.15	2.61	0.29
Log K _{OC}					
Henry's Law constant (atm-m ³ /mole)	7.88x10 ⁻³		0.0069	9.85x10 ⁻³	4.7x10 ⁻⁵
Vapor pressure (mm Hg)	9.6		8.84	69	91
Environmental partitioning summary	Volatilization from moist and dry soil surfaces is expected. In aquatic environments BTEX compounds will adsorb to suspended solids and sediments and will volatilize from surface water. BTEX compounds will exist as vapors in the atmosphere.			High mobility in soils and volatilization from both moist and dry soils are expected. In aquatic environments, these compounds do not adsorb to suspended solids and sediments. Volatilization is an important process. In the atmosphere, these compounds exist solely in the vapor phase.	
Half-lives	The atmospheric half-life is 55 hours. Aquatic volatilization half-life is estimated at between 1.1 and 99 hours.		The atmospheric half-life of this compound is about 27 hours. Aquatic volatilization half-life is estimated at between 3 and 99 hours.	The half-life for the reaction with hydroxyl radicals in air is estimated to be 7 days. There is a wide range of degradation half-lives under anaerobic conditions. An approximate average half-life is 1 year.	The half-life for the reaction with hydroxyl radicals in air is estimated to be about 14 days.
Degradation summary	Biodegradation occurs under both aerobic and anaerobic conditions. Abiotic degradation is primarily photolytic. Ethylbenzene was degraded in aerobic conditions within 10-16 days, and in conditions of low initial oxygen, it was rapidly degraded in 21 days until the available oxygen was depleted.	Biodegradation occurs under both aerobic and anaerobic conditions. Abiotic degradation is primarily photolytic.		Trichloroethylene is not degraded aerobically. It is degraded anaerobically under methanogenic conditions.	Aerobic degradation is the main degradation pathway. Atmospheric degradation pathways include photodecomposition and degradation by reaction with hydroxyl radicals.
Degradation lag time					

Table A-35: Solvents

Characteristics	Ethylbenzene	Toluene	M- and P-Xylene	Trichloroethylene	Methyl ethyl ketone
Transport rate summary	Moderate to low mobility in soil.				
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-36: Solvents: Alcohols and Other Solvents

Characteristics	Acetone	Methylene chloride	1,3-Butanediol	Butyne-1,4-diol	Glycol ethers
CASRN	67-64-1	75-09-2	107-88-0	110-65-6	110-80-5, 111-76-2, 107-98-2
Formula	C ₃ H ₆ O	CH ₂ Cl ₂	C ₄ H ₁₀ O ₂	C ₄ H ₆ O ₂	
Water solubility, g/L	Miscible in water	13	Miscible in water	3,740	Miscible in water
Log K _{OW}	-0.24	1.25	-0.29	-0.93	
Log K _{OC}			0.114		
Henry's Law constant (atm-m ³ /mole)	3.97x10 ⁻⁵	3.25X10 ^{-3x}	2.30x10 ⁻⁷	1.684x10 ⁻¹¹	
Vapor pressure (mm Hg)	231	435	0.06	5.56x10 ⁻⁴	
Environmental partitioning summary	Very high mobility in soil, volatilization expected from moist or dry soil surfaces and from water. These compounds exist in the atmosphere solely as vapors.		In the atmosphere, degradation will occur via hydroxyl radicals. Biodegradation in soils and water is likely. Volatilization from moist soils and water is expected. Biodegradation is likely to be an important degradation pathway.		
Half-lives			An atmospheric half-life of about 1.2 days at an atmospheric concentration of 5x10 ⁺⁵ hydroxyl radicals per cm ³ is estimated.	An atmospheric half-life of about 11 hours at an atmospheric concentration of 5x10 ⁺⁵ hydroxyl radicals per cm ³ is estimated.	
Degradation summary	Volatilization is the primary mechanism for removal from aquatic environments. Acetone degrades under both aerobic and anaerobic conditions. Methylene chloride biodegradation may occur in soils or contaminated aquifers under reducing conditions. Acetone undergoes photodegradation in the atmosphere, and not hydrolysis. Methylene chloride is not directly photooxidized; it does undergo hydrolysis in the atmosphere and terrestrial environments.		Aerobic biodegradation occurs. There is not enough data to determine rates. Anaerobic degradation information is not available. Abiotically degraded by hydrolysis in the atmosphere (via hydroxyl radicals). Aquatic hydrolysis is not expected for 1,3-butanediol and information was not found for butyne-1,4-diol.		

Table A-36: Solvents: Alcohols and Other Solvents

Characteristics	Acetone	Methylene chloride	1,3-Butanediol	Butyne-1,4-diol	Glycol ethers
Degradation lag time					
Transport rate summary	Highly mobile in soil.	Highly mobile in soil; adsorbs strongly to peat moss, less strongly to clay, slightly to dolomite sandstone, and not at all to sand.	Highly mobile in soil.		
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-37: Plasticizers and Other Miscellaneous Substances

Characteristics	Di-N-Butyl Phthalate	Bis (2-ethylhexyl) phthalate	Dioxane	3,5,5-Trimethylhexanoic Acid
CASRN	84-74-2	117-81-7	123-91-1	3302-10-1
Formula	C ₁₆ H ₂₂ O ₄	C ₂₄ H ₃₈ O ₄	C ₄ H ₈ O ₂	C ₉ H ₁₈ O ₂
Water solubility, g/L	0.013	Less than 0.01% in water	Miscible with water	
Log K _{OW}	4.9	7.6	-0.27	
Log K _{OC}				
Henry's Law constant (atm-m ³ /mole)	4.5x10 ⁻⁶	1.3x10 ⁻⁷	4.8x10 ⁻⁶	
Vapor pressure (mm Hg)	2.01x10 ⁻⁵	7.23x10 ⁻⁸	38.1	
Environmental partitioning summary	Expected to volatilize from moist soil surfaces but not dry soil surfaces. Will adsorb to suspended solids and sediment in water and is expected to volatilize from water surfaces. It has a low bioconcentration potential. Exists as both a vapor and particulate in the atmosphere.	Not expected to volatilize from soil surfaces. Expected to adsorb to suspended solids and sediments in water and volatilize from water surfaces. Will exist as both a vapor and particulate in the atmosphere.	Expected to volatilize from moist and possibly dry soil surfaces. Not expected to adsorb to suspended solids and sediments. It is expected to volatilize from water surfaces. Exists solely as a vapor in the atmosphere.	
Half-lives	The half-life for hydroxyl radical degradation in air is estimated to be 42 hours. Particulates may be removed by wet and dry deposition.	An aerobic biodegradation half-life of 60 to 70 hours is expected in groundwater. The half-life for hydroxyl radical degradation in air is estimated to be about 18 hours. Particulates may be removed by wet and dry deposition. Observed biological half-lives for bis(2-ethylhexyl) phthalate under aerobic conditions are as follows: pure culture (Penicillium lilacum), 30 days; river water, 4.5 weeks; hydrosol, 14 days; activated sludge, 17 days; and soil, 31 to 98 days.	The half-life for hydroxyl radical degradation in air is estimated to be 35 hours.	

Table A-37: Plasticizers and Other Miscellaneous Substances

Characteristics	Di-N-Butyl Phthalate	Bis (2-ethylhexyl) phthalate	Dioxane	3,5,5-Trimethylhexanoic Acid
Degradation summary	Aerobic and anaerobic biodegradation. Will hydrolyze in the environment. Degraded in the atmosphere by reaction with hydroxyl radicals.	Hydrolysis is not an important degradation pathway. Rapid biodegradation will occur under aerobic conditions in aquatic environments. Some biodegradation may occur in soils. Degraded in the atmosphere by hydroxyl radicals.	Considered recalcitrant/resistant to biodegradation. Degraded by hydroxyl radicals in the atmosphere.	
Degradation lag time				
Transport rate summary	Low mobility in soil.	Immobile in soil.	Very high mobility in soil.	
Mixture effects				
Additional notes			A contaminant of technical grade ethylene glycol, and is an animal carcinogen	

Blank cells indicate information not readily available to EPA at this time.

Chemfate Database (2008).

Sills and Blakeslee (1992).

Table A-38: Degradation Products

Characteristics	Methane	Acetaldehyde	Nitrous acids	Ethanol	Nitrosamines
CASRN	74-82-8	75-07-0	7782-77-6	64-17-5	Category
Formula	CH ₄	C ₂ H ₄ O	HNO ₂	C ₂ H ₆ O	R ₁ N(-R ₂)-N=O
Water solubility, g/L	0.022	1,000		Miscible	
Log K _{OW}	1.09	-0.17		-0.31	
Log K _{OC}					
Henry's Law constant (atm-m ³ /mole)	0.66	6.67x10 ⁻⁵		5x10 ⁻⁶	
Vapor pressure (mm Hg)	4.66x10 ⁵	902		59.3	
Environmental partitioning summary	Volatilization from moist soil surfaces is an important process. Not expected to adsorb to suspended solids and sediments. Volatilization from water surfaces is a dominant fate process in aqueous systems.	Volatilization from moist soil surfaces is expected to be an important fate process; some volatilization may occur from dry soil surfaces. Not expected to adsorb to suspended solids and sediments. Volatilization from water is expected. In the atmosphere, exists as a gas under ambient conditions.		Volatilization from moist soil surfaces is an important fate process; volatilization from dry soil may occur. Volatilization occurs from water surfaces; ethanol does not adsorb to suspended solids and sediment. It is unlikely to be persistent in aquatic environments. Exists solely as a vapor in the atmosphere.	
Half-lives	Volatilization half-lives for a model river and model lake are both 2 hours. The biodegradation half-life of methane was estimated to range from 70 days to infinity. The half-life for the hydroxyl radical reaction in air is estimated to be about 6 years.	Volatilization half-lives for a model river and model lake are 6.5 hrs and 5.3 days, respectively. The half-life for atmospheric reaction with hydroxyl radicals is estimated to be 24 hrs. The half-life in the atmosphere due to photolysis is reported as 8.4 hours and 16 hours.		Volatilization half-lives for a model river and model lake are 3 and 39 days, respectively. The half-life for the hydroxyl radical reaction in air is estimated to be 5 days.	

Table A-38: Degradation Products

Characteristics	Methane	Acetaldehyde	Nitrous acids	Ethanol	Nitrosamines
Degradation summary	Aerobic degradation is an important mechanism in moist soils.	Rapidlybiodegrades in the environment under aerobic and anaerobic conditions. Degraded in the atmosphere by hydroxyl radicals and photolysis.		Aerobic and anaerobic biodegradation are important fate processes. Degraded in the atmosphere by photochemically-produced hydroxyl radicals.	
Degradation lag time					
Transport rate summary	High mobility in soil.	Very highly mobile in soil.		Very high mobility in soil.	
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-39: Emulsifiers and Other Miscellaneous Substances

Characteristics	Propanoic acid	Hexanoic acid	Butanoic acid	Polyamines	Chloroform
CASRN	79-09-4	142-62-1	107-92-6	Category	67-66-3
Formula	C ₃ H ₆ O ₂	C ₆ H ₁₂ O ₂	C ₄ H ₈ O ₂		CHCl ₃
Water solubility, g/L	1,000	10.3	60.0		7.710
Log K _{OW}	0.33	1.92	0.79		1.97
Log K _{OC}					
Henry's Law constant (atm-m ³ /mole)	4.45x10 ⁻⁷	7.58x10 ⁻⁷	5.35x10 ⁻⁷		3.67x10 ⁻³
Vapor pressure (mm Hg)	3.53	0.0435	1.65		197
Environmental partitioning summary	These compounds exist as anions in the soil, making them highly mobile. They do not readily volatilize from most soils and may volatilize from dry soils (especially hexanoic acid and Butanoic acid). In aquatic environments these compounds will exist as anions and will not adsorb to suspended solids and sediments. Volatilization from water surfaces is not an important fate process. These compounds exist as vapors in the atmosphere.				Volatilization from moist soil surfaces is expected to be an important fate process; volatilization from dry soil surfaces may occur. Not expected to adsorb to suspended solids and sediment in water. Volatilization from water surfaces will occur. Exists as a vapor in the atmosphere and is degraded by hydroxyl radicals.
Half-lives	The half-life for the hydroxyl radical reaction in air is estimated to be 13 days. Anaerobic degradation in groundwater occurs with a half life of approximately 21 days.	The half-life for the hydroxyl radical reaction in air is estimated to be 3 days.	The half-life for the hydroxyl radical reaction in air is estimated to be 7 days.		Chloroform was found to have a half-life of 0.3 days when applied 1 cm deep into soil and 1.4 days when applied 10 cm deep. Volatilization half-lives for a model river and model lake are 1.3 hrs and 4.4 days, respectively. The half-life for the hydroxyl radical reaction in air is estimated to be 151 days.

Table A-39: Emulsifiers and Other Miscellaneous Substances

Characteristics	Propanoic acid	Hexanoic acid	Butanoic acid	Polyamines	Chloroform
Degradation summary	These compounds are readily biodegradable under both aerobic and anaerobic conditions. Anaerobic degradation occurs with methanogenesis. Atmospheric degradation occurs via reaction with photochemically-produced hydroxyl radicals.				Chloroform is biodegradeable anaerobically by methanotrophic bacteria.
Degradation lag time					
Transport rate summary	Very high mobility in soil.				Moderate mobility in soil. Poorly retained by aquifer material.
Mixture effects					
Additional notes					

Blank cells indicate information not readily available to EPA at this time.

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
102-71-6	Triethanolamine	Fathead minnow	LC ₅₀ (96 hr)	11,800
107-19-7	Propargyl alcohol	Fathead minnow	LC ₅₀ (96 hr)	1.53
107-21-1	Ethylene glycol	Rainbow trout	LC ₅₀ (96 hr)	>18,500
		Fathead minnow	NOEC (growth, 7 day)	15,380
		Waterflea- <i>Ceriodaphnia dubia</i>	NOEC (reproduction, 7 day)	3,469
		Green algae	EC ₅₀ (96 hr)	7,900
		Duckweed	LOEC (96 hr, frond growth)	10,000
110-65-6	Butyne-1,4-diol	Fathead minnow	LC ₅₀ (96 hr)	53.6
111-42-2	Diethanolamine	Fathead minnow	LC ₅₀ (96 hr)	4,710
111-46-6	Diethylene glycol	Fathead minnow	LC ₅₀ (96 hr)	75,200
112-27-6	Triethylene glycol	Fathead minnow	LC ₅₀ (96 hr)	77,400
112-53-8	1-dodecanol	Algae	LC ₅₀	0.97
		Fathead minnow	LC ₅₀ (96 hr)	1.01
		Harpacticoid	LC ₅₀	0.9
		Northern leopard frog - <i>Rana pipiens</i>	LC ₅₀	0.88
115-77-5	Pentaerythritol	Waterflea-Daphnia magna	EC ₅₀ (24 hr)	38,900
127-08-2	Potassium acetate	Fathead minnow	LC ₅₀	>500
			LC ₅₀ (7 day)	>1,500
		Rainbow trout	LC ₅₀ (96 hr)	>2,100
		Waterflea	LC ₅₀ (48 hr)	>3,000
127-09-3	Sodium acetate	Fathead minnow	LC ₅₀ (48 hr)	2,750
			LC ₅₀ (120 hr)	13,330
		Waterflea	LC ₅₀ (48 hr)	2,400
1310-58-3	Potassium hydroxide	Guppy	LC ₅₀ (24 hr)	165
1310-73-2	Sodium hydroxide	Western mosquitofish	LC ₅₀ (96 hr)	125
136-85-6	Tolyltriazole	Bluegill	LC ₅₀	31
		Waterflea	LC ₅₀	74
		Microtox® (bacteria)	EC ₅₀ (5 min)	6
		Microtox® (bacteria)	EC ₅₀ (15 min)	6
141-43-5	Monoethanolamine	Rainbow trout	LC ₅₀ (96 hr)	150
141-53-7	Sodium formate	Bluegill	LC ₅₀ (24 hr)	5,000
		Waterflea	EC ₅₀ (24 hr)	4,800
			EC ₅₀ (48 hr)	4,400
			EC ₀ (24 hr)	3,300
			EC ₀ (48 hr)	3,200
		Zebrafish	LC ₅₀ (96 hr)	100

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
1934-21-0	FD&C Yellow #5 (constituents)	Fish (species not specified)	LC ₅₀ (72 hr)	>1,000
25265-71-8	Dipropylene glycol	Goldfish	LC ₅₀ (24 hr)	>5,000
25322-68-3	Polyethylene glycol, m.w. from 62 to 106	Rainbow trout	LC ₅₀ (96 hr)	>20,000
504-63-2	1,3-Propylene glycol	Goldfish	LC ₅₀ (24 hr)	>5,000
56-81-5	Glycerol	Rainbow trout	LC ₅₀ (96 hr)	54
57-13-6	Urea	Guppy	LC ₅₀ (96 hr)	17,500
		Fish- <i>Barilius barna</i>	LC ₅₀ (96 hr)	>9,100
		Mozambique tilapia- <i>Tilapia moassambica</i>	LC ₅₀ (96 hr)	22,500
		Carp	LC ₅₀ (48 hr)	>10,000
		Waterflea	EC ₅₀ (24 hr)	>10,000
		Mosquito	LC ₅₀ (4 hr)	60,000
		Freshwater snail	LC ₅₀ (24 hr)	14,241-30,060
57-55-6	Propylene Glycol	Fathead minnow	LC ₅₀ (96 hr)	55,770
			NOEC (growth, 7 day)	<11,530
		Goldfish	LC ₅₀	5,000
		Waterflea- <i>Daphnia magna</i>	LC ₅₀	8,000
		Waterflea- <i>Ceriodaphnia dubia</i>	NOEC (reproduction, 7 day)	13,020
62-56-6	Thiourea	Waterflea- <i>Daphnia magna</i>	LC ₅₀ (48 hr)	9
7558-79-4	Disodium phosphate (aka sodium hydrogen phosphate)	Waterflea- <i>Daphnia magna</i>	LC ₅₀ (48 hr)	3,580
7631-99-4	Sodium nitrate	Rainbow trout	LC ₅₀ (96 hr)	1,658
7664-41-7	Ammonia	Fathead minnow	LC ₅₀ (96 hr)	0.73-8.2
		Goldfish	LC ₅₀ (24-96 hr)	2-2.5
		Rainbow trout	LC ₅₀ (24 hr)	0.068-3.58
		Waterflea	LC ₅₀ (48 hr)	187-189
		Various	EPA National Recommended Water Quality Criteria	Temp., life-stage, time-dependent.
7778-53-2	Potassium phosphate	Western mosquitofish	LC ₅₀ (96 hr)	750
79-10-7	Acrylic acid	Green algae	EC ₅₀ (96 hr)	0.17
			EC ₃ (7 day)	18
		Waterflea	EC ₅₀ (24 hr, immobilization)	765
		Rainbow trout	NOEC (96 hr)	6.3
95-14-7	Benzotriazole	Microtox ® (bacteria)	EC ₅₀ (5 min)	41
			EC ₅₀ (15 min)	42
97-64-3	Ethyl lactate	Zebrafish	LC ₅₀ (96 hr)	320
(25154-52-3)	Nonylphenol	Fish	LC ₅₀	0.17-1.4
		Invertebrates	LC ₅₀	0.17-1.4

Table A-40: Ecological Toxicity Values for Airport Deicing Product Components

CASRN	Chemical Name	Study Species	Concentration Type	Concentration (mg/L)
		Waterflea- <i>Daphnia magna</i>	Life-Cycle Chronic Value	0.02262
		Fathead minnow	Early Life Stage Chronic Value	0.01018
(Multiple)	Nonylphenol ethoxylate	Fathead minnow	LC ₅₀	3.75
		Other fishes	LC ₅₀	4.7-29.2
		Calanoid copepod	LC ₅₀	2.8
		Polychaete worm	LC ₅₀	3.78
(Multiple)	Octylphenol	Fish	LC ₅₀	0.17-1.4
		Invertebrates	LC ₅₀	0.02-3
(Multiple)	Octylphenol ethoxylate	Algae	LC ₅₀	0.027-2.5
		Rainbow trout	LC ₅₀	7.2
		Polychaete worm	LC ₅₀	7.1
(Multiple)	Alcohol ethoxylates	Bluegill	EC ₁₀ (C9-11EO6)	3.882
		Fathead minnow (egg, juvenile)	NOEC (C9-11EO6, reproduction)	0.730
		Green algae	EC ₁₀ (C12E2, growth)	0.030
		Waterflea- <i>Daphnia magna</i>	EC ₁₀ (C14-15EO7)	0.255
(Unknown)	Sodium	Ionic sodium can cause ion imbalance in aquatic organisms.		
(Unknown)	Potassium	Ionic potassium can cause ion imbalance in aquatic organisms.		
(Unknown)	Xanthan Gum	Rainbow trout	LC ₅₀ (96 hr)	420
(Unknown)	Polyacrylic Acid	Bluegill	LC ₅₀ (96 hr)	1,290

Sources: EPA (2000); Environment Canada (2008a); EPA (2005); Environment Canada (2001); IPCS (1997).

Table A-41: Human Health Effects of Airport Deicing Product Components as Reported in IRIS, EPA NRWQC, EPA Drinking Water MCLs, and RSEI

CASRN	Pollutant Name	EPA NRWQC Values		EPA Drinking Water MCL	RfD	RfC	Oral Slope Factor	Inhalation Unit Risk	Drinking Water Slope Factor
		Water & Organism (µg/L)	Organism only (µg/L)	(mg/L)	(mg/kg/day)	(mg/m ³)	(mg/kg-day) ⁻¹	(µg/ m ³) ⁻¹	(µg/L) ⁻¹
100-41-4	Ethylbenzene	530	2,100	0.7	0.1	1			
107-19-7	Propargyl alcohol				0.002				
107-21-1	Ethylene glycol				2	0.4			
108-88-3	Toluene	1,300	15,000	1	0.08	5			
111-42-2	Diethanolamine				0.0014	0.003			
117-81-7	Bis (2-ethylhexyl) phthalate	1.2	2.2	0.006	0.02	0.07			4x10 ⁻⁷
123-91-1	Dioxane				0.1	3	0.011	0.0077	3.1x10 ⁻⁷
62-56-6	Thiourea						1		
75-07-0	Acetaldehyde					0.009		0.0022	
75-21-8	Ethylene oxide					0.03	0.222	0.088	
7664-41-7	Ammonia					0.1			
84-74-2	Di-N-Butyl Phthalate	2,000	4,500		0.1				

Sources: EPA (2006b); EPA (2007); EPA (2008d); EPA (2008e).

Table A-42: Acetate

Fate and Transport	
CASRN	No CASRN
Formula	C ₂ H ₃ O ₂
Environmental partitioning summary	Acetates are not expected to volatilize. They are quite soluble in water. Acetate should rapidly biodegrade under aerobic conditions in surface water, groundwater, and soil.
Degradation products	Acetate degradation produces bicarbonate, carbon dioxide, and water.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils/sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	
Target Organs	
Symptoms	
Ecological Effects	
COD (g per 100 lbs)	11,850-15,500 (in various compounds)
In the aquatic environment, acetate may lower dissolved oxygen levels as it derades because of its COD content. Acetate-containing pavement deicers, including potassium acetate and sodium acetate, may be toxic at sufficiently high concentrations. Specific toxicity values range from a 48-hour LC ₅₀ of 2,400 mg/L for the waterflea to a 120-hour LC ₅₀ of 13,330 mg/L for the fathead minnow (<i>Pimephales promelas</i>) (both for sodium acetate).	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-43: Alcohol Ethoxylates

Fate and Transport	
CASRN	64-17-5
Formula	$\text{CH}_3(\text{CH}_2)_n(\text{OCH}_2\text{CH}_2)_y\text{OH}$
Log K_{oc}	In general, log K _d is a better predictor of behavior than K _{ow} for these substances ^a . Log K _d , as with the other physicochemical parameters, varies by ethoximer. The formula below, as given by Belanger et al. (2006) permits the calculation of an estimated log K _d . $\log K_d = 0.331 * (\text{alkyl chain length}) - 0.009 * (\text{ethoxylate chain length}) - 1.126$
Environmental partitioning summary	Sorption may be important, and is likely to vary by ethoximer.
Degradation summary	Aerobic degradation may be rapid.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system, central nervous system, liver, blood, reproductive system
Symptoms	Irritation to eyes, skin, nose; headache, drowsiness, lassitude (weakness, exhaustion), narcosis; cough; liver damage; anemia; reproductive effects, teratogenic effects, gastrointestinal irritation
Ecological Effects	
Alcohol ethoxylates have toxicity levels similar to those of nonylphenol ethoxylates and octylphenol ethoxylates. Alcohol ethoxylate degradation by-products are less toxic and less persistent than those of nonylphenol ethoxylates and octylphenol ethoxylates. Alcohol ethoxylate toxicity values range from an EC ₁₀ (duration unspecified) of 0.030 mg/L for growth effects in green algae to an EC ₁₀ (duration unspecified) of 3.882 mg/L in the bluegill (<i>Lepomis macrochirus</i>).	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-44: Dyes

Fate and Transport	
Eosin orange, tetrabromofluorescein	17372-87-1
FD&C blue #1, alphanazine	3844-45-9
FD&C yellow #5, tartrazine	1934-21-0
Malonyl green, C.I. Pigment Yellow 34	Trade name
Shilling green	Trade name
See Table A-32 and Table A-33 in Appendix A	
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion, inhalation, dermal contact
Target Organs	Bladder, stomach, kidneys, brain, mouth, esophagus, liver, gallbladder, bile duct, pancreas
Symptoms	Coughing, abdominal pain, pain and redness of the eyes, various cancers
Ecological Effects	
Ecological toxicity information for many dyes used in deicing products is unavailable. Available data on dye toxicity indicates a wide variability in toxicity levels. The most toxic component of FD&C Yellow #5 is toxic at concentrations of 200 mg/L to fish. Toxicity values for eosin orange range from 620 mg/L to 2,200 mg/L for fish. C.I. Pigment Yellow 34 may have high toxicity due to chromate and lead components, but no studies have yet quantified this toxicity level.	
Blank cells indicate information not readily available to EPA at this time.	

Table A-45: Ethylene Glycol

Fate and Transport	
CASRN	107-21-1
Formula	C ₂ H ₆ O ₂
Water solubility, g/L	Freely soluble
Log K_{OW}	-1.36
Log K_{OC}	1 (K _{OC})
Henry's Law constant (atm-m³/mole)	6.00x10 ⁻⁸
Vapor pressure (mm Hg)	0.092
Environmental partitioning summary	Volatilization is not expected to be an important pathway for ethylene glycol. Very high mobility is expected for ethylene glycol in soil, sediment, and water. Experimentally determined adsorption of ethylene glycol to four soils (two clay, two sandy clay) ranged from 0-0.5%. Tracer experiments have shown that ethylene glycol moves through soil with water.
Half-lives	Atmospheric half-life: 50 h at 25° C.
Degradation summary	Very rapid degradation rates in soil, sediment, and water. Soils: 90 to 100% degradation of ethylene glycol was observed in various field soils in 2-12 days (temperatures not known); ethylene glycol in aircraft deicing or anti-icing fluid formulation was completely degraded in runway-side soils within 29 days at 8° C. Water: Hydrolysis and photolysis are not expected to be significant. Ethylene glycol in river water degraded completely in three days at 20° C and in 5 to 14 days at 8° C. Aerobic degradation of ethylene glycol may be essentially complete in less than one to four days under optimal conditions in water or treatment systems, but the impact of the full theoretical biological oxygen demand may not be observed for several weeks.
Degradation lag time	With unacclimated microbial communities there is often a lag of several days before glycol degradation begins.
Transport rate summary	Expected to have very high mobility in soil, sediment, and water.
Mixture effects	Triazoles decrease the degradation rate of glycols. Low temperatures may also greatly decrease the degradation rates of glycols.
Additional notes	Ethylene glycols are expected to share somewhat similar properties, except for polyethylene glycols. Formulated polyethylene glycol products contain different mixtures of polymers, and the properties of the products will vary based on the size and shape of the polymers they contain. All of these substances are expected to be rapidly degraded under aerobic and anaerobic conditions.

Table A-45: Ethylene Glycol

Human Health Effects	
Exposure Limit	Ceiling 50 ppm
MCL	
NOAEL	
RfD	2 mg/kg*day
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system, central nervous system
Symptoms	Irritation eyes, skin, nose, throat; nausea, vomiting, abdominal pain, lassitude (weakness, exhaustion); dizziness, stupor, convulsions, central nervous system depression; skin sensitization
Ecological Effects	
Ethylene glycol has high COD content and can depress dissolved oxygen levels in aquatic environments. Ethylene glycol is also acutely and chronically toxic to aquatic organisms at higher concentrations. Toxicity values range from a 7-day NOEC for reproductive effects of 3,469 mg/L in the waterflea (<i>Ceriodaphnia dubia</i>) to a 96-hr LC ₅₀ of greater than 18,500 mg/L in the rainbow trout (<i>Oncorhynchus mykiss</i>).	
Blank cells indicate information not readily available to EPA at this time.	

Table A-46: Formate

Fate and Transport	
CASRN	No CASRN
Formula	CH ₂ O ₂
Environmental partitioning summary	Formates are not expected to volatilize. They are quite soluble in water, and may be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation summary	Formate is slowly hydrolyzed in water and can be anaerobically degraded by methanogens.
Transport rate summary	Depends on a combination of degradation rate and interaction with soil and sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LOAEL	
Exposure Routes	
Target Organs	
Symptoms	
Ecological Effects	
COD (g per 100 lbs)	4,300 (in sodium formate)
Formates may impact the aquatic environment due to their COD content. Formate-containing compounds used as pavement deicers, including sodium formate and potassium formate, can be toxic at sufficient concentrations. Known toxicity values range from a 96-hr LC ₅₀ of 100 mg/L for zebrafish (<i>Danio rerio</i>) to a 24-hr LC ₅₀ of 5,000 mg/L for bluegill (<i>Lepomis macrochirus</i>).	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-47: Nonylphenol and Nonylphenol Ethoxylates

Fate and Transport		
	Nonylphenol	Nonylphenol Ethoxylates
CASRN	25154-52-3	9016-45-9
Formula		$C_9H_{19}-C_6H_4O(CH_2CH_2O)_nH^a$
Water solubility, g/L	5.43×10^{-3}	All are highly soluble in water, but solubility varies by ethoxymer.
Log K_{OW}	4.1-4.7	
Henry's Law constant (atm-m³/mole)	1.09×10^{-4}	
Vapor pressure (mm Hg)	3.4×10^{-5}	
Environmental partitioning summary	Not expected to volatilize. Likely to partition to organic matter or minerals in soil, but this tendency varies by ethoxymer, and migration through the soil has been observed. In water, as in soil, may sorb to organic matter or particulates.	Although volatility is low, can volatilize from water and result in high atmospheric concentrations. Unlikely to volatilize from soils. Likely to partition to sediments and mineral particles in water and soil but can still leach through soils.
Half-lives	3-26 days under ideal aerobic conditions with acclimated microbial community	2.4 hours to 0.74 days in water. Photolytic half-life in upper layer of surface water is 10-15 hours; in deeper layers, it is much slower. In a sediment mesocosm, a half-life of 66 days was observed. ^a
Degradation summary	A biphasic degradation profile has been observed in soils, with relatively rapid initial degradation of 30-50% of applied nonylphenol degrading in the first several weeks, and the remainder degrading with a half-life of approximately 90 days ^a .	Degradation varies by ethoxymer, and tends to produce some recalcitrant compounds
Transport rate summary		Can leach through soils.
Mixture effects		Surfactants can increase the solubility and transport of less soluble substances.
Additional notes		Specific physical properties vary by ethoxymer.

Table A-47: Nonylphenol and Nonylphenol Ethoxylates

Human Health Effects	
Exposure Limit	
MCL	
NOAEL	10 mg/kg*day
LOAEL	50 mg/kg*day
Exposure Routes	Inhalation, ingestion, skin and/or eye contact
Target Organs	Upper respiratory system, kidneys, skin, eyes, digestive system
Symptoms	Skin and eye irritation, tissue decay, swelling, mottled kidneys, lethargy, coughing, wheezing, shortness of breath, headache, nausea, diarrhea, vomiting, sore throat, burning sensation, shortness of breath, labored breathing, abdominal pain, shock, collapse
Ecological Effects	
Nonylphenol ethoxylates are moderately toxic to aquatic life, but do not persist for long periods of time in water. Available acute toxicity data indicate harmful effects to aquatic life in a range of 2.8 mg/L (LC ₅₀ , duration unknown for a calanoid copepod) to 29.2 mg/L for an unspecified species of fish.	
Nonylphenol, a degradation product of nonylphenol ethoxylates, is more toxic to aquatic organisms than nonylphenol ethoxylates. It persists in the aquatic environment and potentially bioaccumulates in aquatic organisms. Toxicity values range from an “early life stage chronic value” for adverse impacts established by Environment Canada of 0.01 mg/L to an LC ₅₀ value from a study of unspecified fish species of 1.4 mg/L.	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-48: Polyacrylic Acid

Fate and Transport	
CASRN	79-10-7
Water solubility, g/L	1x10 ³
Log K_{ow}	0.35
Log K_{oc}	1.63
Henry's Law constant (atm-m³/mole)	3.2x10 ⁻⁷
Vapor pressure (mm Hg)	3.97
Environmental partitioning summary	Not expected to volatilize from water or moist soil. Slow volatilization from dry soil is possible. Not expected to adsorb to soils or particulates; potential for transport in soil is high.
Degradation summary	Non-polymerized (monomeric) acrylic acid readily biodegrades both aerobically and anaerobically; it reached 68% of its theoretical BOD in two weeks using an activated sludge inoculum, and in a 42 day anaerobic screening study using a sewage seed inoculum, 71% of acrylic acid was degraded. Biodegradability decreases with increasing number of polymerized units and increasing formula molecular weight, dropping off sharply between MWs 700 and 1,000, and for polymers with more than seven units. It appears that monomers and dimers of acrylic acid are completely biodegradable, but there are indications polymers of three to seven units are incompletely biodegraded.
Additional notes	May be contaminated by low-ppm levels of metals.
Human Health Effects	
Exposure Limit	TWA 2 ppm (6 mg/m ³) [skin]
MCL	
NOAEL	140mg/kg/day
LOAEL	15 mg/m ³
Exposure Routes	Inhalation, skin absorption, ingestion, skin and/or eye contact
Target Organs	Eyes, skin, respiratory system
Symptoms	Irritation eyes, skin, respiratory system; eye, skin burns; skin sensitization; in animals: lung, liver, kidney injury
Ecological Effects	
Acrylic acid toxicity values range from a 96-hour EC ₅₀ of 0.17 mg/L for green algae to a 24-hour EC ₅₀ for immobilization effects in the waterflea of 765 mg/L. A 7-day EC ₃ for chronic effects in green algae was measured as 0.17 mg/L.	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-49: Potassium

Fate and Transport	
CASRN	No CASRN
Environmental partitioning summary	Potassium is present in the airport pavement deicers potassium acetate and potassium formate. These materials are not expected to volatilize. These materials are quite soluble in water and can be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation products	Potassium is liberated from potassium acetate and potassium formate through ionization.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils and sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	4,700 mg/day
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion
Target Organs	Circulatory system, kidneys, central nervous system
Symptoms	Listlessness, fatigue, gas pains, constipation, insomnia, low blood sugar, weak muscles and a slow, irregular pulse
Ecological Effects	
Potassium can affect aquatic ecosystems by creating ion imbalances in surface waters and aquatic organisms.	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-50: Propylene Glycol

Fate and Transport	
CASRN	57-55-6
Formula	C ₃ H ₈ O ₂
Water solubility, g/L	Freely soluble
Log K_{ow}	-0.92
Log K_{oc}	0.90
Henry's Law constant (atm-m³/mole)	1.3x10 ⁻⁸
Vapor pressure (mm Hg)	0.13
Environmental partitioning summary	Very high mobility in soils, sediments, and water. Not expected to volatilize readily.
Degradation summary	Propylene glycol was not observed to degrade at 4°C and only degraded at 20°C in soil that was rich in organic matter.
Degradation lag time	For unacclimated microbial communities, there is often a lag of several days before glycol degradation begins.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	30,000 mg/kg
Exposure Routes	Ingestion, injection
Target Organs	Skin, water balance, circulatory system, kidneys
Symptoms	Hyperosmolality, lactic acidosis (the build-up of lactic acid in the body), intravascular hemolysis (the rupturing of blood vessels), central nervous system depression, seizures, coma, hypoglycemia (low blood sugar) and renal failure (all as associated with burn creams).
Ecological Effects	
Propylene glycol has a high COD content and can depress dissolved oxygen levels in aquatic environments. Propylene glycol exhibits acute and chronic toxicity to aquatic life only at higher concentrations. Toxicity values range from an LC ₅₀ (time unknown) of 5,000 mg/L in goldfish (<i>Carassius gibelio</i>) to a 96-hr LC ₅₀ of 55,770 mg/L in fathead minnow (<i>Pimephales promelas</i>).	
Blank cells indicate information not readily available to EPA at this time.	

Table A-51: Sodium

Fate and Transport	
CASRN	No CASRN
Environmental partitioning summary	Sodium is present in the airport pavement deicers sodium acetate and sodium formate. These materials are not expected to volatilize. These materials are quite soluble in water and can be expected to ionize freely. Depending on site-specific factors, the inorganic ions may adsorb or complex with soil or water constituents or remain dissolved in surface water or groundwater.
Degradation products	Sodium is liberated from sodium acetate and sodium formate through ionization.
Transport rate summary	Depends on a combination of degradation rate and interaction with soils and sediments. May be very site-specific.
Human Health Effects	
Exposure Limit	2,300 mg/day
MCL	
NOAEL	
LOAEL	
Exposure Routes	Ingestion, possibly inhalation
Target Organs	Circulatory system, mineral balances
Symptoms	High blood pressure, loss of calcium
Ecological Effects	
Sodium can affect aquatic ecosystems by creating ion imbalances in surface waters and aquatic organisms.	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-52: Tolyltriazoles, Benzotriazoles, Methyl-substituted Benzotriazole

Fate and Transport	
CASRN	No CASRN
Formula	C ₇ H ₇ N ₃ (tolyltriazole)
Environmental partitioning summary	Mobile in groundwater.
Degradation summary	Unlikely to be readily degradable.
Mixture effects	Even at very low concentrations, triazoles have been observed to sharply decrease the biodegradability of other components in mixtures.
Human Health Effects	
Exposure Limit	
MCL	
NOAEL	
LD50 (rat)	600-675 mg/kg
Exposure Routes	
Target Organs	
Symptoms	
Ecological Effects	
Tolyltriazole, a methylated benzotriazole used in aircraft deicing fluid formulations, exhibits moderate acute toxicity in aquatic organisms. Toxicity values range from a 5-minute Microtox® assay value of 6 mg/L for effects on microbial organisms to an LC ₅₀ (duration unspecified) of 74 mg/L in the waterflea.	
Other benzotriazoles have not been studied as thoroughly as tolyltriazole. Microtox® studies with 5- and 15-minute durations have established values of 41 and 42 mg/L, respectively, for effects on microbial organisms.	
<i>Blank cells indicate information not readily available to EPA at this time.</i>	

Table A-53: Urea and Ammonia

Fate and Transport		
	Urea	Ammonia
CASRN	57-13-6	7664-41-7
Formula	CH ₄ N ₂ O	H ₃ N
Water solubility, g/L	545	“31%”
Log K _{OW}	-2.11	0.23
Log K _{OC}	0.903	
Henry’s Law constant (atm-m ³ /mole)		1.61x10 ⁻⁵
Human Health Effects		
Exposure Limit	TWA 25 ppm (18 mg/m ³) ST 35 ppm (27 mg/m ³)	
MCL		
NOAEL		
LOAEL		
Exposure Routes	Inhalation, ingestion (solution), skin and/or eye contact (solution/liquid)	
Target Organs	Eyes, skin, respiratory system	
Symptoms	Irritation to eyes, nose, throat; dyspnea (breathing difficulty), wheezing, chest pain; pulmonary edema; pink frothy sputum; skin burns, vesiculation; liquid: frostbite	
Ecological Effects		
Ammonia is a common by-product of urea degradation and is highly toxic to some aquatic organisms. EPA has established National Recommended Water Quality Criteria for ammonia which vary with pH, temperature, and aquatic organism life stage. LC ₅₀ values for ammonia range from a 24-hr value for rainbow trout (<i>Oncorhynchus mykiss</i>) of 0.068 mg/L to a 48-hr LC ₅₀ for the waterflea of 189 mg/L.		
Blank cells indicate information not readily available to EPA at this time.		

Appendix B: Surveyed Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations ¹	Annual Non-propeller-driven aircraft Departures ²	SOFP Days ³
Albany International	Albany	NY	Small Hub	Y	25,156	36
Albuquerque International Sunport	Albuquerque	NM	Medium Hub	Y	40,969	3
Aspen-Pitkin Co/Sardy Field	Aspen	CO	Non-Hub	Y	2,495	53.5
Austin Straubel International	Green Bay	WI	Small Hub	Y	9,706	31
Austin-Bergstrom International	Austin	TX	Medium Hub	Y	49,601	4
Baltimore-Washington International	Baltimore	MD	Large Hub	Y	114,673	12
Bethel	Bethel	AK	Non-Hub	Y	1,287	55
Birmingham International	Birmingham	AL	Small Hub	Y	29,510	1.5
Bismarck Muni	Bismarck	ND	Non-Hub	Y	3,139	36
Bob Hope	Burbank	CA	Medium Hub	Y	30,411	0
Boeing Field/King County International	Seattle	WA	Non-Hub	Y	3,204	4
Boise Air Terminal/Gowen Fld	Boise	ID	Small Hub	Y	20,888	16
Bradley International	Windsor Locks	CT	Medium Hub	Y	46,878	31
Buffalo Niagara International	Buffalo	NY	Medium Hub	Y	36,429	48.5
Central Wisconsin	Mosinee	WI	Non-Hub	Y	2,781	36
Charlotte/Douglas International	Charlotte	NC	Large Hub	Y	183,722	5.5
Cherry Capital	Traverse City	MI	Non-Hub	Y	5,369	68.5
Chicago Midway International	Chicago	IL	Large Hub	Y	93,123	26
Chicago O'Hare International	Chicago	IL	Large Hub	Y	475,988	26
Cincinnati/Northern Kentucky International	Covington	KY	Large Hub	Y	236,650	17
City of Colorado Springs Municipal	Colorado Springs	CO	Small Hub	Y	19,526	16
Cleveland-Hopkins International	Cleveland	OH	Medium Hub	Y	104,136	36
Dallas Love Field	Dallas	TX	Medium Hub	Y	44,023	8
Dallas/Fort Worth International	Dallas-Fort Worth	TX	Large Hub	Y	345,029	8
Denver International	Denver	CO	Large Hub	Y	222,922	26
Des Moines International	Des Moines	IA	Small Hub	Y	21,871	31
Detroit Metropolitan Wayne County	Detroit	MI	Large Hub	Y	224,328	31
El Paso International	El Paso	TX	Small Hub	Y	26,200	8
Eppley Airfield	Omaha	NE	Medium Hub	Y	31,175	26

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations ¹	Annual Non-propeller-driven aircraft Departures ²	SOFP Days ³
Evansville Regional	Evansville	IN	Non-Hub	Y	7,404	12
Fairbanks International	Fairbanks	AK	Small Hub	Y	6,094	89
Fort Wayne International	Fort Wayne	IN	Non-Hub	Y	13,109	31
General Edward Lawrence Logan International	Boston	MA	Large Hub	Y	162,635	26
General Mitchell International	Milwaukee	WI	Medium Hub	Y	66,798	31
George Bush Intercontinental Arpt/Houston	Houston	TX	Large Hub	Y	244,359	4
Gerald R. Ford International	Grand Rapids	MI	Small Hub	Y	20,854	48.5
Glacier Park International	Kalispell	MT	Non-Hub	Y	3,820	36
Greater Rochester International	Rochester	NY	Small Hub	Y	29,129	43.5
Gulfport-Biloxi International	Gulfport	MS	Small Hub	Y	6,805	4
Hartsfield - Jackson Atlanta International	Atlanta	GA	Large Hub	Y	454,832	1.5
Helena Regional	Helena	MT	Non-Hub	Y	2,839	14.5
Indianapolis International	Indianapolis	IN	Medium Hub	Y	76,351	21
Jackson Hole	Jackson	WY	Non-Hub	Y	1,687	49.5
Jacksonville International	Jacksonville	FL	Medium Hub	Y	36,849	1.5
James M Cox Dayton International	Dayton	OH	Small Hub	Y	34,024	26
John F Kennedy International	New York	NY	Large Hub	Y	162,809	12
John Wayne Airport-Orange County	Santa Ana	CA	Medium Hub	Y	49,807	0
Juneau International	Juneau	AK	Small Hub	Y	5,035	21
Kansas City International	Kansas City	MO	Medium Hub	Y	73,758	27
Ketchikan	Ketchikan	AK	Non-Hub	⁴	2,815	55
La Guardia	New York	NY	Large Hub	Y	166,496	12
Lafayette Regional	Lafayette	LA	Non-Hub	Y	4,205	4
Lambert-St Louis International	St Louis	MO	Large Hub	Y	106,572	17
Long Island Mac Arthur	Islip	NY	Small Hub	Y	12,210	16
Louis Armstrong New Orleans International	New Orleans	LA	Medium Hub	Y	59,063	4
Louisville International-Standiford Field	Louisville	KY	Medium Hub	Y	64,780	12
Lovell Field	Chattanooga	TN	Non-Hub	Y	6,156	1.5
Manchester	Manchester	NH	Medium Hub	Y	31,195	36
Mc Carran International	Las Vegas	NV	Large Hub	Y	187,365	0
Memphis International	Memphis	TN	Medium Hub	Y	152,698	8
Metropolitan Oakland International	Oakland	CA	Large Hub	Y	85,964	0
Minneapolis-St Paul International/Wold-Chamberlain	Minneapolis	MN	Large Hub	Y	219,293	41
Montgomery Regional (Dannelly Field)	Montgomery	AL	Non-Hub	Y	4,266	0

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations ¹	Annual Non-propeller-driven aircraft Departures ²	SOFP Days ³
Nashville International	Nashville	TN	Medium Hub	Y	74,189	5.5
Newark Liberty International	Newark	NJ	Large Hub	Y	207,698	16
Nome	Nome	AK	Non-Hub	Y	1,324	55
Norfolk International	Norfolk	VA	Medium Hub	Y	32,957	5.5
Norman Y. Mineta San Jose International	San Jose	CA	Medium Hub	Y	64,101	0
Northwest Arkansas Regional	Fayetteville/Springdale	AR	Small Hub	Y	16,783	14.5
Ontario International	Ontario	CA	Medium Hub	Y	43,364	0
Outagamie County Regional	Appleton	WI	Non-Hub	Y	8,842	36
Palm Beach International	West Palm Beach	FL	Medium Hub	Y	31,169	0
Pensacola Regional	Pensacola	FL	Small Hub	Y	14,164	1.5
Philadelphia International	Philadelphia	PA	Large Hub	Y	205,128	12
Phoenix Sky Harbor International	Phoenix	AZ	Large Hub	Y	220,200	0
Piedmont Triad International	Greensboro	NC	Small Hub	Y	34,001	14.5
Pittsburgh International	Pittsburgh	PA	Large Hub	Y	89,337	31
Port Columbus International	Columbus	OH	Medium Hub	Y	57,358	26
Portland International	Portland	OR	Medium Hub	Y	61,238	4
Raleigh-Durham International	Raleigh/Durham	NC	Medium Hub	Y	83,276	9.5
Ralph Wien Memorial	Kotzebue	AK	Non-Hub	Y	1,274	55
Rapid City Regional	Rapid City	SD	Non-Hub	Y	3,659	21
Reno/Tahoe International	Reno	NV	Medium Hub	Y	31,378	9.5
Richmond International	Richmond	VA	Small Hub	Y	33,089	12
Rickenbacker International	Columbus	OH	Non-Hub	Y	2,330	26
Roanoke Regional/Woodrum Field	Roanoke	VA	Non-Hub	Y	7,245	16
Rochester International	Rochester	MN	Non-Hub	Y	4,990	46
Ronald Reagan Washington National	Washington	DC	Large Hub	Y	130,879	12
Sacramento International	Sacramento	CA	Medium Hub	Y	51,515	0
Salt Lake City International	Salt Lake City	UT	Large Hub	Y	140,566	14.5
San Antonio International	San Antonio	TX	Medium Hub	Y	46,181	4
San Diego International	San Diego	CA	Large Hub	Y	80,108	0
San Francisco International	San Francisco	CA	Large Hub	Y	137,328	0
Seattle-Tacoma International	Seattle	WA	Large Hub	Y	114,607	1.5
South Bend Regional	South Bend	IN	Small Hub	Y	8,562	48.5
Southwest Florida International	Fort Myers	FL	Medium Hub	Y	32,000	0
Spokane International	Spokane	WA	Small Hub	Y	16,034	31

Table B-1: Surved Airports within Scope for EPA's Regulatory Options for Airport Deicing Operations

Airport Name	Airport City	Airport State	Service Level	Confirmed Deicing Operations ¹	Annual Non-propeller-driven aircraft Departures ²	SOFP Days ³
Stewart International	Newburgh	NY	Non-Hub	Y	6,314	26
Syracuse Hancock International	Syracuse	NY	Small Hub	Y	23,609	43.5
Tampa International	Tampa	FL	Large Hub	Y	85,166	0
Ted Stevens Anchorage International	Anchorage	AK	Medium Hub	Y	61,035	55
Theodore Francis Green State	Providence	RI	Medium Hub	Y	37,606	21
Toledo Express	Toledo	OH	Non-Hub	Y	10,559	36
Tucson International	Tucson	AZ	Medium Hub	Y	26,666	0
Washington Dulles International	Washington	DC	Large Hub	Y	225,552	17
Wilkes-Barre/Scranton International	Wilkes-Barre/Scranton	PA	Non-Hub	Y	4,789	26
Will Rogers World	Oklahoma City	OK	Small Hub	Y	29,664	14.5
William P Hobby	Houston	TX	Medium Hub	Y	57,448	4
Wilmington International	Wilmington	NC	Non-Hub	Y	6,330	4
Yeager	Charleston	WV	Non-Hub	Y	8,003	16

¹ Y = Airport stated in response to EPA Airport Deicing Questionnaire (EPA 2006c) that it conducts deicing operations.

² "Annual non-propeller-driven aircraft departures" derived from data from Federal Aviation Administration for the 2004/2005 winter deicing season

³ Snow or Freezing Precipitation (SOFP) days data is based on National Oceanic and Atmospheric Administration data from 1971 – 1990.

⁴ Ketchikan was sent an airport questionnaire but did not respond.

Appendix C: Documented Impacts from Airport Deicing Discharges

Table C-1: Documented Impacts from Airport Deicing Discharges

Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Airborne Airpark	1998	Hannah, James. 1998. De-Icing Chemicals for Planes Killing Creek, Professor Says. Cleveland Plain Dealer, June 7.	Lytle Creek		F,O	H	Od	X	
Airborne Airpark	2000	State of Ohio Environmental Protection Agency. 2000. Biological and Water Quality Study of the Little Miami River Basin, 1998. OEPA Technical Report Number MAS/1999-12-3. Columbus, OH.	Lytle Creek, Little Miami River, Cowan Creek, Indian Run	D	O				S
Baltimore Washington International Airport	1993	Hartwell, S.I., D.M. Jordahl, E.B. May. 1993. Toxicity of Aircraft De-Icer and Anti-Icer Solutions to Aquatic Organisms. Chesapeake Bay Research and Monitoring Division. CBRM-TX-93-1	Sawmill Creek, Muddy Bridge Branch		O		Co		
Baltimore Washington International Airport	1997	McDowell, A. Scott. 1997. Hayes, Seay, Mattern and Mattern. Letter communication to Stephen Debreceeny.	Patapsco Aquifer	D,B,N		DW			
Baltimore Washington International Airport	1995	Fisher, D.J., M.H. Knott, S.D. Turley, B.S. Turley, L.T. Yonkos and G.P. Ziegler. 1995. The Acute Whole Effluent Toxicity of Storm Water from an International Airport. Environmental Toxicology and Chemistry. 14(6): 1103-1111.	Kitten Branch of Stony Run, Muddy Bridge Branch of Sawmill Creek	B,N	O		Co		
Baltimore Washington International Airport	1997	Pelton, Tom. 1997. EPA Probing Allegation of BWI Runoff; Polluting Chemicals Seeping Into Creek, Environmentalists Say; Airport Cooperating; Public's Health Is Not In Danger, According to State. Baltimore Sun, April 23.	Sawmill Creek				Fo,Od	X	

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² F = Fish Kill; O = Other Organism Impacts

³ H = Human Health; DW = Drinking Water

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⁵ G = Groundwater; S = Sediment

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Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Baltimore Washington International Airport	1997	Pelton, Tom. 1997. De-Icing Fluid Used at BWI Fouls Waters; MD.'s Pride in System Ignores Pollution Data From Other Agencies; BWI is 'Economic Engine'; 11th-Hour Clearance Gives Airport Time, \$1.6 Million for Drains. Baltimore Sun, August 9.	Sawmill Creek		O		Fo,O, Co	X	
Baltimore Washington International Airport	1997	McDowell, A.S. 1997. Sawmill Creek - Watershed "Restoration" Project. Allwood Community Association Site Inspection, March.	Sawmill Creek			DW,HFo,Od			
Baltimore Washington International Airport	1998	Pelton, Tom. 1998. BWI Violated Water Act, Group Claims; Environmentalists File Notice of Intent to Sue; De-Icing Chemicals at Issue; Airport Maintains it Has Tried to Keep Pollution Contained. Baltimore Sun, January 8.	Kitten Branch of Stony Run, Muddy Bridge Branch of Sawmill Creek				Fo,Od	X	
Baltimore Washington International Airport	2001	Ayres, E. 2001. Airports and cities: Can they coexist? Sanunnamed aquifer Diego Earth Times, September.				DW			
Bangor International Airport	2003	New England Grassroots Environment Fund. 2003. Annual Report. Montpelier, Vermont.	Birch Stream			H			
Bangor International Airport	2006	State of Maine Department of Environmental Protection. 2006. 2006 Integrated Water Quality Monitoring and Assessment Report. Report DEPLW0817.	Birch Stream	B	O				
Bradley International Airport	2003	Farmington River Watershed Association. 2003. State of the Farmington River Watershed Report. August.	Rainbow Brook, Seymour Hollow Brook	D					
Bradley International Airport	2004	State of Connecticut Department of Environmental Protection. 2004. List of Connecticut waterbodies not meeting water quality standards.	Rainbow Brook, Seymour Hollow Brook	D	O				
Buffalo Niagara International Airport	1994	Dawson, Dick. 1994. Contaminant Testing Sought at Ellicott Creek Amherst Councilwoman Fears Runoff of De-Icer Fluids from Airport. Buffalo News, May 11.	Ellicott Creek		O		Fo,O, Co		

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Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Chicago O'Hare International Airport	1997	Alliance of Residents Concerning O'Hare, Inc. 1997. O'Hare Found to be Major Water Polluter. ARCO Flight Tracks, May.	Des Planes River, ground water, Bensenville Ditch, Willow Creek, Crystal Creek		F,O	H	Fo,O, Co		G
Chicago O'Hare International Airport	1997	Cowan, P.F. 1997. Water Pollution-Chicago International Airport. Alliance of Residents Concerning O'Hare, Inc., May 28.	Des Planes River, Bensenville Ditch, Willow Creek, Crystal Creek		F,O	H	Od,Co		
Chicago O'Hare International Airport	1998	Worthington, R. 1998. Group Claims O'Hare Fails to Report on De-Icing Toxins. Chicago Tribune, January 9.	unnamed receiving waters						
Cincinnati/Northern Kentucky International Airport	1992	Associated Press. 1992. Cincinnati Airport Cited by State. Cleveland Plain Dealer, June 8.	Elijah Creek		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2003	Alliance of Residents Concerning O'Hare, Inc. 2003. Comments from the Alliance of Residents Concerning O'Hare, Inc. to the Federal Aviation Administration regarding the Draft FAA Five-Year Strategic Plan "Flight Plan" 2004-2008 by Jack Saporito. August 5.	Gunpowder Creek, Elijah's Creek		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2004	Kelly, B.R. and D. Klepal. 2004. Silent Streams. The Cincinnati Enquirer, March 7.	Gunpowder and Elijah Creeks		O		Od,Co	X	
Cincinnati/Northern Kentucky International Airport	2004	Sierra Club. 2004. Water Sentinels: Rescuing the river that wouldn't freeze. Annual Report.	Gunpowder Creek, Elijah's Creek		O		Od,Co		
Cincinnati/Northern Kentucky International Airport	2004	Klepal, Dan. 2004. Airport Pollution Provokes Ire: Residents fault state for going easy on de-icing runoff. The Cincinnati Enquirer, September 10.	Gunpowder and Elijah Creeks	D			Od,Co		
Cincinnati/Northern Kentucky International Airport	2004	KPDES Permit # KY0082864. Kentucky Department for Environmental Protection. Expiration: July 31, 2007.	Elijahs Creek, Gunpowder Creek						

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Cincinnati/Northern Kentucky International Airport	2006	Sierra Club. 2006. An Interview with Tim Guilfoile. August.	Gunpowder Creek		O				
Cincinnati/Northern Kentucky International Airport		Impacts of Deicing Fluids on Elijahs and Gunpowder Creeks, Boone County, Kentucky. Kentucky Department for Environmental Protection.	Elijahs Creek, Gunpowder Creek	D,B,N	O			X	
Cleveland Hopkins International Airport	2001	NPDES Permit # OH0122068. Ohio Environmental Protection Agency. Expiration: October 31, 2006.	Rocky River, Abrams and Silver Creek		O			X	G
Cleveland Hopkins International Airport	1991	Miller, Alan. 1991. De-Icing's Fatal Effect Not Plain. Columbus Dispatch, January 6.	Rocky River						
Cleveland Hopkins International Airport	2001	Kuehner, John C. 2001. Airport ordered to reduce discharge. The Plain Dealer, November 1.	Rocky River, Abram Creek, Silver Creek		F		Od,Co	X	
Cleveland Hopkins International Airport	2001	Egan, D'arcy. 2001. Rocky River fishing in danger as pollutants keep pouring in. The Plain Dealer, October 21.	Rocky River, Lake Erie		O		Od		
Cleveland Hopkins International Airport	2006	Richardson, David C. 2006. Deicing by Design: Cleveland Gets a New Pad. Stormwater. 7(7).	Abrams Creek, Rocky River		F		Od	X	
Dallas/Fort Worth International Airport	2006	Corsi, S.R., G.R. Harwell, S.W. Geis, and D. Bergman. 2006. Impacts of aircraft deicer and anti-icer runoff on receiving waters from Dallas/Fort Worth International Airport, Texas, U.S.A. Environ Toxicol Chem. 25(11):2890-2900	Trigg Lake and Big Bear Creek		O				
Denver International Airport	1997	Scanlon, Bill. 1997. DIA Pollutes Creek / De-Icer Washing off Runways Kills Life in Stream That Flows Toward Barr Lake Bird Sanctuary. Rocky Mountain News, April 22.	Third Creek, Barr Lake		O		Od		S
Denver International Airport	1997	Eddy, Mark. 1997. Airport Deicer Pollutes Creek. Denver Post, April 22.	Third Creek, Barr Lake	D	O		Od,Co		
Denver International Airport	1997	Dafforn, Erik. 1997. 'Til Hill and Valley are Ringing. Wabash Magazine. Summer.	unnamed creek						
Denver International Airport	2001	Ayres, E. 2001. Airports and cities: Can they coexist? Diego Earth Times, September.	SanBarr Lake		O				

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Denver International Airport	2005	Meyerhoff, R., N. Rowan, J. Kieler, J. Barrilleaux, R. Albrecht, and S. Morea. 2005. Development of Site-Specific Dissolved Oxygen Standards in Surface Waters at Denver International Airport. TMDL 2005 Specialty Conference. Water Environment Federation.	Second, Third and Box Elder Creeks	D					S
Des Moines International Airport	1998	Flannery, William. 1998. Status on Recovery of Aircraft Deicing Fluid Operations at the Airport. City Council Communication 98-052. February 16.	Yeader Creek				Od,Co	X	
Des Moines International Airport	2004	Iowa Department of Natural Resources. 2004. Total Maximum Daily Loads For Nutrients and Siltation: Easter Lake, Polk County, Iowa.	Easter Lake	N					
Des Moines International Airport	2005	Iowa Department of Natural Resources. 2005. Total Maximum Daily Load For Priority Organics: Yeader Creek, Polk County, Iowa.	Yeader Creek	B	O		Fo,O, Co	X	S
Detroit Metropolitan Wayne County Airport	1990	Askari, Emilia. 1990. State Probes Airport in Pollution Allegations. Detroit Free Press, August 30.	Detroit River						
Detroit Metropolitan Wayne County Airport	2001	Environmental News Service. 2006. Wayne County Airport Admits De-Icing Chemical Discharge. June 14.	Detroit River	D			Od,Co	X	
Detroit Metropolitan Wayne County Airport	2006	Lochner, Paul. 2006. Wayne County Airport Authority Pleads Guilty to Violation of Clean Water Act. Department of Justice Press Release. June 8.	Frank and Poet Drain		F		Od,Co	X	
General Mitchell International Airport	2001	Corsi, S.R., N.L. Booth, and D.W. Hall. 2001. Aircraft and Runway Deicers at General Mitchell International Airport, Milwaukee, Wisconsin, USA. 1. Biochemical Oxygen Demand and Dissolved Oxygen in Receiving Streams. Environ. Toxicol. Chem. 20(7):1474-1482	Wilson Park Creek, Kinnickinnic River	B	O				
General Mitchell International Airport	2001	Corsi, S.R., D.W. Hall, and S.W. Geis. 2001. Aircraft and Runway Deicers at General Mitchell International Airport, Milwaukee, Wisconsin, USA. 2. Toxicity of Aircraft and Runway Deicers. Environ. Toxicol. Chem. 20(7):1483-1490.	Wilson Park Creek, Kinnickinnic River	N	O				

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General Mitchell International Airport	2003	Cancilla, D.A., J.C. Baird, S.W. Geis, and S.R. Corsi. 2003. Studies of the Environmental Fate and Effect of Aircraft Deicing Fluids: Detection of 5-methyl-1H-benzotriazole in the fathead minnow (<i>Pimephales promelas</i>). Environ. Toxicol. Chem. 22(1):134-140	Wilson Park Creek, Kinnickinnic River		F,O				
General Mitchell International Airport	2006	Sandler, Larry. 2006. Environmental group challenges airport's wastewater permit: Mitchell discharges too much deicing fluid into creek, it says. Milwaukee Journal Sentinel, January 25.	Wilson Creek				Co		
Hartsfield-Jackson Atlanta International Airport	2002	Hamrick, Dave. 2002. Officials unanimous: Our water is safe. The Citizen, February 13.	Flint River			H,DW	Od		
Hartsfield-Jackson Atlanta International Airport	2002	Hamrick, Dave. 2002. EPD: 'We blew it': State agency took 4 days to respond to calls that deicing fluid had been spilled into the Flint River; airport manager promises new procedures will prevent future spills. The Citizen, February 13.	Flint River			DW			
Indianapolis International Airport	1997	Stahl, J.R., T.P. Simon, and E.O. Edberg. 1997. A Preliminary Appraisal of the Biological Integrity of the East Fork White Lick Creek in the West Fork White River Watershed Using Fish Community Assessment. IDEM/32/03/013/1997. December 12.	White Lick Creek		O				
James M. Cox Dayton International Airport	1991	Miller, Alan. 1991. De-Icing's Fatal Effect Not Plain. Columbus Dispatch, January 6.	Mill Creek		F				
James M. Cox Dayton International Airport	1995	State of Ohio Environmental Protection Agency. 1995. Biological and Water Quality Study of Mill Creek: Dayton International Airport, Miami and Montgomery Counties, Ohio. OEPA Technical Report MAS/1995-2-2. Columbus, OH.	Mill Creek	B,N	F,O				
James M. Cox Dayton International Airport	1998	Associated Press. 1998. Panel Settles De-Icing Suit with Homeowners. Cleveland Plain Dealer, March 28.	Mill Creek			DW			G

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James M. Cox Dayton International Airport	2001	State of Ohio Environmental Protection Agency. 2001. Biological and Water Quality Study of the Stillwater River Basin, 1999, Darke, Miami and Montgomery Counties. OEPA Technical Report Number MAS/2001-12-8. Columbus, OH	Mill Creek	B,N	O				
Kansas City International Airport	2007	Missouri Department of Conservation. 2007. Platte River Watershed: Water Quality and Use. <mdc.mo.gov/fish/watershed/platte/watqual/>	Todd Creek		F				
Lambert-St. Louis International Airport	1995	Uhlenbrock, Tom. 1995. Up A Creek Runoff of De-Icer from Lamber Field Pits Airport Against U.S. St. Louis Post Dispatch, February 5.	Coldwater Creek				Od		
Louisville International - Standiford Field	2002	KPDES Permit # KY0092185. Kentucky Department for Environmental Protection. Expiration: December 31, 2007.	Northern Ditch, Fern Creek	D,N	F				
Manchester Airport	2003	CAA News Channel. 2003. New Hampshire Brook to be Tested for Chemicals. The Union Leader and New Hampshire Sunday News, January 27.	Little Cohas Brook				Fo,Od		
Manchester Airport	2006	Kibbe, Cindy. Planes, trains and automobiles: What are southern N.H.'s transportation options? NHBR Daily, April 14.	Merrimack River				Od		
Minneapolis/St. Paul International Airport	2004	Larson, Catherine. 2004. Lower Minnesota River Model Project Proposal. Proposal to Develop an Advanced Water-Quality Model of the Minnesota River, Jordan to the mouth, and Conduct River Monitoring and Studies to Support the Model. January 15.	Minnesota River	B				X	
Minneapolis/St. Paul International Airport	2004	Mikkelson, Stephen. 2004. Water Quality Violations to Cost Metropolitan Airports Commission \$69,076. Minnesota Pollution Control Agency News Release. November 2.	Lower Minnesota River	D				X	

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Minneapolis/St. Paul International Airport	2005	Environmental News Service. 2005. Minnesota Halts Jet Fuel Leaks, Spills at Twin Cities Airport. Environmental News System. March 18.	Minnesota River, Snelling Lake, Mother Lake				Od,Co	X	
Minneapolis/St. Paul International Airport	1993	Meersman, Tom. 1993. New Rules for Airport De-Icers Amount of Chemicals Flushed into River Will be Reduced. Minneapolis Star Tribune, September 29.	Minnesota River	D,B					
Minneapolis/St. Paul International Airport	1993	Meersman, Tom. 1993. FAA-Mandated Plane De-Icing Puts Minnesota River at Risk. Minneapolis Star Tribune, March 10.	Minnesota River						
Minneapolis/St. Paul International Airport	2001	Mills, Karren. 2001. Minneapolis airport saw big jump in runoff from de-icer into Minnesota River. CAA News Channel, May 19.	Minnesota River					X	
Newcastle International Airport	1995	Turnbull, D.A. and J.R. Bevan. 1995. The Impact of Airport De-Icing on a River: The case of the Ouseburn, Newcastle Upon Tyne. Environ. Pollut. 88:321-332.	Ouseburn River	B,N	O				S
Pease Air Force Base	1999	Agency for Toxic Substances and Disease Registry. 1999. groundwater Public Health Assessment: Pease Air Force Base, Portsmouth, Rockingham County, New Hampshire. Department of Health and Human Services. September 30.		N		DW			G
Pittsburgh International Airport	1996	Hopey, Don. 1996. Airport Gets Criticism for Disposal of De-Icer. Pittsburgh Post-Gazette, October 28.	McClarens, Enlow and Montour Runs	N	F	H	Od	X	
Pittsburgh International Airport	1998	Hopey, Don. 1998. Airport Ordered Again to Keep De-Icers Out of Streams. Pittsburgh Post-Gazette, January 31.	McClarens, Enlow and Montour Runs		F	H	Od	X	
Pittsburgh International Airport	1998	Koryak, M. L.J. Stafford, R.J. Reilly, R.H. Hoskin and M.H. Haberman. 1998. The Impact of Airport Deicing Runoff on Water Quality and Aquatic Life in a Pennsylvania Stream. J. Freshwater Ecol. 13(3): 287-298.	Montour Run and tributaries	B,N	O				

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Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Port Columbus International Airport	1998	State of Ohio Environmental Protection Agency. 1998. Biological and Water Quality Study of Mason Run, 1996, Big Walnut Creek Franklin County, Columbus, Ohio. OEPA Technical Report MAS/1996-12-6. Columbus, OH.	Mason Run, Turkey Run, Big Walnut Creek	D,N	F,O				
Port Columbus International Airport	2003	State of Ohio Environmental Protection Agency: Division of Surface Water. Biological and Water Quality Study of Big Walnut Creek Basin. 2003. OEPA Technical Report DSW/EAS 2003-11-10. Columbus, OH.	Big Walnut Creek, Alum Creek and Blacklick Creek watersheds	D,B,N					
Port Columbus International Airport	2004	NPDES Permit # OH0124311. Ohio Environmental Protection Agency. Expiration: July 31, 2007.	Big Walnut Creek, Mason Run	N	O				
Portland International Airport	1997	Wells, Scott. 1997. The Columbia Slough. Prepared for the City of Portland Bureau of Environmental Services. Technical Report EWR-2-97. (March)	Columbia Slough	D,B					
Portland International Airport	1998	Oregon Department of Environmental Quality. 1998. Columbia Slough Total Maximum Daily Loads (TMDLs) For: Chlorophyll a, Dissolved Oxygen, pH, Phosphorus, Bacteria, DDE/DDT, PCBs, Pb, Dieldrin and 2,3,7,8 TCDD	Columbia Slough	D	O				
Portland International Airport,	1998	Stewart, Bill. 1998. Airport Juggles Safety, Pollution Concerns. The Oregonian, February 2	Columbia Slough	D					
Portland International Airport	2005	Johnson, Steve. 2005. Port Plans study to Enhance Airport Deicing Storm Water Collection System. Port of Portland News Release, September 26.	Columbia River					X	
Portland International Airport	2006	Associated Press. 2006. Portland airport's de-icing system harms fish. USA Today, October 17.	Columbia River		O			X	
Raleigh-Durham International Airport	2000	RDU Airport Changes its Runway Deicing Chemical. 2000. The Umstead Coalition Newsletter, November 29.	Big Lake, Sycamore Lake	N					

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Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Rickenbacker International Airport	1996	State of Ohio Environmental Protection Agency: Division of Surface Water. 1996. Biological and Water Quality Study of Lower Big Walnut Creek and Walnut Creek Tributaries. Prepared for State of Ohio Environmental Protection Agency: Division of Emergency and Remedial Response, Columbus, OH.	Walnut Creek, Big Walnut Creek and tributaries		O				
Seattle-Tacoma International Airport	1993	Roberts, C.R. 1993. Airport Antifreeze May Be Toting Chill of Death to Miller Creek. Tacoma News Tribune, January 26.	Miller Creek		O				
Seattle-Tacoma International Airport	1995	Taylor, Rob. 1995. Lawsuit Filed Over Stream Pollution From Sea-Tac Airport. Seattle Post-Intelligencer, August 15.	Des Moines Creek, Miller Creek, Puget Sound					X	
Seattle-Tacoma International Airport	2003	Lange, Larry. 2003. Sea-Tac blamed for fish deaths. Seattle Post-Intelligencer, April 14.	Miller Creek, Puget Sound		F			X	
Spokane International	2002	NPDES Permit # SO3004373. State of Washington Department of Ecology. Expiration: September 20, 2007.	unnamed aquifer						G
Stapleton International Airport	1996	Pillard, D.A. Assessment of Benthic Macroinvertebrate and Fish Communities in a Stream Receiving Storm Water Runoff from a Large Airport. J. Freshwater Ecol. 11(1):51-59.	Sand Creek		O				
Stockholm Arlanda Airport	1993	O'Conner, R. and Douglas, K. 1993 Cleaning up after the big chill: Thousands of rivers and streams are harmed by the de-icing chemicals that keep aircraft flying through the winter. Now airports are being forced to curb this damaging pollution. New Scientist	unnamed receiving waters	D					
Syracuse Hancock International Airport	1999	Atlantic States Legal Foundation, Inc. 1999. Litigation Update. Atlantic States Legal Foundation, Inc. Newsletter.	Bear Trap Creek, Ley Creek					X	
Syracuse Hancock International Airport	2000	Beartrap Creek Reclamation Project Description. GL2000-045	Beartrap Creek		O				

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Syracuse Hancock International Airport	2003	Onondaga Lake Partnership. 2003. Izaak Walton League's Beartrap Efforts Lead to Restored Beartrap Creek. Reflections. 1(3): 6.	Creek		O				
Ted Stevens Anchorage International Airport	1990	Wohlforth, Charles. 1990. Toxic Runoff Adds to Lake Hood Pollution. Anchorage Daily News, May 4.	Lake Hood		O				
Ted Stevens Anchorage International Airport	1991	Pytte, Alyson. 1991. Chemicals Lace Airport Soil Finding Pollution is Easy; Who Pays for Cleanup is the Problem. Anchorage Daily News, September 8.	Lake Hood	N			Od		G
Ted Stevens Anchorage International Airport	2007	deMarban, Alex. 2007. Lake mower clears paths for floatplanes. Anchorage Daily News, August 13.	Lake Hood		O		Co		
Theodore Francis Green State Airport	2004	RIPDES Permit # RI0021598. Rhode Island Department of Environmental Management. Expiration January 1, 2010.	unnamed tributaries of Warwick Pond and Buckeye Brook, and Tuscatucket Brook	D	O		Fo,Od		
Toronto Pearson International Airport	1989	Legislative Assembly of Ontario. Storm Water. Transcript of the July 6, 1989 meeting.	Etobicoke Creek, Mimico Creek, Lake Ontario	B	O			X	S
Unknown international North American airport	1998	Cancilla, D.A., J. Martinez, and G.C. van Aggelen. 1998. Detection of Aircraft Deicing/Antiicing Fluid Additives in a Perched Water Monitoring Well at an International Airport. Environ. Sci. Technol. 32: 3834-3835.	unnamed well		O				G
Victoria International Airport	2003	Reay Watershed: 2003 Fish Kill. <www.peninsulastreams.org/watersheds/reay.shtml>.	Reay Creek		F				
Victoria International Airport	2004	Dickson, Louise. 2004. Polluted creek killing fish: Reclamation work wasted as second major kill wipes out run. Times Colonist. November 1.	North Saanich Creek		F				
Westchester County Airport	1997	Conetta, A., R. Bracchitta, and P. Sherrer. 1997. Storm Water Management and Control of Aircraft Deicing Runoff at Westchester County Airport. Environmental Regulation and Permitting.	Rye Lake, Blind Brook	B					

¹ B = BOD; D = DO; N = Nutrients

² F = Fish Kill; O = Other Organism Impacts

³ H = Human Health; DW = Drinking Water

⁴ Fo = Foam; Od = Odor; Co = Color

⁵ G = Groundwater; S = Sediment

Table C-1: Documented Impacts from Airport Deicing Discharges

Airport Name	Article Year	Article	Waterbody Name	BOD, DO, Nutrients ¹	Wildlife Impacts ²	Human Health Impacts ³	Aesthetic Impacts ⁴	Permit Violations	Other ⁵
Westchester County Airport	1999	Switzenbaum, M.S., S. Veltman, T. Schoenberg, C.M. Durand, D. Mericas and B. Wagoner. 1999. Best Management Practices for Airport Deicing Stormwater. Publication No. 173.	Blind Brook	D	F		Fo		
Westchester County Airport	1999	Associated Press. 1999. De-icing Chemical Found in Westchester Reservoir. New York Times, January 14.	Kensico Reservoir			DW			

¹ B = BOD; D = DO; N = Nutrients

² F = Fish Kill; O = Other Organism Impacts

³ H = Human Health; DW = Drinking Water

⁴ Fo = Foam; Od = Odor; Co = Color

⁵ G = Groundwater; S = Sediment



Fact Sheet

Effluent Guidelines for Airport Deicing Discharges

The Administrator of the U.S. Environmental Protection Agency (EPA) has signed for publication in the *Federal Register* technology-based effluent limitations guidelines and new source performance standards to control discharges of pollutants from airport deicing operations. The requirements generally apply to wastewater associated with the deicing of airfield pavement at primary airports. The rule also establishes new source performance standards for wastewater discharges associated with aircraft deicing for a subset of new airports. EPA expects this regulation to reduce pollutant discharges by at least 16 million pounds per year, at an annual cost of about \$3.5 million.

Background on Airport Deicing

Airlines and airports conduct deicing operations on aircraft and airfield pavement to ensure the safety of passenger and cargo flights. In the absence of controls, deicing chemicals are widely dispersed causing pollutants to enter nearby rivers, lakes, streams, and bays.

Background on Effluent Guidelines

Effluent guidelines are national regulations that control the discharge of pollutants to surface waters and to publicly owned treatment works. EPA issues effluent guidelines for categories of existing sources and new sources under Title III of the Clean Water Act to control pollution from these sources. The guidelines are based on the performance of treatment and control technologies. These guidelines are implemented in discharge permits issued by states and EPA regional offices under the National Pollutant Discharge Elimination System.

Final Rule Requirements

Existing and new primary airports with 1,000 or more annual jet departures ("non-propeller aircraft") that generate wastewater associated with airfield pavement deicing are to use non-urea-containing deicers, or alternatively, meet a numeric effluent limitation for ammonia.

New airports with 10,000 annual departures located in cold climate zones are required to collect 60 percent of aircraft deicing fluid after deicing. Airports that discharge the collected aircraft deicing fluid directly to waters of the U.S. must also meet numeric discharge requirements for chemical oxygen demand. The rule does not establish uniform, national requirements for aircraft deicing discharges at existing airports. Such

requirements will continue to be established in general permits, or for individual permits on a site-specific, best professional judgment basis.

Additional Information

You can view or download the complete text of the *Federal Register* notice on EPA's website at <http://epa.gov/guide/airport>. For additional information, please contact Eric Strassler at strassler.eric@epa.gov or 202-566-1026.



Preliminary Data Summary

Airport Deicing Operations (Revised)



ACKNOWLEDGMENTS AND DISCLAIMER

The Agency would like to acknowledge the contributions of Shari Barash, James Covington III, and Charles Tamulonis to the development of this Preliminary Data Summary. In addition, EPA acknowledges the contribution of Eastern Research Group, Inc.

This report on deicing fluids does not set forth any regulatory requirements under the Clean Water Act. It is intended solely as a presentation of information of which EPA is currently aware concerning the use of deicing fluids at airports. Thus, it does not impose any requirements on any party, including EPA, states, permitting authorities, POTWs, or the regulated community. This report was prepared using information from the following sources: review of selected literature, reports, and advisories; meetings with several interested parties; personal visitation with several persons and airport personnel; the experience of the authors; and other information solicited from stakeholders.

References made in this document to any specific method, product or process, vendor, or corporation do not constitute or imply an endorsement, recommendation, or warranty by the U.S. Environmental Protection Agency. The Agency does not assume any legal liability or responsibility for any third party's use of, or the results of such use of, any information discussed in this report, or represents that its use by such a third party would not infringe on privately owned rights.

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1.0 EXECUTIVE SUMMARY

The deicing and anti-icing of aircraft and airfield surfaces is required by the Federal Aviation Administration (FAA) to ensure the safety of passengers; however, when performed without discharge controls in place, airport deicing operations can result in environmental impacts. In addition to potential aquatic life and human health impacts from the toxicity of deicing and anti-icing chemicals, the biodegradation of propylene or ethylene glycol (i.e., the base chemical of deicing fluid) in surface waters (i.e., lakes, rivers) can greatly impact water quality, including significant reduction in dissolved oxygen (DO) levels. Reduced DO levels can ultimately lead to fish kills.

This Preliminary Data Summary provides information about the air transportation industry and the best practices being employed for aircraft and airfield deicing operations, as well as for the collection, containment, recovery, and treatment of wastewaters containing deicing agents. This study was conducted to meet the obligations of the EPA under Section 304(m) of the Clean Water Act, in accordance with the consent decree in *Natural Resources Defense Council and Public Citizen, Inc. v. Browner* (D.D.C. 89-2980, as modified February 4, 1997). EPA hopes that this study will serve as an objective source of information that can be used by airports, airlines, state and local regulators, and citizen groups.

Deicing involves the removal of frost, snow, or ice from aircraft surfaces or from paved areas including runways, taxiways, and gate areas. Anti-icing refers to the prevention of the accumulation of frost, snow, or ice on these same surfaces. Deicing and anti-icing operations can be performed by using mechanical means (e.g., brooms, brushes, plows) and through the application of chemical agents. Typically, airlines and fixed-base operators (i.e., contract service providers) are responsible for aircraft deicing/anti-icing operations, while airports are responsible for the deicing/anti-icing of airfield pavement. Although compliance with environmental regulations and requirements associated with deicing/anti-icing operations may be shared between the airlines/fixed-base operators and the airports (e.g., airport authority) as co-permittees, the

airport is ultimately responsible for the management of the wastewater that is generated. This responsibility is typically outlined in the airport's discharge permit.

Deicing/anti-icing operations are typically performed from October through May at many of the nation's airports. Although low DO levels are less likely to occur during the coldest period of the deicing season, as the season ends and temperatures rise, airports are still conducting deicing operations. In addition, the snow dump piles containing deicing agents melt, releasing chemicals into receiving streams. EPA believes that more information is necessary to fully determine the effect of temperature on the reduction of DO in receiving streams caused by the biodegradation of deicing chemicals. However, EPA believes that there has been evidence that impacts could occur in some regions throughout much of the deicing season. For example, during past deicing seasons, airports experienced fish kills caused by their discharges. This may be due to reduced DO levels or the aquatic toxicity of the deicing chemicals.

For the purposes of this study, EPA focused on approximately 200 U.S. airports with potentially significant deicing/anti-icing operations. Such airports receive a minimum of one inch, on average, of snowfall annually and conduct at least 10,000 operations (i.e., aircraft take-offs or landings) annually, excluding general aviation¹ operations. These airports are very diverse in terms of climate, location, existing infrastructure, size, type and mix of tenants, resources, and ownership structure. EPA collected technical and economic information on these airports from a variety of sources including: industry questionnaires, site and sampling visits, meetings with industry and regulatory agencies, and literature. In addition, the study includes information that may be applicable to airport deicing operations and the management of associated wastewaters from the U.S. military and from airports in Canada and Europe.

The Phase I Storm Water Discharge Permit regulations specifically cover the direct discharge of deicing agent contaminated storm water from airports into the nation's surface

¹ General Aviation (GA) operations are the portion of civil (i.e., non-military) aviation which encompasses all facets of aviation except air carriers (e.g., passenger and cargo airlines).

waters. Although these regulations were developed by EPA, they are implemented, in most cases, by individual states. When developing individual airport storm water discharge permits, states may take into account local water quality issues. This leads to a large disparity in permit requirements from airport to airport. EPA found that the airports that have accomplished the most in terms of wastewater collection, containment, and recycling/treatment programs were most likely to be striving to comply with stringent storm water discharge permits. EPA finds that, on average, these airports have achieved 70% collection efficiency of the aircraft deicing/anti-icing fluids applied. They have also spent an average of nearly \$20 million, over a period of several years, to finance the necessary equipment and infrastructure changes. EPA notes that since the implementation of EPA's Storm Water Discharge Permit regulations and the resulting increase in the use of best management practices, fewer severe environmental incidents have been reported.

Specific pollutant control practices and technologies implemented at a specific airport are dependent on a variety of factors such as climate, existing infrastructure, cost, and state and local environmental regulations. However, in general, EPA found the following trends among U.S. airports:

- Increased use of propylene glycol-based aircraft deicing fluids over use of ethylene glycol-based fluids;
- Increased use of anti-icing fluids as a means of reducing the volumes of deicing fluid needed;
- Increased efforts by the industry to procure fluids with additives that are less toxic to aquatic life;
- Increased use of alternative airfield pavement deicing chemicals, such as potassium acetate, as a replacement for urea or ethylene glycol-based pavement deicers;
- Increased acceptance and commercial use of source reduction technologies (e.g., forced air and infra-red deicing equipment) used in combination with traditional methods for aircraft deicing;
- Increased use of systems for glycol recycling/recovery from spent aircraft deicing fluid; and

- Increased use of collection, containment, and treatment (on-site or off-site at the Publicly Owned Treatment Works (POTW)).

In addition, more technology vendors are supplying the industry with the equipment and contract management services for containment, collection, recycling/recovery, and treatment technologies. This healthy competition has reduced the costs of these technologies and contract services and made them feasible at some small to medium-size airports.

As part of this study EPA has developed estimates of pollutant loadings to the environment from airport deicing operations. EPA estimates that prior to the implementation of the Phase I Storm Water Discharge Permit regulations (pre-1990) the industry discharged approximately 28 million gallons (50% concentration) of aircraft deicing fluid (ADF) annually to surface waters. This equates to annual discharges of approximately: 14 million gallons of ADF concentrate (prior to dilution with water for application); 12.6 million gallons of pure glycols; or approximately 100 million pounds of BOD₅.

EPA estimates that, due to the best management practices put into place under the storm water permit regulations, current discharges are 21 million gallons of ADF (50% concentration) per year to surface waters with an additional 2 million gallons discharged to POTWs. EPA estimates that this will be further reduced to less than 17 million gallons of ADF (50% concentration) per year discharged to surface waters when the requirements of all airport storm water permits are fully implemented. The volume discharged to POTWs is expected to steadily increase.

Finally, EPA estimated possible reductions in discharges of ADF if effluent limitations guidelines and standards were implemented for airport deicing operations. Assuming that all airports with potentially significant deicing operations could achieve a 70% collection efficiency of ADF applied, EPA estimates that discharges to surface waters from airport deicing operations could be reduced to approximately 4 million gallons ADF (50% concentration) per year (approximately 12.5 million pounds BOD₅ per year). This would likely result in greatly

increased volumes discharged to POTWs, as well as an increase in the use of source reduction technologies, recycling/recovery and treatment systems. In addition, FAA projects that the demand for air transportation services will continue to grow. This may result in increased airport deicing and anti-icing operations. However, with the implementation of pollution control practices and technologies, industry growth may not result in an increase in deicing/anti-icing chemicals discharged to the environment.

EPA believes that most POTWs are equipped to handle discharges from airport deicing/anti-icing operations. However, based on a survey of POTWs that currently accept such discharges, airports must control the flow and the BOD loading discharged to the POTW. Most airports use a combination of wastewater storage and controlled discharge to avoid discharging a “slug-dose” of deicing agent contaminated wastewater to the POTW. In addition, because deicing discharges are seasonal, the airports must slowly “ramp-up” (or acclimate) the POTW at the beginning of each deicing season to avoid an upset.

The economic conditions of the air transportation industry are complex in nature. For the purposes of the study, EPA collected information on airport financial management and ownership structures as well as air carrier (i.e., airline) finances to provide an economic overview of the industry. Airport ownership structures are varied (e.g., public v. private, city council v. independent authority) and lead to the use of different financial accounting practices between airports. In many cases, much of the cost of capital improvements are likely to be passed-through to the airlines as higher fees or to the passenger in the form of passenger facility charges (PFCs). Airlines, generally, operate with low profit margin and may also pass costs through to the passenger in the form of higher ticket prices for certain routes. EPA found that the largest cost to the airlines associated with aircraft deicing was the cost of delaying departure of the aircraft. Therefore, the airlines have a great interest in providing input on the various approaches that an airport may consider when trying to control discharges from airport deicing operations. For instance, depending on an airport’s runway and taxiway configuration, the use of centralized deicing pads may potentially create or reduce departure delays. However, the greatest potential economic impact to the industry from implementing capital improvements to reduce discharges

from airport deicing operations may be a reduction of quality or frequency of service to airports that do not serve large cities (i.e., smaller airports). For example, an airline may choose to operate less flights per day into a particular airport or to operate smaller aircraft on that route. For this reason, EPA believes the collection of airline route-specific data may be necessary to perform a full analysis of the industry's economic and financial condition.

2.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is required by Section 301(d) of the Federal Water Pollution Control Act Amendments of 1972 and 1977 (the “Act”) to review and revise every five years, if appropriate, effluent limitations promulgated pursuant to Sections 301, 304, and 306. Effluent limitations guidelines and standards (or “effluent guidelines”) are technology-based national standards that are developed by EPA on an industry-by-industry basis, and are intended to represent the greatest pollutant reductions that are economically achievable for an industry. These limits are applied uniformly to facilities within the industry scope defined by the regulations regardless of the condition of the water body receiving the discharge. To address variations inherent in certain industries, different numeric limitations may be set for groups of facilities (i.e., subcategories) within the industry based on their fundamental differences, such as manufacturing processes, products, water use, or wastewater pollutant loadings. The limits and standards that are developed are used by permit writers and control authorities (e.g., Publicly Owned Treatment Works or “POTW”) to write wastewater discharge permits. The permits may be more stringent due to water quality considerations but may not be less stringent than the national effluent guidelines. EPA has issued national technology-based effluent guidelines for over 50 industries.

EPA conducted a study of airport deicing operations (the Study) to collect engineering, economic, and environmental data for use in determining whether national categorical effluent limitations guidelines and standards should be developed for this category of dischargers. A secondary purpose of the Study was to provide information to permit writers, control authorities, airports, and airlines in developing pollutant control strategies for discharges from airport deicing operations. EPA was required to conduct the Study under Section 304(m) of the Clean Water Act (CWA), in accordance with a consent decree in *Natural Resources Defense Council and Public Citizen, Inc. v. Browner* (D.D.C. 89-2980, as modified February 4, 1997). The consent decree required that EPA, at a minimum, address the following:

- “a. The effectiveness of the current storm water permitting system and the comparative effectiveness of an effluent guideline approach;
- b. A characterization of wastewater from deicing operations in terms of pollutant concentrations, volumes, and environmental impacts;
- c. The feasibility and effectiveness (in different geographic regions) of various deicing material management technology including complete capture or recycling, product substitution (e.g., propylene glycol for ethylene glycol), and alternative deicing methods (e.g., infrared heating);
- d. For each technology, management measure or maintenance activity examined, the types of appropriate numeric or otherwise objective measurable goals, surrogate indicators, performance measures, or operation or design criteria (including zero discharge) that have been or could be effectively employed;
- e. The cost and cost minimization opportunities of deicing material management; and
- f. The status and trends of deicing chemical use in the airport industry and in the development and use of prevention and treatment technologies.”

EPA collected and reviewed data from numerous sources to fulfill the requirements of the consent decree and to increase its understanding of technical, economic, and environmental issues related to airport deicing operations. Technical issues include: aircraft, runway, and taxiway deicing processes; deicing equipment; wastewater generation; wastewater collection, and handling; and pollution prevention/treatment technologies. Economic issues include significant economic and financial aspects of the air transportation industry (i.e., airports and airlines). Environmental issues include impacts from discharges of storm water contaminated with deicing/anti-icing chemicals.

This document discusses the Agency’s findings about whether regulatory development of national categorical effluent limitations guidelines and standards should be undertaken for this category of dischargers and to meet the objectives of the consent decree. The document describes data-collection activities (Section 3.0), a technical profile of the industry (Section 4.0), climatic influences and deicing/anti-icing agent- contaminated storm water

generation and discharge (Section 5.0), pollution prevention opportunities (Section 6.0), wastewater collection, treatment, and disposal (Section 7.0), and wastewater characterization (Section 8.0). This document also discusses the toxicity of deicing/anti-icing fluids (Section 9.0), provides an environmental assessment of the impacts associated with airport deicing/anti-icing (Section 10.0), and provides estimated pollutant load removals and costs to manage wastewater from deicing operations (Section 11.0). Trends in the industry (Section 12.0), the relationship a national effluent guideline would have to other regulations (Section 13.0), and an economic profile of the industry and facility economic data (Section 14.0) are also included. A glossary of frequently used terms and acronyms is also included (Section 15.0).

3.0 DATA-COLLECTION ACTIVITIES

EPA collected data from a variety of sources, including existing data from previous EPA and other governmental data-collection efforts, industry-provided information, data collected from questionnaire surveys, and site visit and sampling data. Each of these data sources is discussed below, as well as the quality assurance/quality control (QA/QC) and other data-editing procedures. Summaries and analyses of the data collected by EPA are presented in the remainder of this document.

Sections 3.1 and 3.2 describe EPA's 1993 screen questionnaire and EPA's mini-questionnaires, respectively. Section 3.3 discusses EPA site visits and Section 3.4 discusses EPA sampling. Data submitted by airports is presented in Section 3.5, and Section 3.6 discusses meetings with various interested parties. Finally, Section 3.7 discusses technical literature, Section 3.8 discusses other data sources, and Section 3.9 presents the references for the section. Appendix A contains information regarding the location of airports referenced in this section.

3.1 1993 Screener Questionnaire

In 1992, EPA began developing effluent limitations guidelines and standards for the Transportation Equipment Cleaning Industry (TECI). The scope of the TECI regulation at that time included: facilities that clean the interiors of tank trucks, rail tank cars, and tank barges; facilities that clean aircraft exteriors; and facilities that deice/anti-ice aircraft and/or pavement. Initial data-collection efforts for this program related to airport deicing operations included development and administration of a screener questionnaire, the U.S. Environmental Protection Agency Aircraft and Pavement Screener Questionnaire administered in 1993. The screener questionnaire was developed, in part, to enable EPA to: (1) identify facilities that perform TECI-Aircraft operations; (2) evaluate facilities based on wastewater, economic, and operational characteristics; and (3) develop technical and economic profiles of the industry. Subsequent to distribution of the screener questionnaire, EPA decided not to include the aircraft segment as part of the TECI effluent guideline as a result of a revision to the EPA's storm water program that

required storm water permits to address wastewater discharges from these practices (EPA's storm water program is discussed in Section 13.1) and an assessment that this segment's activities were significantly different than other TECI segments' activities.

Facilities chosen to receive a screener questionnaire were selected from the Aircraft Site Identification Database (a subset of the TECI Site Identification Database). This database contained information for 3,957 facilities that potentially perform aircraft exterior cleaning and/or aircraft or pavement deicing/anti-icing operations (e.g., airlines and fixed based operators (FBOs)). Facilities listed in the database were a stratified random sample of the 4,778 facilities that compose the total potential industry population. EPA mailed the screener questionnaire to a statistical random sample of 760 facilities that potentially perform aircraft exterior cleaning and/or aircraft or pavement deicing/anti-icing operations (TECI-Aircraft operations).

Following the screener questionnaire mailout and analyses of responses, EPA estimated that, in 1993, there were 588 facilities (i.e., airlines and FBOs) that perform deicing/anti-icing operations. For the purposes of this Study, EPA used responses from facilities that perform deicing/anti-icing operations to develop a technical profile of the industry and to identify trends in the industry. Additional details concerning the 1993 screener questionnaire are presented in a report entitled Development of Survey Weights for the U.S. Environmental Protection Agency Aircraft and Pavement Screener Questionnaire (1).

3.2 Mini-Questionnaires

To collect more detailed and current information, albeit from fewer facilities, EPA mailed mini-questionnaires to various industry representatives and other interested parties. Due to Paperwork Reduction Act concerns, EPA selected only a small portion of the industry (major and regional airports and airlines, technology vendors, and POTWs) to receive a questionnaire. Airlines were asked to submit only financial data, while airports were asked to submit financial and technical information. Technology vendors and POTWs were asked to provide only technical

information. The Air Transport Association (ATA) provided one collective questionnaire response for the 12 major carriers while eight regional airlines were each sent questionnaires. See Section 14.0 for additional information on the airline questionnaires.

EPA selected a technically representative group of recipients based on a set of selection criteria for each questionnaire type. EPA requested data through the 1998-1999 deicing season to obtain the most up-to-date data available from the industry. The data are used to describe and characterize the industry, and estimate current and projected pollutant discharge loadings from the industry. Unlike the 1993 screener questionnaire, the mini- questionnaires are not considered a statistical survey of the industry. The report entitled Methodology for Selection of Mini-Questionnaire Recipients (2) describes EPA's selection methodology and presents questionnaire recipients. These mini-questionnaires are discussed in more detail in Sections 3.2.1 through 3.2.3.

3.2.1 Airport Questionnaire

The airport questionnaire requests information from airports regarding aircraft and airfield pavement deicing and anti-icing activities performed at an airport and associated wastewater handling and treatment, in addition to airport structure, finances, and operations. EPA used two primary criteria to select airport mini-questionnaire recipients: airport size and mean annual snowfall. Airport size groupings and mean annual snowfall groupings were defined independently, and then combined to form airport categories. EPA identified data gaps by first identifying categories for which data are already available via EPA-sponsored site visits (see Section 3.3), and then determining which categories require data, or additional data, through questionnaires. EPA selected nine airports that represent airport categories for which little or no data were available to complete a questionnaire.

3.2.1.1 Airport Questionnaire Development

EPA sent a draft version of the questionnaire to representatives from two industry trade associations (American Association of Airport Executives (AAAE) and the Airport Council International - North America (ACI-NA)) for review and comment. Comments from AAAE and ACI-NA were incorporated into the final version of the questionnaire.

The questionnaire included two parts:

1. Part A: Technical Information
 - Section 1: General Information,
 - Section 2: Airfield Pavement Deicing/Anti-icing Operations,
 - Section 3: Aircraft Deicing/Anti-icing Operations,
 - Section 4: Aircraft and Pavement Deicing/Anti-icing Fluid Collection, Treatment, and Disposal; and
2. Part B: Airport Structure, Finances, and Operations.

Part A requested technical information concerning deicing operations at airports. Information was used to develop an industry profile and estimate pollutant discharge loadings from airfield pavement and aircraft deicers/anti-icers. Part A also requested information regarding deicing chemical collection, disposal, and treatment practices, which was used to identify and evaluate applicable pollution prevention and wastewater collection and treatment techniques available to the industry. Part B requested information necessary to develop a general industry economic profile (see Section 14.0 for additional information).

3.2.1.2 Airport Questionnaire Administration

EPA mailed the airport questionnaire in June 1999 to nine selected airports. One airport voluntarily submitted a questionnaire. The Agency completed a detailed engineering review of the questionnaires and contacted by telephone respondents who provided incomplete or contradictory technical information. The information gathered from the questionnaires was

entered into EPA's Airport Matrix, a database that contains information on all aspects of airfield pavement and aircraft deicing for the airports for which detailed information is available (via EPA site visits or the questionnaires). The Airport Matrix was used to characterize the industry, validate EPA's snowfall and operations groups, and estimate baseline pollutant loadings discharged to U.S. surface waters and to POTWs.

3.2.2 Vendor Questionnaire

Vendors that received a questionnaire included manufacturers, businesses, and operators of equipment used to collect, control, recycle/recover, treat, or reduce the generation of glycol-contaminated wastewater from aircraft and airfield pavement deicing and anti-icing. EPA identified nine vendors that specialize in certain aspects of these areas based on information obtained during engineering site visits to airports and meetings with industry representatives. In general, EPA selected vendors for which little or no data were previously available.

3.2.2.1 Vendor Questionnaire Development

A draft version of the questionnaire was sent to one treatment technology vendor, Inland Technologies, Inc. (Inland), for review and comment. Comments from Inland were incorporated into the final version of the questionnaire. The questionnaire was divided into the following sections:

- Section 1: General Information;
- Section 2: Information on Specific Equipment and Services;
- Section 3: Rates and Charges;
- Section 4: Future Operations;
- Section 5: Wastewater Treatment and Recycling/Recovery;
- Section 6: Process Influent and Effluent;
- Section 7: Residuals and Solid Waste; and
- Section 8: Additional Information.

The questionnaire requested information necessary to identify and characterize the types of equipment manufactured, leased, or operated by the vendor. The questionnaire also requested information necessary to assess costs to the industry for operating the equipment and to further characterize wastewater treatment and recycling/recovery operations.

3.2.2.2 Vendor Questionnaire Administration

The vendor questionnaire was mailed in June 1999 to nine selected vendors and one Canadian vendor. The Agency completed a detailed engineering review of the questionnaires and contacted by telephone respondents who provided incomplete or contradictory technical information. The information gathered from the questionnaires was summarized in a report and was used to provide costs for managing wastewater from airport deicing operations.

3.2.3 POTW Questionnaire

EPA developed the POTW questionnaire to obtain information from POTWs that accept or have accepted wastewaters containing airport deicing chemicals. EPA selected POTW questionnaire recipients based on the general characteristics of the discharges they receive or once received (e.g., receive discharges of all aircraft deicing/anti-icing agent-contaminated wastewater, receive discharges of only low-strength agent-contaminated wastewater). EPA obtained information regarding POTWs from EPA site visits, discussions with airport, airline, and POTW trade association members, discussions with treatment technology vendors, and literature and newspaper searches.

3.2.3.1 POTW Questionnaire Development

A draft version of the questionnaire was sent to a representative for the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) for review and comment. Comments from MWRDGC were incorporated into the final version of the questionnaire. The questionnaire was divided into the following two sections:

- Section 1: General/Background Information; and
- Section 2: Information Regarding the Acceptance or Rejection of Wastewater Containing Deicing Chemicals.

The questionnaire requested information regarding potential pollutants in wastewater discharges to POTWs from airports, data to characterize the types of discharges the POTW receives, and potential environmental impacts from accepting deicing wastewater containing deicing agents. These data were used to assess the potential impacts that wastewater discharges from airport deicing operations may have on POTW operations.

3.2.3.2 POTW Questionnaire Administration

The POTW questionnaire was mailed in August 1999 to nine selected POTWs. The Agency completed a detailed engineering review of the questionnaires and contacted by telephone respondents who provided incomplete or contradictory technical information. The information gathered from the questionnaires was summarized in a report and was used to provide additional information on environmental impacts from the discharge of wastewater containing deicing agents.

3.3 EPA Site Visits

The Agency conducted 16 engineering site visits at airports to collect information about aircraft, runway, and taxiway deicing processes; deicing equipment; and deicing wastewater generation, collection, handling, and treatment technologies. During these site visits, EPA also evaluated potential sampling locations (as described in Section 3.4). One visit was conducted in April 1997, prior to the formal commencement of this Study, and was used to gather preliminary information about the industry. EPA site visits to the remaining airports examined a range of deicing activities and management practices and took place from September 1997 through March 1999.

EPA used information collected from literature searches and contact with trade association members to identify representative airports for site visits. In general, the Agency considered the following three criteria to select facilities that encompassed the range of deicing/anti-icing operations, wastewater characteristics, and wastewater treatment practices:

1. Size of airport;
2. Geographic location of airport (i.e., typical winter climate); and
3. Technologies in place (e.g., pollution prevention practices, collection techniques, and on-site wastewater treatment facilities).

Airport-specific selection criteria are contained in site visit reports (SVRs) prepared for each airport visited by EPA. Unfortunately, EPA was unable to visit all airports that represent the broad range of size, location, and technologies and, therefore, used questionnaire data (see Section 3.2.1) to augment EPA's site visit program.

During the site visits, EPA collected the following information:

- General airport and deicing operations information, including size and age of the airport, the party(ies) responsible for aircraft and pavement deicing, and current airline tenants;
- A general description of deicing/anti-icing operations, including equipment used, location(s) of deicing operations, chemicals used, and pollution prevention techniques employed;
- Volumes, specific procedures, and type of fluid used for aircraft and pavement deicing/anti-icing;
- Wastewater characterization information, including the typical volume of ADF-contaminated storm water generated, collection methods used, and pollutant concentrations;
- On-site wastewater treatment data, including the treatment technologies used, treatment costs, monitoring, discharge, and permit information; and
- Airport financial information.

This information is documented in the SVR for each airport visited.

3.4 EPA Sampling

During the Study, the Agency conducted six sampling episodes. Two of these were conducted to obtain data on ADFs. EPA conducted one episode to analyze Type I undiluted ethylene glycol-based ADF and conducted another to analyze Type I undiluted propylene glycol-based ADF. The four remaining episodes were conducted to obtain untreated glycol-contaminated wastewater characterization data and treated final effluent data from airports performing a variety of collection and treatment techniques.

To obtain representative sampling data for the industry, EPA collected the following samples:

- Storm water outfall which drains aircraft deicing/anti-icing areas (sample collected during the deicing season, but not concurrent with a deicing event);
- Wastewater discharge to a POTW from an airport retention basin used to collect ADF-contaminated wastewater;
- Influent to and effluent from an anaerobic biological treatment system used to treat ADF-contaminated wastewater at an airport;
- Influent to and effluent from a reverse osmosis treatment system used to treat low-strength ADF-contaminated wastewater and to recover glycol for further processing;
- Influent to and effluent from an aerobic biological treatment system used to treat ADF-contaminated wastewater;
- Undiluted propylene glycol-based aircraft deicing fluid;
- Undiluted ethylene glycol-based aircraft deicing fluid;
- Trip blank(s);

- Equipment blank(s); and
- Duplicate wastewater samples.

In general, the following classes of pollutants were analyzed:

- Whole effluent acute toxicity (WET)
 - *Pimephales Promelas* (Fathead Minnow),
 - *Ceriodaphnia Dubia*;
- Volatile organics (at only two sampling episodes);
- Semivolatile organics (including tolyltriazoles);
- Metals;
- Glycols;
- Biochemical oxygen demand, 5-day (BOD₅);
- Total organic carbon (TOC);
- Hexane extractable material (HEM) and non-polar material (SGT-HEM); and
- Ammonia as nitrogen.

The undiluted ADFs were diluted to 50% solutions with reagent grade water and analyzed for all pollutant classes except BOD₅, glycols, WET, HEM, and SGT-HEM. Section 8.3 discusses the results of EPA's sampling effort.

During the sampling period, field measurements of temperature, pH, nitrate/nitrite, ammonia, and glycol concentration were collected for each sample point. Wastestream flow, production data (i.e., number and type of aircraft deiced/anti-iced), and any information on nondeicing/non-anti-icing operations that generate wastewater that is commingled with deicing/anti-icing wastewater were also collected when available.

During the sampling episode, EPA and EPA contractor personnel collected and preserved samples and shipped them to EPA contract laboratories for analysis. Sample collection and preservation were performed according to EPA protocols as specified in the Quality Assurance Project Plan for Field Sampling and Analysis at Airports (QAPP) (3) and the EAD Sampling Guide (4).

In general, grab samples were collected from all sample streams. These streams are not expected to significantly vary over time (i.e, samples were collected subsequent to extended equalization). EPA collected the required types of quality control samples as specified in the QAPP, such as trip blanks and duplicate samples, to verify the precision and accuracy of sample analyses. The list of analytes for each episode, analytical methods used, and the analytical results, including quality control samples, are included in the Sampling Episode Report (SER) prepared for each sampling episode.

3.5 Data Submitted by Airports

Facilities that discharge wastewater or storm water directly to surface waters of the United States must have a National Pollutant Discharge Elimination System (NPDES) permit, which can establish effluent limitations for various pollutants and require that facilities monitor the levels of these pollutants in their effluent. POTWs may also require facilities to monitor pollutant levels in their wastewater prior to discharge. EPA requested permit and self-monitoring data from airports at which EPA conducted site visits as well as from those that responded to the airport questionnaire. Self-monitoring data were submitted in various formats, including daily and monthly summaries. The monitored pollutants varied among airports; however, most airports monitor for BOD₅ and/or glycols. These data were used to support EPA's operations and snowfall groupings and were used in combination with EPA's sampling data to estimate pollutant loadings discharged to U.S. surface waters (see Section 11.1). Table 3-1 at the end of this section summarizes the specific types of data collected from individual airports.

3.6 **Meetings with Federal Agencies, Industry Representatives, Trade Associations, and Technology Vendors**

Between 1997 and 1999, EPA participated in several meetings with the Federal Aviation Administration (FAA), fluid formulators, airlines, industry associations, technology vendors, and other interested parties to discuss environmental and operational issues related to aircraft deicing and anti-icing operations. The purpose of the meetings was to gather current detailed information about the industry. These meetings served as a forum for the transfer of information between EPA and industry representatives on all aspects of airport deicing operations, including wastewater collection and treatment technologies. EPA participated in meetings with the following groups:

- Federal Aviation Administration;
- Airport, airline, and fixed based operator (FBO) representatives:
 - American Association Airline Executives (AAAE),
 - Airport Council International - North America (ACI-NA),
 - Air Transport Association (ATA),
 - Regional Airlines Association (RAA),
 - Dames and Moore (a consultant to airlines and airports), and
 - Air Canada; and
- Deicing/anti-icing fluid and treatment technology vendors:
 - AR Plus and VQuip,
 - Council for Environmentally Sound Deicing (CESD)/Lyondell Chemical Company (formerly ARCO),
 - EFX Systems,
 - Inland Technologies, and

– Union Carbide.

In addition to meetings, EPA also attended the following industry conferences:

- The Seventh Annual Aircraft and Airfield Deicing Conference and Exposition held in Washington, DC in August 1998;
- Society of Automotive Engineers (SAE) G-12 Deicing Facilities Subcommittee Meeting in Orlando, FL in October 1998;
- National Aviation Environmental Management Conference in Columbus, OH in March 1999;
- Airport Deicing Summit (hosted by the Albany International Airport Authority) in March 1999;
- The Clean Airport Summit held in Chicago, IL in April 1999;
- SAE G-12 Committee Meeting in Toronto, Canada in May 1999;
- The Eighth Annual Aircraft and Airfield Deicing Conference and Exposition held in Washington, DC in August 1999; and
- SAE G-12 Deicing Facilities Subcommittee Meeting in Washington, DC in November 1999.

By participating in these meetings and conferences, EPA was able to obtain up-to-date information about aircraft and airfield deicing/anti-icing methods, wastewater collection and treatment practices, and economic and financial aspects of the industry. EPA used this information throughout its analyses and incorporated it into this report.

3.7 Literature

EPA performed several Internet and literature searches to identify papers, presentations, and other applicable materials for use in the Study. Literature sources were identified using the Dialog® service. Literature collected by EPA covers such topics as the

toxicity of ADFs and their components, estimates of the volume of ADF used by the industry, glycol mitigation techniques, alternative fluid types, pollution prevention practices, economic and financial data, and environmental impacts. EPA also collected information from the U.S. Air Force, which conducted its own study of deicing and anti-icing operations at Air Force bases.

EPA used data from these literature sources to estimate pollutant loadings to the industry and to identify and describe deicing operations and practices, available treatment technologies and their performance, toxicity data, environmental impacts, and trends in the industry.

3.8 Other Data Sources

In addition to the sources listed above, EPA collected data from the Permit Compliance System and Toxics Release Inventory databases. These databases classify facilities that discharge wastewater using four-digit Standard Industrial Classification (SIC) codes. EPA used SIC code 4581 (Airports, Flying Fields, and Services) to identify facilities in the Permit Compliance System and Toxics Release Inventory databases that potentially discharge aircraft and/or pavement deicing/anti-icing wastewater. The Agency also used these databases to calculate and/or validate pollutant loading estimates to the industry.

EPA also collected data from state, local, and other federal agencies. EPA spoke with some state permitting agencies (e.g., NY, CT, WI) and local permit or pretreatment agencies (e.g., Albany, Windsor Locks) during site visits to gain a better understanding of local issues. EPA also collected data from the United States Geological Survey (USGS), which has been performing a study at General Mitchell International Airport in Milwaukee, Wisconsin. The USGS collected glycol samples from the airport's outfalls and downstream of the receiving waters. In addition, although EPA does not use a similar toxicity scale, the Agency acquired an acute toxicity scale from the U.S. Fish and Wildlife Service that compares concentration to toxicity. EPA Region 3 provided permit and sampling data for two airports in its jurisdiction, Ronald Reagan Washington National Airport and Dulles International Airport. EPA also

acquired, from FAA, operations and enplanement data for one full year, which were used in the airport questionnaire development, and several advisory circulars, which were used to better understand the industry and its current regulations. EPA also obtained extensive economic and financial information from published reports by FAA, the Department of Transportation (DOT), the Bureau of Transportation Statistics (part of DOT), and the General Accounting Office.

EPA also collected data from Environment Canada, the Canadian federal agency responsible for environmental protection and conservation, and Transport Canada, the Canadian federal agency responsible for transportation issues. Specifically, EPA collected information about the Canadian Glycol Guidelines and the Canadian Water Quality Guidelines for Glycols developed in the 1990s. Environment Canada and Transport Canada provided EPA with several final, and in some cases draft, reports describing studies they have conducted to evaluate the effect and fate of ADFs in the environment. These reports included results from several aquatic toxicity studies performed using formulated ADFs. See Section 13.3 for more information regarding the Canadian guidelines.

3.9 References

1. Eastern Research Group, Inc. Development of Survey Weights for the U.S. Environmental Protection Agency Aircraft and Pavement Screener Questionnaire (DCN T10343).
2. Eastern Research Group, Inc. Methodology for Selection of Mini-Questionnaire Recipients. (DCN T10545).
3. Eastern Research Group, Inc. Quality Assurance Project Plan for Field Sampling and Analysis at Airports. February 10, 1999 (DCN T10233).
4. Viar and Company. EAD Sampling Guide. June 1991 (DCN T10218).

Table 3-1**Summary of Data Submitted by Airports**

Airport	Permit Information (a)	Analytical Monitoring Data	ADF Usage Volumes
Airborne Air Park	✓		✓
Albany International	✓	✓	✓
Anchorage International	✓		✓
Baltimore-Washington International	✓	✓	✓
Billings Logan International	✓		✓
Bradley International	✓	✓	✓
Buffalo International	✓		✓
Chicago O'Hare International	✓	✓	✓
Cleveland Hopkins International	✓		✓
Dallas-Ft. Worth International	✓	✓	✓
Denver International	✓		✓
Des Moines International	✓		✓
Duluth International	✓		✓
General Mitchell International	✓	✓	✓
Greater Rockford	✓	✓	✓
Kansas City International	✓	✓	✓
Key Field (Meridian)	✓		✓
Logan International	✓	✓	✓
Minneapolis-St. Paul International	✓		✓
Newark International	✓		✓
Portland International	✓		
Richmond International	N/A		
Ronald Reagan Washington National	✓	✓	✓
Seattle-Tacoma International	✓		✓
Salt Lake City International	✓		✓
Tri-State (Huntington)	✓		✓
Washington Dulles International	✓	✓	✓

N/A - Not applicable (i.e., no current storm water permit in place).

(a) Although general permit information were available, specific permit information (e.g., monitored parameters and frequency) was not always provided.

4.0 TECHNICAL PROFILE

This section presents an overview of the air transportation industry (Section 4.1), a description of airport deicing/anti-icing operations (Section 4.2), and a profile of the airport deicing operations “industry” (i.e., airports that have deicing/anti-icing operations) (Section 4.3). Information presented in this section is based on data provided by facilities in response to screener questionnaires, mini-questionnaires, EPA site visits and sampling episodes, and data collected from other non-EPA sources (see Section 3.0).

4.1 Air Transportation Industry Overview

EPA is mainly concerned with deicing/anti-icing activities at facilities classified within Standard Industrial Classification (SIC) code 4581 (Airports, Flying Fields, and Airport Terminal Services). There are different types and sizes of airports, as well as aircraft serving these airports, depending on the airport and its location. For example, some airports that serve only cargo carriers generally service only large jets. The Federal Aviation Administration (FAA) has created several different classification codes for airports and aircraft. These classifications are mainly used for FAA funding purposes.

4.1.1 Airport Types and Sizes

There are currently 18,345 civil landing areas¹ in the U.S., which include airports as well as landing areas developed specifically for helicopters and seaplanes (1). Although the FAA is responsible for controlling all airspace, it does not control all airports. The FAA has identified 3,344 airports that are currently important to national transportation (1). Most of these airports are owned by the cities or counties they serve and only a few airports are privately owned. Of the approximately 15,000 civil landing areas that are not considered important to

¹Note that civil landing areas do not include stand-alone military landing areas (i.e., military landing areas that are not located at a public airport).

national transportation, 1,000 do not meet the minimum criteria to be considered important; 1,000 are located at inadequate sites, are redundant to publicly owned airports, or have too little activity to qualify for inclusion; and the remaining 13,000 are not open to the general public (1).

Airport size can be measured either by enplanements or operations. The FAA defines airport size based on enplanements. Commercial service airports are those that are publicly owned, receive passenger service, and have 2,500 or more annual enplanements. Primary commercial airports are those with more than 10,000 annual enplanements; nonprimary commercial service airports are those with annual enplanements ranging from 2,500 to 10,000. According to the FAA, in January 1998 there were 413 primary commercial airports and 125 nonprimary commercial service airports (1). The FAA further classifies primary commercial airports by hubs. Large hub airports are defined as those airports with 1% or more of all U.S. enplanements, medium hubs are those with 0.25% to 0.9999% of enplanements, small hubs are those with 0.05% to 0.2499% of enplanements, and nonhubs are those with 10,001 to 0.0499% of enplanements. In addition to commercial service, there are classifications for general aviation (GA) and reliever airports. Most civil aircraft operations occur at GA airports, which comprise 95% of all airports and service 98% of all registered civil aircraft. Reliever airports are typically general aviation airports that are located near a commercial service airport and serve as a reliever to congested airports. The number of airports in each category is listed below.

Category			Number of Airports	Percentage of U.S. Enplanements
Commercial	Primary	Large hub	29	67%
		Medium hub	42	22%
		Small hub	70	7%
		Nonhub	272	3%
	Non-primary	Other	125	<1%
Relievers			334	0%
General aviation			2,472	0%

Source: Reference (1).

The FAA also maintains records of airport operations (number of arrivals and departures) for FAA-towered or contractor-towered airports. EPA is not aware of any FAA airport size categories defined by airport operations. Operations are divided into the following aviation categories that are described below: air carrier, air taxi, general aviation, and military operations.

Aviation Category	Definition
Air carrier	A certified aircraft with a seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds carrying passengers or cargo for hire or compensation; includes U.S. and foreign flag carriers. The four types of air carriers are: majors, nationals, large regionals, and medium regionals.
Air taxi	An aircraft designed to have a maximum seating capacity of 60 seats or less or a maximum payload capacity of 18,000 pounds or less carrying passengers or cargo for hire or compensation; may also be referred to as a commuter aircraft if noncertified.
General aviation	Takeoffs and landings of all civil aircraft, except those classified as air carriers or air taxis.
Military	All classes of military operations (e.g., Air Force, Army, Navy, U.S. Coast Guard, Air National Guard) at FAA air traffic facilities.

Source: Reference (2).

Section 14.1 provides a detailed profile of significant economic and financial aspects of U.S. airports.

4.1.2 Geographic Location of Airports

Airports are distributed throughout the entire U.S., and more likely to be located near population centers. According to the FAA, 70% of the U.S. population resides within 20 miles of at least one of the 538 commercial airports (1). A large percentage of primary hub commercial airports (97% in 1996) are located adjacent to environmentally sensitive areas (i.e., water bodies) such as wetlands, rivers, coastal areas, creeks, and lakes (3).

4.1.3 Types of Airlines

Airlines are classified by the services they offer and their annual revenues. The four classifications for airlines are: major, national, regional, and cargo. They all operate under federal regulations; however, the regulations to which a particular airline is subject depends on their aircraft fleet. Section 14.2 provides a detailed profile of significant economic and financial aspects of U.S. airlines.

Major airlines earn annual revenues of \$1 billion or more in scheduled service. There were 12 major airlines in the U.S. in 1996 (4). These carriers generally can provide scheduled service with large aircraft (i.e., aircraft with 61 or more seats and a payload of more than 18,000 pounds) (4).

National airlines earn annual revenues of between \$100 million and \$1 billion in scheduled service (4). Many of the airlines in this category serve particular regions of the country, although this is not required. These carriers mostly operate medium and large size jets (4).

Regional carriers are airlines whose services are generally limited to a single region of the country. These carriers are divided into three groups: large, medium, and small. Large regional carriers earn annual revenues of between \$20 million and \$100 million and operate aircraft with more than 60 seats. Medium regional carriers earn annual revenues of less than \$20 million, but operate aircraft similar to large regional carriers. Small regional carriers, often called commuters, are the largest segment of the regional airline business and mostly operate planes that have less than 30 seats. There is no revenue cut-off for this group (4).

Regional airlines may be private business carriers, commercial airlines, charter airlines, or airlines that provide a combination of these services. Private business carriers represent about 60% of the flights of regional airlines. Regional airlines serve all airports served by the major airlines as well as 300 smaller airports that are not served by any major airline. At

larger airports, all of the regional airlines typically operate out of one gate area. However, some regional airlines that are affiliated with major airlines (e.g., American Eagle, which is affiliated with American Airlines) may have their own gate areas or use the same gate areas as their larger affiliate. Although regional airlines carry about 10% of all airline passengers, they represent about 40% of all flight operations. Regional airlines conduct a disproportionately large number of flight operations per passenger because their aircraft are smaller, and, therefore, carry fewer passengers per operation. In addition, their aircraft have a higher utilization rate, shorter flights, and spend less time on the ground between flights.

Cargo carriers are airlines that primarily carry cargo using aircraft called “freighters” (4). Freighters are essentially passenger aircraft with all or nearly all of the passenger seats removed. There is no revenue cut-off for this group.

4.2 Deicing/Anti-Icing Operations

A major concern for the safety of passengers is the clearing of ice and snow build-up on runways, taxiways, roadways, gate areas, and aircraft. Two basic types of deicing/anti-icing operations are generally performed at an airport: the deicing/anti-icing of aircraft, and the deicing/anti-icing of paved areas, including runways, taxiways, roadways, and gate areas. The most common technique for the deicing/anti-icing of aircraft is the application of chemical deicing/anti-icing agents. Deicing of runways, taxiways, and roadways is most commonly performed using mechanical means but may also be performed using chemical agents. The anti-icing of paved areas is typically conducted with anti-icing chemicals. The following subsections describe the methods and materials used to deice and anti-ice aircraft and paved areas at airports.

4.2.1 Aircraft Deicing/Anti-icing

Aircraft deicing involves the removal of frost, snow, or ice from an aircraft. Aircraft anti-icing generally refers to the prevention of the accumulation of frost, snow, or ice. Both are typically discussed as one operation throughout this section.

The responsibility for performing deicing/anti-icing varies between airports, but it is usually performed by a combination of individual airlines and fixed-based operators (FBOs). Airlines typically select procedures for deicing/anti-icing their aircraft, which are then approved by the FAA. EPA is aware of only one airport authority, Westchester, New York, that performs aircraft deicing. Even in this case, the airport authority functions as an FBO when performing deicing operations.

In the deicing/anti-icing process, aircraft are usually sprayed with deicing/anti-icing fluids (ADF) that contain chemical deicing agents; however, nonchemical methods are also performed. Deicing/anti-icing occurs when the weather conditions are such that ice or snow accumulates on an aircraft. During snowstorms, freezing rain, or cold weather that causes frost to accumulate on aircraft surfaces including the wings, deicing is necessary to ensure the safe operation of aircraft. Studies have concluded that even very little icing, if located on critical aircraft surfaces (e.g., leading edge of the wing), can cause significant decreases in lift. Typical tests show that 1/32nd of an inch of ice accumulation along the leading edge of a large jet or 1/64th of an inch on a smaller aircraft can decrease lift on takeoff from 12% to 24%, depending on the size of the aircraft (5).

The typical deicing season runs from October through April. In colder areas the deicing season may extend over a longer period, and in warmer climates the deicing season may be shorter, with the exception of frost removal, which may rarely be done.

ADF works by adhering to aircraft surfaces to remove and/or prevent snow and ice accumulation. Nonchemical methods use mechanical or thermal forces to prevent, remove, or melt ice and snow. Two types of deicing are performed: wet-weather and dry-weather deicing, depending on a number of climatic and operational factors. Wet-weather deicing is performed during storm events that include precipitation such as snow, sleet, or freezing rain. Dry-weather deicing is performed when changes in the ambient temperature cause frost or ice to form on aircraft but no precipitation is present. Dry-weather deicing may also be performed on some types of aircraft whose fuel tanks become super-cooled during high-altitude flight, resulting in ice

formation at lower altitudes and after landing. Dry-weather deicing may occur at temperatures up to 55° Fahrenheit (F), but generally requires a significantly smaller volume of deicing fluid than wet-weather deicing.

During typical wet-weather conditions, 150 to 1,000 gallons of ADF may be used on a single commercial jet, while a much smaller volume, as little as 10 gallons, may be used on a small corporate jet (6, 7, 8). An estimated 1,000 to 4,000 gallons may be needed to deice a commercial jet during severe weather conditions (9). Aircraft anti-icing fluids are applied in much smaller volumes than their deicing counterparts. A commercial jet requires approximately 35 gallons of fluid for anti-icing after deicing (7). Generally, dry-weather deicing requires 20 to 50 gallons of deicing fluid, depending on the size of the aircraft (7, 10).

4.2.1.1 Fluid Types

Aircraft deicers are categorized into four classes: Type I, Type II, Type III, and Type IV. Not all types are currently used. Fluid types vary by composition and allowed holdover times (i.e., the amount of time the residual fluid will protect an aircraft from ice formation). Type I is the most commonly used fluid and is used primarily for aircraft deicing. These types of fluids, which contain either ethylene glycol or propylene glycol, water, and additives, remove accumulated ice and snow from aircraft surfaces. Types II, III, and IV were developed for anti-icing and form a protective anti-icing film on aircraft surfaces to prevent the accumulation of ice and snow. Anti-icing fluids are composed of either ethylene glycol or propylene glycol, a small amount of thickener, water, and additives. The additives in aircraft deicing and anti-icing fluids may include corrosion inhibitors, flame retardants, wetting agents, identifying dyes, and foam suppressors.

Type II and Type IV fluids were designed for use on all types of aircraft while Type III fluids were designed for use on smaller, commuter aircraft. Most of the larger U.S. airlines use Type IV fluids exclusively for aircraft anti-icing because of its increased holdover time, but many smaller and regional airlines use Type II fluids due to cost considerations (Type IV

fluids require specialized application equipment). According to a representative from the Regional Airlines Association (RAA), Type III fluids are not currently used, and are not available for purchase.

FAA regulations do not stipulate which fluid should be used but recommend that commercial carriers and owners of private aircraft use fluids that meet the standards set by the Society of Automotive Engineers (SAE) (see Section 13.5). All current formulations in the U.S. use either ethylene glycol or propylene glycol as a freezing point depressant. Diethylene glycol is also an approved freezing point depressant; however, no diethylene glycol-based deicing fluids are currently used in the U.S.

Temperature and weather conditions dictate the required concentration of glycol in any type of fluid. Some entities that perform deicing vary the glycol concentration based on weather conditions (concentrations may range from 30% to 70% glycol). This is referred to as “blending to temperature.” Others use the same concentration regardless of weather conditions. Those who use the same concentration throughout a deicing season typically use a concentration applicable to worst-case cold weather conditions (usually around 50% glycol). This conservative practice may result in fewer operator mistakes and is particularly suited to smaller airports that lack storage for preparing multistrength solutions.

Type I fluids are commonly purchased as concentrated glycol solutions (8% water, 90% glycol, and <2% additives) and diluted as needed prior to application. Type II and IV fluids are sold preformulated to the appropriate concentration (33% water, 65% glycol, and 2% additives) and do not require dilution prior to application.

4.2.1.2 Fluid Uses

All ADFs work by lowering the freezing point of water. ADF is applied to ensure that the freezing point of any water on aircraft remains at a temperature not greater than 20° F below the ambient air or aircraft surface temperature, whichever is lower (FAA Advisory Circular

No. 20-117). All ADFs must lower the freezing point of water to -18°F or lower when applied. A typical Type I deicing fluid contains approximately 50% to 60% glycol after being diluted for application. This concentration will depress the freezing point of water to between -40°F and -50°F . Current formulations of propylene glycol-based ADFs require a greater concentration of glycol than ethylene glycol-based ADFs to attain the same freezing point depression. The minimum freeze point for ethylene glycol-based ADFs (approximately -58°F) occurs when the fluid consists of approximately 60% ethylene glycol and 40% water. The minimum freeze point for propylene glycol-based ADFs (-75°F) is lower than that for ethylene glycol-based ADFs, but occurs at a higher glycol concentration.

The main difference in capability among all of the different fluid types is the holdover time. Holdover time is the period of time when ice or snow is prevented from adhering to the surface of an aircraft (i.e., the amount of time between application and takeoff). Type I fluids have between a 6- and 15-minute holdover time in a light snow. Because of this brief time span, Type I fluids are used for deicing and for only short-term anti-icing protection. Although rarely used, Type II fluids provide approximately a 45-minute holdover time in a light snow. Type IV fluids can provide up to a 70-minute holdover time, depending on atmospheric conditions. Because anti-icing fluids are more expensive than deicing fluids, larger amounts of Type I fluids are commonly used to remove snow and ice and then much smaller amounts of anti-icing fluid are applied if necessary.

Most larger airlines use both Type I and Type IV fluids, while smaller commercial airlines may use both Type I and Type II fluids or no anti-icing fluids at all. Smaller airlines have been generally unable to afford the specialized equipment required to apply Type IV fluids, although some small airlines may be deiced by FBOs that use Type IV fluids. Also, some small airlines have recently purchased used Type IV application trucks from larger airlines who have upgraded to trucks that can apply both Type I and Type IV fluids. Airlines that can afford to invest in specialized equipment first evaluate if Type IV fluids are necessary at each of their stations by analyzing historical weather data, airline operations figures, airport infrastructure, and

airport congestion. For example, increased holdover times provided by Type IV fluids may not be necessary at small airports with short taxiing times and no congestion.

Although Type IV fluids are more effective at preventing ice formation than Type I fluids, they are not as effective at depressing the freezing point of water. Therefore, airports located in colder regions may use Type I fluids for both deicing and anti-icing.

4.2.1.3 Fluid Application

Deicing fluids are generally heated to 150° F to 180° F prior to application, while anti-icing fluids are typically applied at ambient temperatures. All fluid types are usually applied under pressure using a nozzle. The pressure of the liquid hitting the surface of the aircraft physically removes some of the snow and ice, while the high temperature and chemical properties of the fluid melts the remaining snow and ice. The solution that remains on the aircraft helps prevent further snow and ice build-up. Special nozzles are necessary to apply anti-icing fluids due to their high viscosity. When ambient temperatures are above 26° F, the FAA allows the use of hot water (heated to 140° F) to melt and remove snow and ice followed by application of anti-icing fluid. Most airlines do not currently use this method because it is considered to be too dangerous and could compromise passenger safety. A major concern with hot water deicing is flash freezing (i.e., freezing on contact with aircraft) and the potential to build thick layers of ice both on the aircraft and on the ground.

ADF is generally stored in either above-ground storage tanks, underground storage tanks, tank trucks, or mini-bulk (450-gallon) containers. Type I fluids are either diluted in mixing vessels, or mixed as they are pumped into deicing trucks or tank trucks using a proportioner. This device pumps both concentrated deicing fluid and water simultaneously at predetermined flow rates to achieve a desired solution concentration. If the fluid requires heating prior to application, it is heated in mixing vessels or in trucks.

ADF is typically applied using deicing trucks or fixed booms. Some deicer trucks contain multiple storage compartments to carry deicing fluids of varying strengths or types. Storage tanks may be equipped with thermal blankets to heat the fluids. Deicing trucks typically have a movable boom with a cherry picker equipped with a nozzle at the end of the boom. An operator in the cherry picker basket directs the high-pressure spray at aircraft surfaces, while a driver moves the truck. Specially designed deicing trucks may be used to deice areas of the aircraft that are low to the ground or hard to reach, such as landing gear.

Some airports are equipped with fixed-boom deicing equipment, which typically includes a permanently mounted boom with a nozzle, or a cherry picker with a nozzle, that moves along the boom. Pumps supply ADF from mixing tanks to the boom. Because fixed booms are less mobile than deicing trucks, deicing trucks may be needed to deice hard-to-reach areas not serviced by the booms.

Prior to application, many operators test their ADF to determine its glycol concentration. Densitometers and refractometers are two types of equipment often used to measure glycol concentrations in the field. After deicing operations are complete, some fluid may remain in deicing trucks and mixing vessels. This fluid is typically stored in the trucks or pumped into a storage tank until the next deicing event. The fluid (including Type I fluid diluted to application strength) may be stored at the end of the deicing season for use the following season.

Aircraft deicing and anti-icing operations usually occur at terminal gates, gate aprons, taxiways, or pads. Aircraft deicing/anti-icing pads may be located near terminals and gates, along taxiways serving departure runways, or near the departure end of runways. Each airport may use only one or a combination of all of these locations for deicing/anti-icing. The amount and type of deicing performed at each location may vary. For example, an airport with aircraft deicing/anti-icing pads may allow only minimal deicing (i.e., engines and wheel base) at gates, the minimum amount of deicing necessary to move the aircraft safely, and require all other deicing to be conducted at the pad.

If deicing is not conducted at the gate, then, prior to takeoff, an aircraft will taxi to airport-approved deicing/anti-icing locations. Depending on the deicing location design, several aircraft may be deiced simultaneously on a single deicing pad. Deicing trucks and/or fixed booms apply the appropriate ADF. From one to four deicer trucks may be used for deicing a single aircraft, depending on its size and weather conditions. Estimates based on EPA site visits to airports indicate that deicing application time may range from 5 to 20 minutes, while anti-icing application time ranges from 4 to 6 minutes. When holdover times are exceeded prior to takeoff, secondary deicing/anti-icing is necessary. Secondary deicing/anti-icing is typically conducted at a remote deicing/anti-icing pad adjacent to the runway, if available. However, many airports are not equipped with remote deicing/anti-icing pads, and aircraft must return to the gate or other designated deicing/anti-icing locations for secondary deicing/anti-icing, which can substantially delay their departure. The need for secondary deicing will likely decrease as more airlines use Type IV fluids to extend the allowable holdover time.

4.2.1.4 Variables That Affect Fluid Use

The variables that affect the volume of deicing fluid used and the time needed to deice aircraft include: ambient temperature; amount of snow and ice build-up on aircraft; aircraft type and size; type/severity of current precipitation; deicing fluid glycol concentration; aircraft surface temperature; relative humidity; solar radiation; wind velocity and direction; deicing procedure used; proximity to other aircraft, equipment, and buildings; aircraft component geometry and surface roughness; and the deicing personnel. Climatic- and weather-related influences are the predominant variables that affect fluid usage and are described in Section 5.0.

The FAA has issued regulations on when and how to conduct deicing/anti-icing operations to ensure safe air travel. They have also published advisories and guidance for designing aircraft deicing facilities and for conducting aircraft deicing/anti-icing under various weather conditions and aircraft types. However, the aircraft pilot is ultimately responsible for determining whether the deicing performed is adequate. The pilot may inspect the aircraft after deicing and order additional deicing or anti-icing.

EPA learned from data-collection efforts that one of the most significant operational factors affecting fluid usage is personnel. A large portion of aircraft deicing staff, particularly at larger airports, is newly hired and trained each year. High employee turnover results from low pay and poor work conditions (e.g., exposure to storm events and fluid). In addition, airlines at hub airports tend to use temporary employees for aircraft deicing. Although the cost of fluid can prevent wasting fluid, many of these new hires are initially taught that “a little is good, but more is better,” and spray more fluid than is necessary due to the potential liability associated with improperly deicing an aircraft. Although new hires receive eight hours of FAA-mandated training, industry sources tell EPA that three years of experience is required to become adept at aircraft deicing. Personnel turnover is generally much lower at smaller airports because aircraft deicing staff at these airports tend to have other responsibilities, such as baggage handling or maintenance. See Section 6.2.16 for additional information on personnel training and recent industry efforts to improve this factor.

4.2.1.5 Dry-Weather Deicing

Dry-weather deicing, also referred to as clear ice deicing, may be performed whenever ambient temperatures are cold enough to form ice on aircraft wings (below 55° F). Dry-weather deicing is also used to defrost windshields and wingtips on commuter planes and is usually conducted throughout the entire deicing/anti-icing season.

Airplane models MD-80s and DC-9s are more likely to require dry-weather deicing than other aircraft because their fuel tanks are located under their wings. The tanks may become super-cooled during flight, causing frost or ice to form on the wings when the aircraft lands. Generally, only a small volume of aircraft deicing fluid is needed to remove this ice, approximately 20 to 50 gallons per aircraft. Some airlines are attempting to eliminate the need for dry-weather deicing by retrofitting these aircraft with specially designed thermal blankets; however, these blankets have caused corrosion problems in electric systems.

4.2.1.6 Nonchemical Deicing Methods

Nonchemical deicing methods use mechanical or thermal means to remove ice and snow from aircraft. Dry, powdery snow can be swept from aircraft using brooms or brushes. Hot air blowers can also be used to remove snow mechanically with forced air and also to melt ice and snow. In addition, some smaller aircraft are equipped with inflatable pneumatic or hydraulic boots that can expand to break ice off of the leading edges of wings and elevators.

Mechanical snow removal methods (e.g., using nylon brooms and ropes to remove snow from parked aircraft) are typically only used in the early morning because they are time- and labor-intensive and would be too disruptive to airline schedules during the day. Mechanical methods are typically also used in conjunction with fluid application and are dependent on climate and operational variables. Personnel must be properly trained and provided with appropriate equipment so as not to damage navigational equipment mounted on aircraft. Airlines typically use brooms to remove as much snow and ice as possible before applying conventional aircraft deicing fluids.

Forced-air/hot-air deicing systems are currently in operation at a few U.S. airports and are being assessed by several airlines (see Section 6.2.3 for more detailed information). These systems use forced air to blow snow and ice from aircraft surfaces. Some systems allow deicing fluids to be added to the forced air stream at different flow settings (e.g., 9 and 20 gpm), while other systems require separate application of deicing fluid. Several vendors are currently developing self-contained, truck-mounted versions of these forced-air systems, and most systems can be retrofitted onto existing deicing trucks.

A similar method to truck-mounted forced-air systems is the double gantry forced-air spray system. The gantries support a set of high- and low-pressure nozzles, which blast the aircraft surfaces with heated air at 40 to 500 pounds per square inch. When weather conditions are severe, a small volume of water and glycol may be added to the air stream to remove dense

coverings of snow and ice. Use of the gantry system is limited because it is a permanently mounted system and has been known to cause bottlenecks and delay aircraft departure.

Another alternative to chemical deicing/anti-icing methods is infrared (IR) heating of aircraft. One IR system consists of an open-ended hangar-type structure with natural gas powered IR generators suspended from the ceiling. The IR wavelengths are targeted to heat ice and snow, and minimize heating of aircraft components. The IR energy and wavelength may be adjusted to suit the type of aircraft. Although the system can deice an aircraft, it cannot provide aircraft with anti-icing protection. Consequently, when the ambient temperature is below freezing, anti-icing fluid is typically applied to the aircraft after it leaves the hangar. Testing is being planned to determine if it is possible that melted snow and ice can refreeze prior to Type IV application following IR deicing. Since the aircraft surfaces are dry, the volume of anti-icing fluid required is less than for typical anti-icing operations. In addition, a small amount of deicing fluid may be required for deicing areas of the aircraft not reached by the IR radiation, such as the flap tracks and elevators. The system, therefore, does not completely replace glycol-based fluids, but greatly reduces the volume required. See Section 6.2.5 for additional information on IR deicing.

4.2.2 Pavement Deicing/Anti-icing

Pavement deicing/anti-icing removes or prevents the accumulation of frost, snow, or ice on runways, taxiways, aprons, gates, and ramps. A combination of mechanical methods and chemical deicing/anti-icing agents are used for pavement deicing at airports. Runway deicing/anti-icing is typically performed by the airport's operating authority or a contractor hired by the authority. Some ramp, apron, gate, and taxiway deicing/anti-icing may be performed by other entities, such as airlines and FBOs that operate on those areas. Pavement deicing typically occurs during the same season as aircraft deicing, but may be shorter than the aircraft deicing season.

4.2.2.1 Mechanical Methods

Mechanical methods, such as plows, brushes, blowers, and shovels for snow removal, are the most common form of runway deicing, and may be used in combination with chemical methods. Airports generally own multiple pieces of snow removal equipment and have employees trained to operate them. Because winter storm events can be unpredictable, personnel trained in pavement deicing/anti-icing may be available at an airport 24 hours a day during the winter season.

4.2.2.2 Chemical Methods

Because ice, sleet, and snow may be difficult to remove by mechanical methods alone, most airports use a combination of mechanical methods and chemical deicing agents. Common pavement deicing and anti-icing agents include ethylene glycol, propylene glycol, urea, an ethylene glycol-based fluid known as UCAR (containing approximately 50% ethylene glycol, 25% urea, and 25% water by weight), potassium acetate, sodium acetate, sodium formate, and calcium magnesium acetate (CMA). Sand may be used to increase the friction of icy paved areas, but it may be detrimental to the mechanical workings of aircraft. Salt (i.e., sodium chloride or potassium chloride) may be used to deice/anti-ice paved areas that are not used by aircraft (e.g., automobile roadways and parking areas) but are not considered suitable for deicing/anti-icing taxiways, runways, aprons, and ramps because of their corrosive effects. Potassium acetate has also been reported as potentially degrading insulation in electrical systems (e.g., runway lights). An industry workgroup is currently investigating this issue.

Many airports perform deicing of heavy accumulations of snow and ice using mechanical equipment followed by chemical applications. Pavement anti-icing may be performed based on predicted weather conditions and pavement temperature. Deicing and anti-icing solutions are applied using either truck-mounted spray equipment or manual methods. Section 6.5 further discusses pavement deicing/anti-icing operations.

4.3 Airports with Deicing/Anti-Icing Operations

The number of airports performing deicing/anti-icing operations in the U.S. is unknown. In addition, the amount of deicing/anti-icing fluids or agents used varies greatly among airports, as does the amount of wastewater generated. Factors affecting the amount of deicing/anti-icing fluids used and the volume of wastewater generated include airport size, airport location and weather, and airlines using the airport. These and other industry characteristics are described in the following subsections.

4.3.1 Number of Airports Performing Aircraft and Runway Deicing

EPA is not aware of any sources estimating the number of airports performing aircraft and pavement deicing operations. EPA also recognizes that not all airports that perform deicing/anti-icing operations contribute significant pollutant loadings to the environment from these activities. For example, a large airport in Florida may deice aircraft only approximately 10 days per year for defrosting purposes. These operations are not likely to significantly impact the surrounding environment (or publicly owned treatment works (POTW)) because only a small amount, if any, of spent deicing fluid enters the environment, and pollutant loadings from these airports would be negligible. Therefore, for purposes of this study, EPA focused on airports that potentially perform significant deicing/anti-icing operations.

4.3.1.1 Number of Airports Potentially Performing Significant Deicing/Anti-Icing Operations

EPA determined potentially significant deicing/anti-icing operations based on airport size and weather. In general, deicing/anti-icing operations include aircraft deicing, which is typically performed by airlines or a FBO, and pavement deicing, which is typically performed by airports. EPA received aircraft operations and total enplanement data from the FAA for over 400 airports, and used aircraft operations data as a measure of airport size for the following reasons. First, aircraft deicing is performed on a per-aircraft basis, which is more closely related to airport

operations than enplanements. Second, the volume of aircraft deicing fluid (ADF) required for deicing is not impacted by whether or not the aircraft is fully loaded with passengers. For the purposes of this study, EPA selected a benchmark of 10,000 operations per year (excluding general aviation) to represent significant operations; therefore, the Agency excluded airports with less than 10,000 annual operations from further analyses. EPA did not include general aviation in its operation measurement because EPA believes that most general aviation aircraft do not operate during deicing conditions.

EPA also used weather information to identify airports that are likely to perform potentially significant deicing/anti-icing operations. For the purposes of this study, EPA determined that mean annual snowfall (including ice pellets and sleet) of less than 1 inch would not result in significant deicing operations; therefore, EPA excluded airports in regions with annual snowfall less than 1 inch from further analyses.

As a result, EPA focused on wastewater generated and the impact associated with deicing events at airports with annual operations greater than 10,000 (excluding general aviation) and an average of 1 inch or greater of snowfall per year. Figure 4-1, located at the end of this section, shows a geographic representation of the estimated 212 airports that meet these criteria. As expected, these airports are highly concentrated in the eastern part of the U.S. where the population is more dense. Few airports are located in the far South, where there is little or no snowfall. EPA is aware that other airports (e.g., private, military, or non-FAA-towered) may exist that meet the criteria defined above; however, EPA was limited by the data provided by the FAA.

4.3.1.2 Other Estimates of Number of Airports

In a survey of the top 125 busiest airports in the U.S. (including territories) conducted by the National Resources Defense Council (NRDC) in 1996, 61 airports supplied data concerning deicing activities at the airport. Out of the 61 airports that responded, 51 answered that they perform deicing, eight answered that they do not perform deicing, and two answered

that they only rarely deice (6). The eight airports that do not deice are located outside the continental U.S. (e.g., Puerto Rico, Virgin Islands), or are located in very warm climates (e.g., Fort Lauderdale, FL, Phoenix, AZ). Both Los Angeles International and San Francisco International responded that they did not deice in the timeframe for which data were requested, which suggests that there are several airports along the coast of California which may perform no deicing. Overall, the majority of large airports do deice (6).

Air Transport Association members have indicated that the deicing industry primarily comprises 40 airports and 25 airlines, while American Association of Airport Executives (AAAE) members have stated that approximately 90% of deicing operations are performed at 10% of airports (11). AAAE distributed a questionnaire in 1993 to 340 airports to collect information about deicer usage and aircraft operations. Of the 59 airports that responded to the questionnaire, approximately one-half reported using glycol-based ADFs (11).

EPA did not use the results of the NRDC study to estimate the total number of airports that perform deicing operations because the survey was limited only to the 125 busiest airports, which does not cover all airports that EPA believes perform significant deicing operations. Similarly, EPA did not rely on ATA and AAAE members' assessments of the number of airports performing significant deicing/anti-icing operations because they are not based on statistically valid surveys.

4.3.2 Annual ADF and Pavement Deicer Usage

The volumes of aircraft and pavement deicing/anti-icing fluids or agents used has varied greatly over the past decade. EPA has identified several sources that estimate the amount of aircraft and/or pavement deicer usage. EPA did not consider any one source as correct or absolute. The data presented in this section are informative only and are not necessarily directly comparable. In general, the data show that deicer usage has increased, probably due to the combination of the following factors: 1) deicer usage is highly dependent on weather conditions, which can vary greatly from year to year; 2) deicer users report volumes in different fluid

concentrations, which are sometimes incorrectly compared to one another; 3) an airline crash in 1992 heightened awareness of the potential danger associated with ice, which resulted in increased fluid usages for the next several years; and 4) increased usage of anti-icing (i.e., Type II and IV) fluids may have decreased the volume of deicing (i.e., Type I) fluids required.

1992 FAA Survey

In 1992, the FAA conducted a survey of airport deicing/anti-icing operations at U.S. airports to address operational practices and storm water controls at that time. Results of the survey were used to assist airports in complying with the EPA's recently promulgated storm water program (see Section 12.1). Ninety-six airports, representing a wide range of airport sizes and locations, responded to the questionnaire. However, several major airports did not submit a questionnaire and several respondents did not fully answer all questions. Therefore, the data collected from the survey should be considered anecdotal information and not a statistical representation of the industry at that time.

According to the FAA survey, the predominate aircraft ADF used at that time was ethylene glycol; only 24 airports reported using any propylene glycol. Only four airports in the survey reported using anti-icing fluids (Type II) (12).

According to the FAA survey, most airports used urea and/or ethylene glycol for pavement deicing. For airports that reported using ethylene glycol for pavement deicing/anti-icing, volumes ranged from 200 gallons to 187,000 gallons per airport. Twenty-nine airports combined reported using over a total of 800,000 gallons of ethylene glycol as a pavement deicer between 1989 and 1991. For airports that reported the use of urea as a pavement deicer, volumes ranged from 100 pounds to 715 tons per airport. Twenty-seven airports reported a combined total use of over 4,000 tons of urea as a pavement deicer between 1989 and 1991. One airport reported using calcium magnesium acetate (CMA) and another reported using potassium acetate. Several airports noted using UCAR, a pre-mixed solution of ethylene glycol, urea, and water. Propylene glycol was allowed as a runway deicer subsequent to the FAA survey (12).

According to the FAA survey, the average annual volume of ethylene glycol used for aircraft deicing by all respondents between 1989 and 1991 was approximately 2.16 million gallons. Individual airports reported ethylene glycol use for aircraft deicing ranging from 0.6 to 520,000 gallons per year. As expected, the largest volumes were generally associated with the FAA large hubs. For the same time period, only 650,000 gallons of propylene glycol were used with individual airports reporting propylene glycol use ranging from 75 gallons to 250,000 gallons per year. Only a few airports reported using Type II fluids, from 300 to 10,000 gallons per year (12).

1993 AAAE Survey

According the AAAE survey discussed above, most deicer usage reported involved glycol-based ADFs. ADF usage for the 59 airports that responded to the survey ranged from 0 to 1,200,000 gallons per year (Note: AAAE's report did not specify the basis year for glycol usage data). The median glycol usage was 3,650 gallons per year, and the mean was 44,600 gallons per year. AAAE found that seven airports (12% of the respondents) used more than 50,000 gallons of glycol per year; these respondents accounted for 85% of the total glycol used by all respondents. AAAE also found that 44 airports (75% of the respondents) used less than 20,000 gallons of glycol per year; these respondents accounted for only 6% of the total glycol used by all respondents (11).

Other Non-EPA Estimates

Researchers estimate that at least 11 million gallons of concentrated ADF were used at the 20 largest airports in North America during the winter of 1992-1993 (8). Environment Canada has estimated that an average of 14 million gallons of concentrated ADF are used in North America in a typical year (13).

1992 EPA Screener Questionnaire

Based on an analysis of results from EPA's screener questionnaire (see Section 3.1), the Agency estimates that 5.3 million gallons of ADF were used in 1992. Note that the screener questionnaire did not specify whether the reported volume is as concentrated or applied volumes; therefore, these data likely represent multiple dilutions. ADF volumes ranged from 1 gallon per year to 672,393 gallons per year per facility (note that multiple "facilities" (i.e., airlines and FBOs) may operate at a given airport). Ethylene glycol, urea, and sand were the most common pavement deicing agents in 1992. The estimated total volume of liquid pavement deicers used in 1992 was 12,300 gallons, with volumes ranging from 10 to 5,500 gallons per facility. The estimated total volume of solid pavement deicers used in 1992 was 950,000 pounds, with amounts ranging from 20 to 234,544 pounds per facility. Other pavement deicers reported as being used in 1992 include propylene glycol, potassium acetate, CMA, and sodium formate (14).

Post-1993 EPA Deicing Study Data-Collection Activities

EPA used data collected from site visits and mini-questionnaires to estimate ADF usage. The following table summarizes the range of ADF volumes used by fluid type for these airports. Note that there are wide ranges due to differences in climate and severity of weather conditions in the years for which data were requested.

Fluid Type	Range of Volumes Used Per Airport (Gallons/Year)
Type I ethylene glycol-based	3,500 - 700,000(a)
Type II/IV ethylene glycol-based	600 - 180,000
Type I propylene glycol-based	257 - 833,000(a)
Type II/IV propylene glycol-based	2,500 - 143,000

Source: Reference (14).

(a) These volumes are expressed as "concentrated" volumes (i.e., they do not account for water addition).

In general, most U.S. airports reported that both ethylene glycol- and propylene glycol-based fluids are used at their airport; however, several airports reported that only

propylene glycol-based fluids are used. The range of applied ADF volumes (after accounting for dilution of Type I fluids) per airport is 514 to 2,134,000 gallons per year (15).

EPA estimates a current annual national ADF applied usage volume of 35 million gallons at 212 facilities based on information collected from EPA's 1999 mini-questionnaires (see Section 3.2) and site visits conducted between 1997 and 1999 (see Section 3.3) and the extrapolation methodology described in Section 11.0. Note that as discussed in Section 11.0, not all ADF applied is discharged.

According to EPA site visits and the mini-questionnaire, the most common pavement deicer is potassium acetate, although several facilities still use urea. Most airports also use sand to help increase friction between aircraft and pavement surfaces. Several airports noted that they recently discontinued the use of urea and/or ethylene glycol due to environmental concerns, such as high biochemical oxygen demand (BOD).

4.4 References

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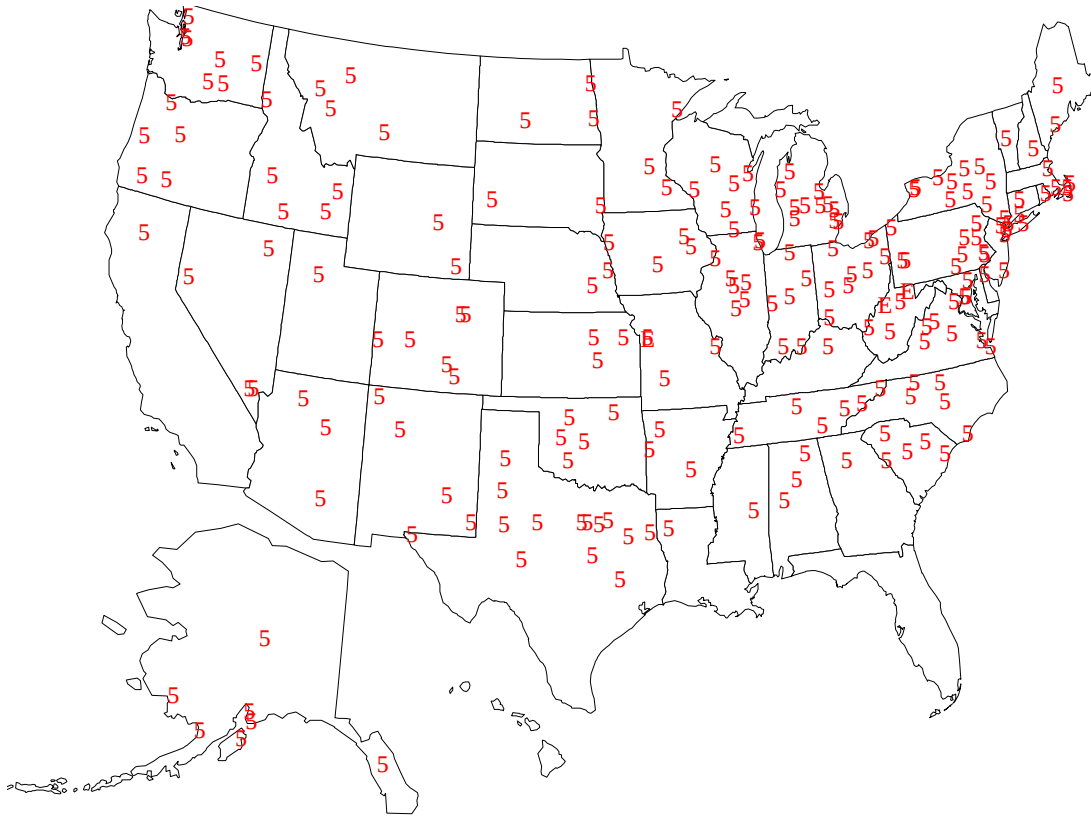


Figure 4-1

**Geographic Distribution of Airports with Annual Operations Greater than 10,000 and
Mean Annual Snowfall Greater than 1 Inch**

5.0 CLIMATIC INFLUENCES AND DEICING/ANTI-ICING AGENT-CONTAMINATED STORM WATER GENERATION AND DISCHARGE

This section discusses the impact that climatic factors such as temperature, precipitation, and humidity (i.e., atmospheric moisture) have on deicing/anti-icing agent usage, which subsequently impacts the amount of contaminated storm water generated and pollutant concentrations discharged. Section 5.1 discusses various types of climatic conditions that result in the need for airport deicing operations. Section 5.2 discusses methods to measure these conditions, and examines each method as a possible indicator of the amount of deicing/anti-icing agents used. Section 5.3 describes EPA's estimate of the total deicing/anti-icing agent-contaminated storm water volume generated, and Section 5.4 discusses discharge of contaminated storm water. Appendix A contains information regarding the location of airports referenced in this section.

5.1 How Climatic Conditions Affect Deicing/Anti-icing Chemical Usage

Most airport deicing/anti-icing operations typically occur due to low temperatures and/or precipitation. Without these environmental factors, significant airport deicing/anti-icing operations would probably not exist. Airports generally use significant volumes of deicing/anti-icing agents because of some form of precipitation (i.e., storm event). While it is true that several airports use deicing/anti-icing agents when there is no precipitation, the volumes of agents used under these conditions are typically very small compared to the volumes used during storm events. In most cases, deicing/anti-icing agents used during nonstorm (i.e., dry-weather deicing) events are retained on or evaporate from the pavement, and do not enter an airport's storm water collection system. Because fluid used during dry-weather deicing is relatively small compared to that during storm events and does not generally generate contaminated storm water, EPA believes the vast majority of contaminated storm water is generated during precipitation events.

Precipitation includes snowfall, rainfall, sleet (including freezing rain), and ice. Each of these conditions affect the volume and type of deicing/anti-icing agents required to

adequately prevent ice from forming on aircraft and pavement surfaces. Although there are no specific guidelines for the volume of deicing/anti-icing agents required based on precipitation type, deicing/anti-icing agents are generally used in greatest quantities when the ambient temperature is near or below freezing and there is heavy (or wet) accumulating snow or ice falling or forming on surfaces. In contrast, relatively small volumes of deicing/anti-icing agents are required for dry, powdery snow conditions, which can be removed easily using mostly mechanical methods.

Rain at or near freezing temperatures may also require significant deicing/anti-icing agent usage as a precaution because a slight temperature decrease would result in significant ice or snow formation. Unlike snow, ice strongly adheres to aircraft and pavement surfaces, making it more difficult to remove. Freezing rain is said to require the most deicing/anti-icing agent usage because the rain freezes on contact with the aircraft or pavement surface and coats to form a solid layer of ice.

5.2 Correlating Climatic Conditions to Deicing/Anti-icing Agent Usage

When considering the impact of climatic conditions on deicing operations, EPA evaluated the following four different climatic measures: 1) mean annual snowfall, 2) snowfall duration, 3) mean annual days below freezing, and 4) heating degree days. Each of these measures is described in more detail below, including the advantages and disadvantages of correlating each measure to deicing/anti-icing agent usage.

5.2.1 Mean Annual Snowfall

Mean annual snowfall can be measured in terms of depth of snow or liquid equivalence of snowfall. Depth of snow is a measure of the snow height relative to a ground point that is considered zero depth; it is commonly measured by the National Oceanic and Atmospheric Administration (NOAA) in inches. Liquid equivalence measures snow density and can be used to compare snowfall density in two different regions. Liquid equivalence converts

the depth of snowfall in a given region to a liquid volume. For example, if Denver received 12 inches of snow and New York received 4 inches of snow, the amount of snowfall, in terms of liquid equivalence, may be the same if the snowfall in New York were significantly “wetter.”

Mean annual snowfall is a good measure of the intensity of precipitation over a deicing season; however, it does not differentiate between an area with 10 5-inch storms and an area with two 25-inch storms. Although both areas have a total of 50 inches of snow per year, the deicing/anti-icing chemical usage at airports in these areas would differ greatly (assuming all other operational factors are equivalent).

EPA believes that mean annual snowfall, in terms of snowfall depth, is the best measure to use when correlating deicing/anti-icing agent usage to weather because these data are readily available for most airports and measure the total amount of precipitation received over a deicing season. Appendix B contains mean annual snowfall data for select U.S. cities and Appendix C contains a contour map of the U.S. in terms of snowfall depth. EPA is aware that there are several other site-specific factors, such as the type of precipitation (e.g., freezing rain versus dry snow), number of operations, aircraft size, and applicator training, that dictate the amount of deicing fluid used.

5.2.2 Snowfall Duration

Duration of snowfall is another potential measure of deicing/anti-icing agent usage. This measure records the time duration of snowfall and may indicate the amount of time for which deicing/anti-icing agents are applied; however, it does not measure snowfall intensity. Atlases typically include snowfall durations.

5.2.3 Mean Annual Days Below Freezing

Another potential measure of deicing/anti-icing agent usage is the mean number of days in a year during which the temperature falls below 32° F. While this measure is a good indicator of how cold the ambient temperature is and the potential for deicing, it does not actually measure precipitation. Therefore, an airport may be in a very cold location with a high number of days below 32° F, but may be in a dry climate and experience very little precipitation. This airport would probably use less deicing/anti-icing agents compared to another airport in a warmer location (on average) with more snow or ice.

5.2.4 Heating Degree Days

The final measure considered by EPA is number of heating degree days per year (an engineering index of heating fuel requirements), calculated by finding a daily mean temperature (calculated from the maximum and minimum temperatures recorded for the day), and subtracting it from 65° F. For example, if the mean temperature for a given day is 40° F, then there are 25 heating degree days associated with that calendar day. If the daily mean temperature is 65° F or greater, then there are zero heating degree days. These data are kept by the National Weather Service, a division of NOAA. However, heating degree days are a measure of temperature, not precipitation, and therefore, may not correlate to deicing/anti-icing agent usage. According to a NOAA representative, the colder the temperature, the less precipitation is likely to occur, such as in Northern Canada, which receives little snowfall even though it is extremely cold (1). Thus, deicing/anti-icing agent usage would be less in very cold, dry areas than in cold, moist areas.

5.3 Volume of Contaminated Storm Water Generated

EPA is not aware of any estimates of the annual volume of storm water contaminated with deicing chemicals that is generated by airports. In fact, the amount of storm water generated by deicing/anti-icing operations can be highly variable from year to year and is

difficult to quantify because it is very site- and storm-specific. The volume of storm water generated from deicing operations is a function of precipitation, deicing/anti-icing agent usage, and airport wastewater containment and collection techniques. Even during particular precipitation events, many airports do not know how much deicing/anti-icing agent-contaminated storm water is generated because they are not able to contain all of it. For these airports, contaminated storm water either runs off to grassy areas where it is retained or percolates into the ground. EPA is aware that, to make a more accurate conclusion regarding total storm water generation, more site-specific information including the size and runoff coefficient(s) of the drainage areas and storm water drainage and control structures would be required.

EPA also recognizes that site-specific airport deicing/anti-icing procedures will affect the volume of contaminated wastewater generated. If an airport performs deicing/anti-icing operations only in designated areas, lesser volumes of contaminated wastewater will be generated than at an airport that does not limit deicing/anti-icing operations to a designated area (all other factors being equal). Specifically, the unconstrained airport would generate a greater volume of contaminated wastewater with lower pollutant concentrations. Therefore, EPA recognizes that each airport generates a unique volume of contaminated wastewater.

Other storm water discharges associated with industrial activities at airports include discharges from aircraft fueling, cleaning, and maintenance areas, car rental services, and washing areas. The volume of storm water generated from these other sources is site-specific and may not be commingled with deicing/anti-icing contaminated storm water. For the purposes of this study, EPA did not specifically consider storm water other than that from aircraft and airfield pavement deicing areas.

EPA obtained estimates of collected contaminated wastewater volumes from airports that the Agency visited. Albany International Airport collects between 15 and 25 million gallons of contaminated wastewater per year. Bradley International Airport collected 350,000 gallons of contaminated wastewater in January 1999. Minneapolis-St. Paul International Airport collects approximately 9 million gallons of contaminated wastewater per year.

While EPA recognizes that the volume of contaminated wastewater is unique to each airport and deicing season, estimating a general range of volume of deicing/anti-icing agent-contaminated wastewater generated in the U.S. is important to evaluating past, present, and future pollutant concentrations discharged from deicing/anti-icing operations. For the purposes of this study, EPA estimated the volume of contaminated wastewater using the estimated aircraft deicing/anti-icing fluid (ADF) usage volume (provided in Section 11.1) and the range of glycol concentrations (i.e., ethylene glycol and propylene glycol) in contaminated storm water. Using sampling data provided by the industry and from EPA's data-collection efforts, EPA determined that a nondetect glycol concentration is a reasonable lower bound of expected glycol concentrations. Because airports use different analytical methods with different analytical detection limits, EPA used a common detection limit of 10 mg/L. For the upper bound, EPA used the highest detected glycol concentration from the sampling data, 47,000 mg/L (2). Using this range of glycol concentrations and EPA's estimate of the total annual volume of ADF applied (based on EPA's estimate of the 212 airports with potentially significant deicing operations), EPA estimates that the annual volume of ADF-contaminated storm water generated in any specific year ranges between 300 million and 1.4 trillion gallons per year. Based on a visual inspection of the arrayed sampling data, EPA believes that an average of approximately 7 billion gallons of contaminated storm water is generated per year. (See Section 11.1 for a discussion of pollutant loadings discharged to surface waters.)

5.4 Method of Contaminated Storm Water Discharge

Based on EPA's data-collection activities for this study, airports discharge storm water contaminated with deicing agents either directly to surface waters or both directly to surface waters and indirectly to a POTW. Specifically, EPA identified 11 airports that hold both direct and indirect discharge permits versus 13 airports that hold only direct discharge permits (3). In addition, one airport did not hold a discharge permit (the airport uses evaporation), and one airport holds only an indirect discharge permit. Section 13.2 describes permit conditions.

The choice of utilizing direct, indirect, or a combination of wastewater discharge results largely from airport infrastructure; the choice of best management practices employed at the airport; the stringency of the state NPDES permit; and whether the POTW will accept wastewater from airport deicing operations. Although the discharge of wastewater generated from deicing/anti-icing activities is typically the responsibility of the airport where these activities take place, there are often several other entities involved (e.g., airlines, fixed-based operators (FBOs)). In some cases, airlines and/or FBOs are co-permittees on airport discharge permits. For example, Des Moines International Airport has an NPDES permit with co-permittees. The City of Des Moines is the owner and operator of the airport and acts as the airport's representative and coordinates co-permittee efforts to achieve permit compliance. The co-permittees are tenants of the airport facility, including airline companies, FBOs, military or other government establishments, and other parties that have contracts with the airport authority to conduct business operations on airport property that result in storm water discharges associated with industrial activities (including deicing areas).

5.5 **References**

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6.0 POLLUTION PREVENTION

EPA's storm water program combined with local environmental issues such as fish kills and odor problems have prompted airports and airlines to investigate a wide range of pollution prevention practices designed to eliminate or minimize the environmental impact of aircraft deicing/anti-icing fluids (ADFs) and airfield pavement deicing/anti-icing chemicals without compromising safety. This section summarizes the pollution prevention practices used by U.S. airports, military bases, and foreign commercial airports, and provides information about pollution prevention methods and technologies currently under development. Practice- or technology-specific costs are provided where available. Additional cost information provided by technology vendors and airports is included in Section 11.2

To date, there are four basic approaches to pollution prevention for aircraft deicing/anti-icing operations: (1) elimination of glycol-based fluids through the development of an environmentally benign alternative fluid; (2) minimization of the volume of fluid applied to aircraft through the development of better fluids, improved application methods, and innovative aircraft deicing technologies; (3) development of collection and disposal strategies that prevent the release of ADF-contaminated wastewater to the environment; and (4) development of glycol recycling methods. Approaches to pollution prevention for airfield pavement deicing/anti-icing operations include: (1) adoption of alternative pavement deicing/anti-icing chemicals that are less harmful to the environment; (2) reduction or elimination of pavement deicing/anti-icing chemicals through the implementation of alternative deicing/anti-icing technologies; and (3) minimization of the amount of agents applied through the use of good maintenance practices, preventive anti-icing techniques, and runway condition monitoring systems. Although each approach is discussed separately, a combination of pollution prevention practices are typically used at U.S. airports. The pollution prevention practices selected by an airport or airline for use at a particular airport often depend on a variety of airport-specific factors, including climate; total amount of chemical deicing and anti-icing agents applied; number of airlines; aircraft fleet mix; number of aircraft operations; costs; presence of existing infrastructure; availability of land; and impact on aircraft

departures. EPA recognizes that some of the pollution prevention practices discussed in this section may not be practical or economically feasible for all U.S. airports.

Section 6.1 discusses alternative aircraft deicing/anti-icing agents, and section 6.2 describes aircraft deicing fluid minimization methods. Section 6.3 presents aircraft deicer/anti-icer collection and containment methods. Section 6.4 discusses glycol recycling and Section 6.5 presents pollution prevention practices for airfield parent deicing/anti-icing operations. Appendix A contains information regarding the location of airports referenced in this section.

6.1 Alternative Aircraft Deicing/Anti-Icing Agents

One plausible solution to the environmental problems associated with glycol-based ADFs is their replacement with more environmentally benign products. Despite considerable interest in developing substitute ADFs, little progress has been made. Most of the current research is thought to be in a preliminary stage and it will likely be some time before a suitable replacement is found. Substitute products need to be biodegradable and less toxic than current products, but must also contain compounds that are noncorrosive to aircraft parts. To be economically viable, substitute chemicals must be inexpensive and at least as effective in maintaining air safety as the glycol-based fluids they replace.

The National Aeronautics and Space Administration's Ames Laboratory in California is attempting to develop effective, non-glycol-based aircraft deicing and anti-icing agents (1). The current status of the project is unknown, but the research is believed to be progressing slowly.

The U.S. Air Force has also expressed interest in finding an environmentally benign substitute for glycol-based ADFs (2). The Air Force Office of Scientific Research is currently funding a number of research projects designed to discover a nontoxic, biodegradable ADF. Many of these projects focus on discovering how naturally occurring antifreeze molecules inhibit ice crystal growth. For example, Professor John Duman at the University of Notre Dame

is exploring the structure of antifreeze molecules found in overwintering larvae of the beetle *Dendroides canadensis* to determine how these molecules inhibit ice crystal growth. A similar project directed by Professor Chi-Hing Cheng-DeVries of the University of Illinois is investigating antifreeze molecules found in polar fish. The goal of these projects is to synthesize a naturally occurring compound that can be formulated into an effective, nontoxic, anti-icing agent.

6.2 Aircraft Deicing Fluid Minimization Methods

Since it is unlikely that any new products will be available in the near future, the U.S. Air Force and some domestic carriers have been investigating ways to reduce the volume of ADF used, without compromising safety. The ADF minimization methods described in this section enable pollution to be reduced through source reduction.

6.2.1 Type IV Anti-icing Fluids

Aircraft anti-icing fluids are designed to adhere to aircraft surfaces and prevent ice and snow build-up for set periods of time, known as holdover times. Currently, two types of aircraft anti-icing fluids are used in the United States, Type II and Type IV fluids. Although Type I fluids can provide limited anti-icing protection, they are primarily used for deicing aircraft, are generally applied in much larger volumes, and typically provide less than 15 minutes holdover time. Type II and Type IV fluids are similar to Type I fluids, but contain thickening agents, usually polymers, that provide improved anti-icing properties. The viscosity of anti-icer fluids decreases with wind shear, which enables the fluids to be shed from aircraft surfaces during takeoff. Type IV fluids represent the most recent advances in aircraft anti-icing agents and provide longer holdover times than Type II fluids. Although holdover times vary with weather conditions, the typical holdover time for a Type II fluid is approximately 45 minutes in a light snow. Type IV fluids, however, may provide protection for as long as 70 minutes under the same weather conditions (3). Due to their improved anti-icing capabilities, Type IV fluids have been credited with reducing the amount of deicing fluid used by eliminating repeated deicing and anti-

icing of aircraft prior to takeoff (4). Most of the larger U.S. carriers now use Type IV fluids exclusively for anti-icing.

One potential disadvantage of using Type IV fluids is the possibility for increased airfield contamination. Because Type IV fluids adhere to aircraft surfaces, greater use of Type IV fluids may increase the volume of fluid deposited on runways and adjacent grassy areas. Since runways rarely have contaminated storm water collection systems, anti-icing fluids shed from aircraft during takeoff enter the environment and may contaminate soils, groundwater, and nearby streams. Although some components of anti-icing fluids, such as glycols, are easily degraded by microorganisms present in soils, other components, such as tolyltriazoles, are believed to persist in the environment (see Section 10.1.2).

6.2.2 Preventive Anti-icing

Preventive anti-icing is the application of glycol-based anti-icing fluid prior to the start of icing conditions or a storm event to limit ice and snow build-up and facilitate its removal. The principal advantage of this method is an overall reduction in the volume of glycol-based fluids applied to aircraft. Anti-icing fluids are applied in much smaller volumes than their deicing Type I counterparts. A Boeing 727, for example, can be anti-iced using approximately 35 gallons of fluid, whereas deicing requires at least 150 gallons of Type I fluid and may be as much as 2,000 gallons during a severe storm event. To be effective as a preventative, anti-icing fluids must be applied to aircraft prior to the advent of icing conditions or a storm event.

The U.S. Air Force has also experimented with preventive anti-icing techniques and has concluded they can be effective in reducing the volume of fluid applied to aircraft, provided operations personnel carefully coordinate their activities with local weather reports (2). The U.S. Air Force has not implemented widespread use of preventive anti-icing practices due to concerns that anti-icing fluids may degrade aircraft parts, particularly those made from composite materials, when the fluids are left on for extended periods (5).

One drawback to preventive anti-icing is the problem of obtaining accurate weather forecasts containing enough information for operations personnel to make informed decisions. Inaccurate forecasts may result in unnecessary anti-icing. Operations personnel typically rely on local weather stations to provide accurate and timely weather forecasts; however, several U.S. airlines have established meteorological groups, which provide weather forecasts for major destinations. The National Center for Atmospheric Research in Boulder, Colorado, has developed a new weather forecasting system specifically designed for use at airports that provides snowfall forecasts thirty minutes in advance of precipitation. The system is known as Weather Support to Deicing Decision Making (WSDDM) and its development was funded by the Federal Aviation Administration (FAA) (6). Forecasts are based on information collected from surface weather stations, snow-weighing gauges, and Doppler radars located at or near the airport. The information is processed by computers and displayed graphically on video monitors at the airport. During the 1997-1998 winter season, the system was tested by Delta and U.S. Airways at La Guardia airport in New York and by United and American at O'Hare airport in Chicago. In July 1998, the WSDDM system became available commercially from ARINC, a company specializing in aviation communication and air traffic management systems. The system costs approximately \$100,000 to install. It is currently in operation at La Guardia airport, where it is used by Delta for managing aircraft deicing/anti-icing and by the New York Port Authority for managing airfield snow removal. Airlines hope this system will provide sufficient storm warning information to perform preventive anti-icing of aircraft prior to the arrival of a storm, enabling airlines to continue to operate safely with less deicing fluid.

Anti-icing fluids are sometimes applied to aircraft to provide overnight protection from frost and storm events. This practice is purported to greatly reduce the volume of Type I fluid needed to remove ice and snow from aircraft surfaces the following morning. For example, a fixed-base operator at one airport reported applying Type IV fluid for overnight protection to one of two aircraft parked side by side. A major snow storm occurred during the night and both aircraft were deiced the next morning using Type I fluid. The aircraft treated with Type IV fluid required 860 gallons of Type I fluid to deice, while the untreated aircraft required 1,820 gallons

(7). Several airlines, however, have expressed concern that anti-icing fluids may dry out and damage aircraft if left on for extended periods (8).

Several U.S. airlines (United, Delta, American, and Midwest Express) have experimented with anti-icing aircraft immediately after landing (1). The intent is to prevent ice and snow build-up while the aircraft is at the gate, and consequently reduce the amount of deicing and anti-icing required before departure. For aircraft with short turn-around times, the protection afforded by preventive anti-icing may even eliminate the need for further deicing prior to departure. Study results indicate this practice saves time and reduces the amount of Type I fluid used during a storm event (1).

6.2.3 Forced-Air Aircraft Deicing Systems

Forced-air aircraft deicing systems have been available for many years, but have not seen widespread application in the United States primarily due to their high cost over conventional deicing systems. The first systems used a high-pressure air jet to blast ice and snow from aircraft surfaces, which has proven to be very effective for removing dry, powdery snow from cold, dry aircraft surfaces. All Nippon Airways, for example, has used forced-air systems for over 20 years to remove overnight accumulations of snow at several northern airports in Japan and believe it removes dry snow faster than using deicing fluids. All Nippon Airways personnel can reportedly remove 5 cm of snow from a passenger jet in about 15 minutes using a forced-air deicing system.

In the past, U.S. carriers were less enthusiastic about forced-air systems because they were not very effective for removing ice and wet snow; conditions that are typical for most U.S. airports. In recent years, however, the development of new hybrid systems, which combine forced-air with fine sprays of heated Type I fluids, have rekindled interest in this technology.

In the early 1990s, FMC Corporation (formerly Aviation Environmental Compliance Inc.) developed a forced-air aircraft deicing system designed to remove snow and ice

from aircraft surfaces using a high-pressure air stream combined with a fine spray of glycol-based aircraft deicing fluid. The system is known as the AirFirst Deicing System™ and can be used in an air-only mode for removing light snow and ice. The system consists of a self-contained, truck-mounted unit fitted with a turbine engine and a dual source nozzle. The dual source nozzle allows deicing fluid to be added to the air stream to help remove ice and protect against freezing precipitation (2, 5).

Today, forced-air aircraft deicing systems are also manufactured by Premier, Global, and Vestergaard and are similar to the FMC AirFirst Deicing System™. The Premier system, known as the Hybrid Deicing System™ (HDS), was developed in collaboration with Allied Signal and consists of a centrifugal compressor, an ADF storage tank with heater, a high-pressure fluid pump, and a coaxial nozzle. The coaxial nozzle is designed to emit a high-velocity stream of heated ADF surrounded by a high-velocity air jet. The compressed air exits the nozzle at approximately 750 miles per hour. ADF can be applied at either 9 gpm (7,500 psi) or 20 gpm (3,300 psi), depending on the weather conditions. The unit can also be operated in an air-only mode for removing dry snow. HDS units are currently used by Delta Airlines at General Mitchell International Airport in Milwaukee, Wisconsin, and by the U.S. Navy at the Brunswick Naval Air Station in Maine. For the 1998-1999 deicing season, Delta estimates the HDS unit enabled the airline to reduce the volume of ADF used in Milwaukee by about 85% (9, 10).

The Vestergaard system is mounted on Vestergaard's Elephant Gamma Deicer truck and uses forced air combined with an ADF spray to deice aircraft. The unit supplies forced air at a pressure of 56 psi and can be operated with or without ADF injection. The first Vestergaard forced-air system was purchased by All Nippon Airways last year and is currently used at the Nagano Airport in Japan to remove snow from aircraft parked at the airport overnight.

The Global system, known as AirPlus™, is a self-contained unit weighing approximately 85 pounds that consists of a compressor and two articulated nozzles (one for ADF and the other for forced air). Unlike the other forced-air systems where the compressor is mounted on the truck, the compressor on the Global system is mounted under the operator's seat

in the enclosed cab attached to the articulated boom. AirPlus™ can be operated in four different modes: (1) forced air only; (2) forced air with ADF injection; (3) ADF and forced air (supplied by separate nozzles); and (4) ADF only. The forced air exits the forced air nozzle at 725 miles per hour (about 1,350 cfm) with a pressure of 11 psi. ADF can be injected into the air stream at approximately 10 gallons per minute. The second nozzle can provide either heated Type I fluid at 60 gallons per minute or Type IV fluid at 20 gallons per minute. The cargo carrier, Emery Worldwide, tested the unit at Dayton International Airport in Ohio during the 1998-1999 deicing season. For the 1999-2000 deicing season, five AirPlus™ systems will be used by American Airlines at Chicago O'Hare International Airport and two will be used by Skyway Airlines (a division of Midwest Express) at General Mitchell International Airport in Milwaukee. According to Global representatives, the AirPlus™ system can reduce the volume of ADF used by an airline by at least 30 percent.

The forced-air systems cost approximately \$250,000. FMC and Global also market retrofit kits for use on existing deicing trucks that cost between \$80,000 and \$100,000 (2). To date, only a limited number of hybrid forced-air deicing systems have been purchased by U.S. carriers (e.g., Delta, United, American, Northwest, Emery Worldwide, Skyway, and Federal Express). Airlines have been cautious about investing in this new technology for a variety of reasons, the most important being concern the high-velocity air jet will damage aircraft surfaces. When a forced-air system is used to remove ice, airlines are concerned that ice chunks blasted from aircraft surfaces at high velocity will injure ramp personnel or damage aircraft. Many airlines are also worried the forced-air systems will be more expensive to maintain and less reliable than traditional deicer trucks. Some airlines believe that widespread use of forced-air systems will result in higher purchase prices for ADF due to reduced demand. Despite these problems, forced-air deicing systems offer several benefits to the airline industry, including reductions in the volume of fluid purchased, less frequent refilling of deicer trucks, and reduced costs for wastewater disposal.

The principle environmental benefit of the hybrid forced-air deicing systems is their ability to minimize the volume of fluid required to deice aircraft; however, glycol-based anti-icing

fluids may still need to be applied in certain weather conditions. While conventional deicing with large volumes of hot Type I fluids provide temporary anti-icing protection by heating the aircraft surface, forced-air deicing systems provide little anti-icing protection. Consequently, the time between completion of deicing and application of anti-icing fluids may be less than with conventional deicer trucks.

The U.S. Air Force has also experimented with forced-air deicing and has developed a system that uses forced hot air to remove snow and ice from aircraft surfaces. The forced hot air is supplied by MA1A compressors, which have been fitted to existing deicer trucks. The forced hot air system does not eliminate glycol-based ADFs, which are typically applied to aircraft after treatment with forced hot air. Nevertheless, it greatly reduces the volume of fluid required to effectively deice aircraft. The forced hot air system is currently in use at several northern Air Force bases (5, 11, 12, 13).

6.2.4 Computer-Controlled Fixed-Gantry Aircraft Deicing Systems

An alternative approach to aircraft deicing are the fixed-gantry systems, which are self-contained “car wash style” aircraft deicing systems. Fixed-gantry systems have been installed at only a few airports worldwide, and, although purported to deice aircraft quickly and efficiently, they have failed to receive widespread approval from the industry. EPA knows of no U.S. airports at which fixed-gantry systems are in use today.

In the typical fixed-gantry system, aircraft taxi onto the gantry pad and nozzles mounted on the gantry frame spray the aircraft with hot deicing fluid. The nozzles are controlled by computers that are programmed to deliver the appropriate amount of fluid uniformly over the entire aircraft for a variety of aircraft types and sizes. The deicing process takes approximately 8 to 12 minutes (5). Runoff is collected either in gutters or trench drains and pumped to storage tanks for treatment, recycling, or disposal (14). Gantry systems are typically located on taxiways near the end of the principal departure runway, reducing the time between aircraft deicing and take-off (3).

Deicing Systems AB (DSAB), based in Kiruna, Sweden, is a leading manufacturer of fixed-gantry deicing systems. DSAB installed its gantry system at the Munich Airport in Germany in 1992 at a cost of approximately \$5 million. The system consists of a computer-controlled, movable steel frame fitted with nozzles. The frame passes over the parked aircraft while the computer controls the operation of the nozzles, starting and stopping the flow from each nozzle as appropriate, depending on the type of aircraft. The speed of the gantry can be adjusted to suit prevailing weather conditions. The gantry is 70 meters wide and 21 meters high and can deice aircraft ranging in size from the Fokker 100 to the Boeing 747-400. The Munich system also includes a collection system for spent aircraft deicing fluid. The collected runoff is sent to an on-site glycol recycling facility also operated by DSAB (5).

In addition to Munich, DSAB has installed its gantry system at the Kallax Airport in Lulea, Sweden and the Stanford Field Airport in Louisville, Kentucky. United Parcel Service (UPS) purchased the DSAB gantry for its hub operations at Stanford Field Airport in 1988 at a cost of approximately \$6 million. The system purchased by UPS was designed to deice Boeing 727s, Boeing 757s and McDonnell Douglas DC-8s (15).

An alternative gantry system, called the Whisper Wash™, has been developed by Catalyst and Chemical Service, Inc. The Whisper Wash™ is a portable deicing system that uses both deicing fluid and high-pressure hot air to deice/anti-ice aircraft. The system consists of adjustable, cantilevered arms mounted on two modified flat-bed trailers. To accommodate different types of aircraft, the height of the arms is adjusted using hydraulic jacks. Each arm supports two sets of nozzles; one set delivers high-pressure hot air while the other delivers low-pressure deicing fluid. The nozzles used to deliver the deicing fluid are specially designed low-shear nozzles, which can be used to apply Type IV fluids as well as Type I fluids. The Whisper Wash™ system can also be operated in an air-only mode to remove light snow. According to the manufacturers, Whisper Wash™ can reduce ADF usage by up to 70% and can deice an aircraft in less time than is required for convention deicing using deicing trucks. Two versions of the system are currently available: a large system capable of handling wide-bodied aircraft and a small system capable of deicing general aviation aircraft and commercial narrow-bodied aircraft. The system

costs \$1.2 million, with annual maintenance and labor costs of approximately \$209,000. The manufacturer also offers an optional ADF-containment system consisting of a perforated pipe installed around the perimeter of the deicing area, which drain to sumps. Currently, no commercial application of the Whisper Wash™ system is known (5,6).

Proponents of the computer-controlled gantry systems assert that these systems: (1) quickly and efficiently deice aircraft using the minimum volume of aircraft deicing fluid, (2) can be operated by personnel with minimum training and experience, and (3) can collect as much as 80% of the deicing fluid sprayed (5). Despite these purported advantages, fixed-gantry systems are not popular with airlines or airport authorities. Airports are reluctant to invest in fixed-gantry systems because they require a relatively large capital investment and require considerable space that cannot be converted to other uses during good weather conditions. Airlines dislike fixed gantries because they can cause bottlenecks and delay aircraft departure. Some users argue that gantry systems actually apply more deicing fluid than necessary because they deice aircraft indiscriminately, including areas that may not require deicing. In addition, gantry systems cannot deice engine inlets, the undercarriage, or the underside of aircraft wings, making it necessary for airlines to perform additional deicing using traditional deicer trucks (5). According to recent reports, dissatisfaction with the performance of their fixed-gantry systems prompted UPS and some European airports to dismantle them.

6.2.5 Infrared Aircraft Deicing Technology

In recent years, a new method of aircraft deicing has been developed that relies on infrared radiation. The leading manufacturers of infrared-based aircraft deicing systems are Radiant Energy Corporation (formerly Process Technologies, Inc.) and Infra-Red Technologies, Inc. Radiant Energy markets a fixed-hangar deicing system known as InfraTek™, while Infra-Red Technologies markets a mobile system known as Ice Cat™. Both systems have the potential to greatly reduce the amount of glycol-based fluids used for aircraft deicing. Neither system is widely used by airlines or airports, although the InfraTek™ system is currently in commercial use

at three U.S. airports. A third system, under development by Sun Lase Inc., is designed to use computer-controlled infrared lasers to deice aircraft. Each system is described in detail below.

InfraTek™

InfraTek™ was developed under a Cooperative Research and Development Agreement between Radiant Energy and the FAA. Under the agreement, Radiant Energy developed the system and FAA provided expertise, advice, and test aircraft. A prototype was tested at Rochester International Airport in February 1996. Tests conducted by the FAA in March 1996 demonstrated that the InfraTek™ system could deice a Boeing 727 in six minutes, the approximate time required to deice an aircraft using conventional fluids (17). Additional testing conducted by the FAA and Radiant Energy showed that the infrared radiation did not damage aircraft components. The FAA measured aircraft surface temperatures during deicing and found that they never exceeded 94° F. Based on these results, the FAA approved deicing/anti-icing procedures that use the InfraTek™ system for commercial aircraft in 1997 (18).

The InfraTek™ system consists of an open-ended, hangar-type structure with infrared generators suspended from the ceiling. The infrared generators, called Energy Processing Units (EPUs), are fueled by natural gas. The infrared wavelengths are targeted to heat ice and snow, while minimizing the heating of aircraft components. The energy and wavelength generated by the EPUs can be adjusted to suit aircraft type. The system, operated similarly to a car wash, is controlled by computer and is designed to be operated by one person. Prior to deicing, the hangar floor is heated for 30 minutes to facilitate the melting of ice from aircraft landing gear and the underparts of the wings and fuselage. Once the floor is heated, the system is ready to receive aircraft. Aircraft taxi or are towed into the open-ended hangar immediately before takeoff. Typically, a six-minute cycle is used, which includes two minutes at full EPU power followed by four minutes at half power. The cycle time can be shortened for aircraft covered with a light frost.

Although the system can deice aircraft, it cannot provide anti-icing protection. When the ambient temperature is below freezing, precipitation can rapidly freeze on aircraft surfaces after it leaves the InfraTek™ hangar. Consequently, anti-icing fluid is applied to the aircraft when necessary to protect the aircraft during taxiing and takeoff. In addition, a small volume of deicing fluid may be required to deice areas of the aircraft not reached by the infrared radiation, including the flap tracks and elevators. While the InfraTek™ system does not completely eliminate glycol-based fluids, it greatly reduces the volume required. Radiant Energy estimates that the system reduces the volume of glycol-based deicing fluids applied to aircraft by approximately 90% (19). InfraTek™ is reportedly less effective with snow (as compared to ice), where the crystal structure of the flakes is thought to diffuse and reflect the infrared radiation rather than absorbing it (3). Radiant Energy is, therefore, considering adding blowers to remove loose snow from aircraft surfaces and improve efficiency.

The first commercial InfraTek™ system was installed at Buffalo-Niagara International Airport in March 1997 and is used for deicing general aviation and commuter aircraft. The hangar installed at Buffalo is 42 feet high, 111 feet wide, and 126 feet long and is capable of deicing aircraft as large as the ATR 72. In bad weather, it can deice four or five aircraft per hour (20). Customers are charged a fixed fee based on the size of their aircraft (i.e., wing span and fuselage length), as opposed to conventional deicing using Type I fluids, where charges are based on the volume of fluid applied. Customers prefer the fixed-fee payment structure because it enables them to budget for winter operations more accurately. Due to the success of the InfraTek™ system, Buffalo-Niagara International Airport is considering installing a larger system capable of handling commercial jets and cargo aircraft.

Radiant Energy installed its second commercial InfraTek™ system at the Oneida County Airport in Rhineland, Wisconsin in February 1998. This system is similar in size to the one installed at Buffalo-Niagara International Airport, but is slightly taller, allowing British Aerospace 146 commuter aircraft to be deiced (21). A third InfraTek™ system has been installed at Newark International Airport by Continental Airlines for use during the 1999-2000 winter. This system is capable of deicing narrow-bodied commercial aircraft as large as the Boeing 737,

and will be used primarily by Continental Airlines, although general aviation and other commercial airlines have also expressed interest.

In addition to reducing fluid use, deicing using the InfraTek™ system reportedly costs less than traditional deicing with deicing agents. InfraTek™ reportedly deices a Boeing 727 for under \$350, compared with the cost of approximately \$5,000 for deicing the same aircraft with glycol-based fluids (2).

Radiant Energy markets several different hangar sizes for the InfraTek™ system. The smallest system is designed to handle small general aviation and corporate aircraft, while the largest system is designed to handle large passenger jets and cargo aircraft. The largest system currently available is 95 feet high, 275 feet wide, and 320 feet long, which can accommodate aircraft as large as the Boeing 747 (19). The capital cost of the InfraTek™ system depends on the size of the hangar and ranges from \$1 million to \$4 million (5).

The principle disadvantages of the InfraTek™ system are its physical size and aircraft processing capacity. Land-locked airports located in urban areas may have difficulty finding sites for the InfraTek™ system, particularly since the selected site must both comply with FAA regulations and be convenient for aircraft taxiing to active runways. Airlines worry that the system's limited processing capacity will cause bottlenecks, resulting in unnecessary delays. While airport-wide implementation of the InfraTek™ system may be impractical at large airports with heavy traffic volumes, implementation may be practical at smaller airports that do not have congestion problems or by some tenants at larger airports (e.g., commuter airlines, general aviation). Airlines are also concerned about the potential for melted precipitation to refreeze in aerodynamically quiet areas, possibly resulting in the wing flaps and elevators malfunctioning. Although Radiant Energy reports that it has not seen any evidence that refreezing occurs in these areas, the company plans to undertake a test program with APS Aviation, Inc. to study the issue (22).

Ice Cat™

The Ice Cat™ system is a mobile, truck-mounted system that uses infrared radiation to remove frost, ice, and snow from aircraft surfaces. Infrared radiation is provided by an array of flameless infrared emitters (i.e., catalytic heaters) fueled by natural gas, propane, or butane. The infrared emitters are mounted on an articulated boom fitted to a specially designed truck. The boom lifts and positions the infrared emitters approximately 2 to 5 feet above the aircraft surface. Each unit is computer controlled. Depending on the size of the aircraft, one or two Ice Cat™ trucks may be used to deice an aircraft. According to the manufacturer, the deicing process requires approximately 6 to 10 minutes to complete, during which infrared radiation melts ice and snow accumulated on the aircraft and raises the temperature of the aircraft skin. By raising the temperature of the aircraft skin, Ice Cat™ temporarily prevents residual surface water and/or precipitation from freezing on aircraft surfaces. Sensors mounted on the boom monitor the surface temperature of the aircraft to ensure it never exceeds 140° F (23).

Infra-Red Technologies sponsored a demonstration of the Ice Cat™ in November 1997 at Kansas City International Airport where it was used to deice a Beechcraft Queen Air. Further tests were conducted in March 1998 at Kansas City where Ice Cat™ was used to deice a Boeing 727 and at the Pittsburgh National Guard Base where it was used to deice a military KC-135 supertanker. Ice Cat™ has also been tested by Transport Canada using an Air Canada Boeing 737 and Fokker F-428 (23). Infra-Red Technologies has continued to improve Ice Cat™ and recently added a spray system designed to apply a light coating of Type IV (anti-icing) fluid.

Ice Cat™ is reportedly a cost-effective alternative to deicing with traditional glycol-based aircraft deicing agents. According to the manufacturer, Ice-Cat™ can deice a Boeing 737 for as little as \$5 (23). The cost of the system is unknown, but is believed to be comparable to that of traditional deicer trucks.

Despite its purported advantages, no commercial application of the Ice Cat™ system is currently known. Although Ice-Cat™ is equipped with temperature sensors, many U.S.

airlines are worried that it may damage aircraft by overheating the aircraft's skin. In addition, the large size of the infrared panels may make Ice-Cat™ difficult to maneuver in the confined space of the gate area. Airlines are concerned about the potential for collisions between Ice-Cat™ and parked aircraft.

Sun Lase Inc.

Sun Lase Inc. is currently developing an infrared laser-based system designed to quickly and efficiently deice aircraft. The system will use a high-power, infrared (i.e., 10-micron wavelength) laser beam to melt ice on aircraft surfaces. The laser beam will be generated by CO₂ lasers and directed at the aircraft surface using mirrors. The mirrors will be controlled by computer, allowing the laser beam to be moved across the aircraft in a predetermined manner. The computer will control the laser alignment and simultaneously monitor the thermal temperature of the aircraft skin. The laser beam will cover a surface area of approximately 1 square meter and deliver an intensity of 2.5 Watts/cm². For safety, the laser beam will be combined with red light to enable operators to observe the position of the beam. The lasers can be mounted on a truck or on telescopic poles. The system is designed to be operated by one person. Sun Lase has applied for a U.S. patent and is currently constructing a prototype (24).

6.2.6 Hot Water Aircraft Deicing

The FAA permits aircraft to be deiced using hot water followed by the application of an anti-icing fluid when ambient air temperatures are above 27° F (3). None of the major U.S. airlines currently use this method because they believe it would compromise the safety of passengers and ground operations staff. Airlines are concerned about flash freezing and the potential to build up thick layers of ice both on the aircraft and on the pavement. The water may also enter and freeze on flap tracks, elevators, and other aircraft parts, potentially affecting aircraft handling and performance. Water freezing in hoses, nozzles, and tanks when deicer trucks are not in use is also a concern.

6.2.7 Varying Glycol Content to Ambient Air Temperature

Although Type I fluid can be purchased in a prediluted ready-to-use form, many airlines and fixed-base operators prefer to purchase their Type I fluid in concentrated form (approximately 90% glycol) and dilute to a glycol concentration appropriate to the local weather conditions (13, 25). Some airlines mix Type I fluids specific to each deicing event based on prevailing weather conditions, thereby minimizing the amount of deicing fluid sprayed. For example, Delta Airlines uses a “Local Area Expert,” a person well trained in deicing operations, to determine the glycol concentration appropriate for the prevailing temperature. This practice enables Delta to use Type I fluids containing as little as 30% glycol, rather than the typical 50/50 glycol and water mixture, when weather conditions are mild.

A similar practice is used at Denver International Airport where the airport’s FBO supplies airlines with Type I fluids containing glycol concentrations that are appropriate for the ambient air temperature. The FBO purchases Type I fluid in a concentrated form, stores it in 20,000-gallon storage tanks at the airport’s glycol recycling facility, and mixes it with water in a 10,000-gallon tank equipped with a mixer. The concentrated fluid and water are metered into the mixing tank in the appropriate proportions and a built-in densitometer is used to verify the glycol concentration.

Due to storage problems and concerns about human error, some airlines prefer to mix Type I fluids to meet historical temperature minimums. Northwest Airlines, for example, analyzes historical temperature data for a given airport and selects a glycol content to match the lowest temperature the airport is likely to experience. This practice may result in fewer mistakes and is particularly suited to some smaller airports that lack storage for preparing multiple-strength solutions.

Where possible, the U.S. Air Force also adjusts the glycol concentration of its aircraft deicing fluids based on ambient air temperatures. At some bases, the Air Force uses deicer trucks with two-chamber tanks: one for concentrated aircraft deicing fluid and the other for

heated water. The flow rate from each tank can be adjusted to alter the glycol concentration of the fluid as it is applied to aircraft. One disadvantage of the two-chamber deicer trucks is that the water may freeze when the trucks are not in use. This problem caused personnel at some northern bases to remove the baffles and create a single tank in which the deicing fluid can be mixed to meet prevailing or anticipated weather conditions prior to application (13).

6.2.8 Enclosed-Basket Deicing Trucks

Airlines typically use open-basket configurations, called “cherry pickers,” to apply ADF. The open baskets provide little protection for personnel, who are frequently sprayed by aircraft deicing and anti-icing fluids. An enclosed-basket design is now available that improves operator working conditions (2). By enabling operators to get closer to the aircraft, the enclosed basket reportedly reduces over-spray and helps to minimize the volume of fluid used to deice aircraft. As a result, some airlines have reported 30% reductions in aircraft deicing fluid usage. As a result of these benefits, many U.S. airlines now employ a fleet of enclosed-basket deicing trucks at their hubs and larger stations. Several companies manufacture the enclosed-basket deicing trucks, including Simon Aviation Ground Equipment, Elberta Industries, Premeir, and FMC (5).

6.2.9 Mechanical Methods

The volume of ADF applied to aircraft can be minimized by mechanically deicing the aircraft prior to chemical deicing (2). The U.S. Air Force, for example, uses brooms, squeegees, and ropes to remove ice and snow from aircraft surfaces (26, 27). These methods are more effective at removing snow rather than ice. When performed incorrectly, they can damage aircraft antennas and sensors. Mechanical methods are generally only practical for smaller aircraft; for large aircraft, they can be prohibitively time-consuming and labor intensive. Despite these drawbacks, Northwest Airlines uses brooms fitted with long handles to remove snow from large passenger aircraft. This method is used only in the early mornings, when it is least disruptive to Northwest’s departure schedule.

6.2.10 Aircraft Deicing Using Solar Radiation

At several U.S. Air Force bases, aircraft parked on ramps are oriented to maximize the melting of accumulated snow and ice by sunlight. This method reduces the volume of aircraft deicing fluid used during the winter season, but is practical only for general aviation and certain military flights that can be delayed without negative economic or operational impacts (13, 26).

6.2.11 Hangar Storage

Many general aviation aircraft and some commuter and military aircraft are stored in hangars overnight and during storm events, eliminating the need for aircraft deicing. In addition, heated aircraft hangars are sometimes used to deice aircraft. In either case, anti-icing may be necessary in certain weather conditions to prevent ice and snow from accumulating on aircraft surfaces during taxiing and takeoff. After leaving the hangar, aircraft are anti-iced by spraying with a small volume of glycol-based anti-icing fluid (typically 2 gallons for very small aircraft). Because of the small volumes applied, the volume of ADF-contaminated wastewater generated is much less than would have been generated had aircraft been stored outdoors. The Tri-State Airport in Huntington, West Virginia, for example, estimates that their 84-foot-by-120-foot heated aircraft hangar saved approximately 1,500 gallons of Type I fluid last year and estimates that a new 70-foot-by-100-foot heated hangar will save an additional 1,000 gallons of Type I fluid during the 1999-2000 deicing season. Tri-State Airport handles approximately 46,000 operations each year of which approximately 70% are conducted by general aviation aircraft that are easily stored in aircraft hangars.

6.2.12 Aircraft Covers

Where hangar space is not available, aircraft covers or blankets are sometimes used as an alternative method to minimize frost, ice, and snow accumulation on aircraft surfaces (28). Aircraft covers are typically used for small general aviation aircraft to protect the wings, tail, and engine inlets. There are currently two types of covers available: solid and mesh covers.

Solid covers are made from nylon or canvas and should not be used in strong winds. In cold weather, they tend to become hard and freeze to the wings, making them difficult to remove. Mesh covers are made from a very fine mesh fabric and are designed for use in windy conditions. They are easier to remove in cold weather but provide less protection, tending to leave residual ice on wing surfaces (29).

Northwest Airlines experimented with aircraft covers for large passenger aircraft, but was dissatisfied with their performance. Northwest found them to be relatively easy to install, but difficult and time-consuming to remove as they become hard and inflexible when cold. In some instances, condensation trapped between the wing and the cover froze, binding the cover tightly to the wing surface. In addition, covers that came in contact with the pavement picked up grit, which damaged aircraft surfaces as the covers were pulled into place. Based on this experience and the high cost of the covers (approximately \$10,000), Northwest concluded that aircraft covers are impractical for use on large passenger aircraft.

6.2.13 Thermal Blankets for MD-80s and DC-9s

The MD-80 and DC-9 aircraft are particularly prone to icing. Fuel stored in tanks located below the aircraft's wings becomes super-cooled during flight. Ice forms on wing surfaces as the aircraft descends and lands, and may form on days when the ambient air temperature is well above freezing. This ice is removed prior to takeoff by applying a small volume of ADF, typically 25 to 50 gallons, in a process known as "clear ice" deicing. Although the volume of fluid used is small, "clear ice" deicing is regularly performed on these aircraft throughout the winter months. Consequently, many airlines operating large fleets of MD-80s and DC-9s are attempting to eliminate the need for "clear ice" deicing by retrofitting these aircraft with specially designed thermal blankets. The blankets are bonded to the wing surface and consist of nickel-plated carbon fibers sandwiched between fiberglass layers. The blankets are manufactured by Allied-Signal Aerospace and cost approximately \$35,000 (2). The airlines are pleased with the overall performance of the blankets and believe they significantly reduce the volume of aircraft deicing fluid used for "clear ice" deicing of MD-80s and DC-9s.

6.2.14 Ice-Detection Systems

Pilots and aircraft deicing crews often have difficulty detecting ice on aircraft wings, particularly at night when visibility is poor. Consequently, aircraft are deiced whenever ice is suspected to be present. This conservative approach is appropriate from a safety standpoint, but may lead to unnecessary application of ADFs. One solution is the use of ice-detection systems. Although some ice-detection systems are known to have difficulty detecting ice on painted surfaces and composite materials, most systems improve safety while increasing the efficiency of aircraft deicing/anti-icing operations.

There are currently two types of ice-detection systems available: a remote system and a wing-mounted system. SPAR Aerospace markets a remote detection system developed by Cox and Company. The system is known as the Contamination Detection System™ (CSD-1) and uses an infrared camera to detect ice and evaluate the integrity of anti-icing fluids on aircraft surfaces (4). The camera can be used at distances of 58 feet from the aircraft. The CSD-1 is reported to be capable of detecting clear ice films as thin as 0.01 inches and can detect ice crystals forming in Type IV fluids (25). The system costs approximately \$60,000 (5).

Allied-Signal Aerospace has developed a wing-mounted system known as the Clean Wing Detection System™. This system uses sensors mounted in the upper surface of the wing to detect surface contamination. The sensors can identify the type of contamination (e.g., frost, ice, snow, and deicing/anti-icing fluid) and measure its thickness (4). The system is also designed to measure the performance of anti-icing fluids and can determine when additional deicing/anti-icing is warranted. The cost of this system depends on the number of sensors installed and ranges from \$50,000 for four sensors to \$75,000 for eight sensors (2).

BF Goodrich, a leading manufacturer of in-flight ice detectors, markets a remote detection system, called the IceHawk™ Wide Area Ice Detector, which uses an infrared light beam to detect ice, snow, and frost on aircraft surfaces. The IceHawk™ is designed to detect frozen contamination up to 60 feet from the aircraft and has been approved by the FAA to replace

the tactile inspection. The system works by scanning the aircraft surface with a polarized infrared beam. The system analyzes the polarization of the reflected signal and generates an image on a color, LCD monitor. Infrared signals reflected from surfaces contaminated with ice, frost or snow are unpolarized. These areas are displayed on the monitor in red. The system can detect ice covered by deicing and anti-icing fluids and can be used in any lighting or weather conditions without recalibration. The units are portable and may be either handheld or mounted on deicer trucks and are currently being used by Delta Airlines, Federal Express, and the U.S. Air Force. BF Goodrich is also developing an onboard version of the IceHawk™ in which the sensor is installed above a passenger window in the fuselage at a position behind the wing. The company has tested a prototype of the new system on an FAA Boeing 727 last winter and plans to conduct additional testing during the 1999-2000 winter (30).

6.2.15 Airport Traffic Flow Strategies and Departure Slot Allocation Systems

More effective airport management plans and better communication during storm events can help avoid unnecessary repeated application of ADF, particularly at the busier and more congested airports. The FAA recommends that airport management collaborate with the airlines, FBOs, air traffic control, and other interested parties to develop communication procedures and traffic flow strategies for winter operations. Winter traffic flow strategies can identify the shortest taxiing routes and minimize holdover times for deiced aircraft, thereby reducing or eliminating the need for repeated deicing/anti-icing and reducing the amount of fluid used for secondary deicing (31).

Some airports have instituted a departure slot allocation system to reduce delays caused by runway congestion and enable aircraft to depart immediately after being deiced. Using this system, air traffic control estimates the number of departures possible based on the particular weather conditions and assigns departure times (slots) to aircraft before they are deiced. Since the number of departures is normally reduced during snow and ice conditions, the available departure slots are usually allocated to airlines based on their percentage of the total flights scheduled that day. For example, on a typical day, the schedule may have 200 flights, with 70%

of the departures by airline A, 25% by airline B, and 5% by airline C. If the departure rate is reduced to 20 aircraft every hour due to bad weather, then air traffic control will assign 70% of available departure slots (14 slots) to airline A, 25% (5 slots) to airline B, and 5% (1 slot) to airline C. This practice is particularly beneficial at large, congested airports where it enables airline operations personnel to coordinate the deicing of an aircraft with its allocated takeoff time.

One problem encountered by airports using the slot allocation system is the difficulty of enforcing compliance. While most airlines voluntarily comply with the slot allocation system, aircraft from some airlines start taxiing even though they have not been allocated a departure slot. For the slot allocation system to work effectively, air traffic control must police the system by denying errant aircraft takeoff clearance.

Several airlines cancel inbound flights prior to or during severe weather conditions. This traffic flow strategy reduces the volume of fluid used by reducing the number of aircraft requiring deicing. For example, at General Mitchell International Airport in Milwaukee, Wisconsin, some airlines cancel flights and transport passengers by bus to nearby Chicago O'Hare International Airport.

6.2.16 Personnel Training and Experience

An important factor affecting the efficiency of aircraft deicing/anti-icing operations is the training and experience of personnel involved in aircraft deicing/anti-icing. Most airlines and FBOs do not have employees dedicated to aircraft deicing/anti-icing and use ground operations personnel (e.g., baggage handlers, mechanics) or hire temporary staff. Due to low pay and poor working conditions, employee turnover is typically high. Consequently, a large portion of aircraft deicing/anti-icing staff, particularly at larger airports, is newly hired and trained each year. Due to inexperience and concerns about the consequences of inadequate deicing/anti-icing, new hires often spray more fluid than necessary. While the eight hours of FAA-mandated training received by new hires ensures the safe operation of aircraft, several years of experience may be necessary for an employee to become efficient at aircraft deicing/anti-icing. Well-trained and

experienced deicing/anti-icing personnel improve the efficiency of aircraft deicing/anti-icing operations and minimize the volume of fluid used, while ensuring passenger safety.

The training and experience of airport personnel may also affect the efficiency of aircraft deicing/anti-icing operations. Airport personnel are typically responsible for clearing taxiways, gate areas, ramps, aprons, and deicing pads. When these areas are not adequately cleared, snow and ice accumulate on the undercarriage and the underside of aircraft during taxing and must be removed prior to takeoff. As a result, poor winter maintenance of airfields tends to increase the volume of aircraft deicing fluids applied by making it necessary to perform secondary aircraft deicing at departure runways.

6.2.17 Other ADF Minimization Practices

Additional sources of ADF discharges to the environment include spills from overfilling deicer truck tanks and leaks from worn or defective fittings on deicer trucks and other application equipment. These sources of ADF can be greatly reduced by equipping deicer trucks with dripless fittings and automatic filling shutoff valves. At Albany International Airport, all deicer trucks are required to be fitted with sight gauges and automatic filling shutoff valves that prevent tanks from being filled above 80% of their capacity. The cost of retrofitting existing deicer trucks was approximately \$250 per truck (32).

Unnecessary releases of ADF to the environment can also be reduced by locating ADF storage tanks within the boundaries of the designated aircraft deicing/anti-icing collection and containment areas. At Denver International Airport, for example, deicer trucks are refilled from ADF storage tanks located on the aircraft deicing/anti-icing pads. Since the deicer trucks do not leave the containment area, any spills or leaks from defective fittings or overfilled tanks are collected along with the other ADF-contaminated storm water.

6.2.18 Glycol Minimization Methods Currently Under Development

Foster-Miller, Inc. is developing a surface treatment or coating that would provide anti-icing protection by preventing ice and snow from adhering to aircraft surfaces. Theoretically, this technology combined with the forced-air deicing system discussed in Section 6.2.3 could greatly reduce the need for glycol-based ADFs by enabling snow and ice to be easily blown from aircraft surfaces. Foster-Miller is currently evaluating possible aircraft surface coatings. The project is funded by the Department of Transportation's National Center for Environmental Research and Quality Assurance (33).

Professor Victor Petrenko of Dartmouth's Thayer School of Engineering is developing an alternative deicing technique that uses electricity to loosen ice from aircraft surfaces. The electricity disrupts the orientation of surface water molecules, breaking bonds between the ice crystals and the metal substrate. Similar to the surface coatings discussed above, this method would rely on forced-air to blow snow and ice from aircraft surfaces. To date, the method has only been demonstrated in the laboratory using steel and other solid materials. Additional research will be necessary to determine whether the electrical current used to loosen the ice will interfere with sophisticated aircraft navigational equipment and electrical systems.

Polaris Thermal Energy Systems, Inc., in association with Transport Canada and Continental Airlines, is investigating the possibility of introducing heated fuel in wing fuel tanks to prevent frost, ice, and snow from forming on wing surfaces when the aircraft is on the ground. Polaris believes this method will be especially advantageous for MD-80s and DC-9s, where fuel stored under the wings tends to become super-cooled during flight, causing clear ice to form on the surface of the wings after the aircraft has landed. In preliminary tests conducted by Polaris and Transport Canada, the method has proven effective in minimizing the volume of deicing fluids required. One test, conducted by Polaris in March 1997, demonstrated that the method could, under certain weather conditions, eliminate the use of conventional glycol-based deicing fluids. The test was conducted at Cleveland's Hopkins International Airport using an MD-80 owned by Continental Airlines. The aircraft arrived at the airport at 1:08 a.m. with approximately 8,000

pounds of super-cooled fuel stored in its tanks. Polaris introduced 1,000 pounds of heated fuel (heated to approximately 85° F) into the aircraft's fuel tanks at 2 a.m. Polaris monitored the wing temperature using infrared photography and found the surface temperature rapidly increased by 10° F. Additional heated fuel was added at 2:20 a.m. and 3:00 a.m., raising the average wing surface temperature to 79° F. Although the ambient temperature was about 18° F and a light to heavy snow fell during the early morning hours, the aircraft did not need deicing with conventional fluids prior to its scheduled 7:40 a.m. departure. Polaris estimates the cost of heating the fuel was approximately \$40 (34). While this method may reduce discharges of ADF to U.S. surface waters by reducing the overall volume of ADF applied to aircraft, it may result in additional cross-media impacts (e.g., increased air emissions).

6.3 Aircraft Deicer/Anti-icer Collection and Containment Methods

In response to EPA's 1990 storm water program and state and local requirements, many U.S. airports are collecting wastewater from aircraft deicing/anti-icing operations to prevent or minimize discharges at storm water outfalls. Airports use a variety of collection methods, including gate and ramp area drainage collection systems, storm sewer plugs, designated aircraft deicing pads, temporary aircraft deicing pads, storm drain valves, and specially designed glycol-vacuum vehicles. Individual airports often rely on a combination of these collection strategies, varying the collection method to suit tenant requirements, utilize existing infrastructure, or adapt to site-specific constraints. Collected wastewater may then be processed to recycle/recover glycol, treated on site, discharged to a publicly owned treatment works (POTW), or a combination of these methods. The following subsections describe in detail the various wastewater collection methods used by the industry. Federal aid from the FAA-administered Airport Improvement Program may be used to finance construction of wastewater collection systems and storage facilities (35). Funding for this program, however, is limited and deicing/anti-icing wastewater collection projects must compete with other important airport improvement projects, such as resurfacing airport runways, upgrading runway lighting systems, and constructing new taxiways.

6.3.1 Aircraft Deicing Facilities

As airport authorities began to grapple with the problems of collecting wastewater from aircraft deicing operations and meeting NPDES permit limits, they soon realized that wastewater could be collected more efficiently by confining aircraft deicing operations to small, designated areas where provisions for containment and collection could be installed. As a result, several U.S. airports constructed specially designed aircraft deicing facilities called aircraft deicing pads. Denver International Airport, Salt Lake City International Airport, Pittsburgh International Airport, Baltimore Washington International Airport, Dayton International Airport, Minneapolis-St. Paul International Airport, and Detroit Metropolitan Wayne County Airport are currently using deicing pads. In Canada, Toronto's L.B. Pearson International Airport and Montreal's Dorval International Airport have constructed large deicing facilities consisting of multiple deicing pads.

In general, aircraft deicing pads consist of a concrete or asphalt platform, a drainage collection system, and a wastewater storage facility. The platform is graded and sometimes grooved to channel wastewater to the drainage collection system. The collection system typically consists of trench or square drains connected to underground storm water pipes, which are usually fitted with diversion boxes to allow ADF-contaminated wastewater to be diverted to a wastewater storage facility during the deicing season. The wastewater is stored in detention ponds, tanks, or underground concrete basins. The pads are typically designed to accommodate more than one aircraft at a time and are usually divided into individual aircraft deicing bays. Some pads also include snow melters (discussed in Section 6.3.7) for disposal of ADF-contaminated snow collected on and around the deicing pad. The resultant wastewater is collected by the pad's drainage collection system and diverted to the wastewater storage facility.

Aircraft are deiced on the pads using conventional deicer trucks or fixed-boom applicators. To avoid collisions, deicer trucks are parked in designated areas when aircraft are entering or exiting the pad. Fixed-boom applicators are less popular with airlines and are known to be installed at only three aircraft deicing pads in the U.S. (one pad at Denver International

Airport and two pads at Pittsburgh International Airport (20)). When not being used for deicing, the pads often serve as aircraft parking aprons or holding pads.

Since most commercial aircraft are able to taxi prior to deicing and can be deiced with their engines running, aircraft deicing pads may, upon approval by FAA, be located on taxiways, on cargo or general aviation ramps, near departure runways, or adjacent to passenger terminals. The FAA recommends that pads should be constructed to accommodate the largest aircraft the airport serves (i.e., widest wingspan and longest fuselage) and should have sufficient capacity to handle peak periods of aircraft departures without causing departure delays (35). Deicing pads may also require additional personnel for monitoring aircraft movements on the pad and managing wastewater collection. The number, location, and size of aircraft deicing pads required for a particular airport depends on the number of operations, the types of aircraft using the airport, the meteorological conditions typically experienced, the availability of land, and the physical layout of the airport. For some airports, deicing pads may be unnecessary due to efficient ADF-collection systems installed at the passenger terminals and cargo ramps (see Section 6.3.2).

The largest and most technologically advanced aircraft deicing pads are located in Canada at Montreal's Dorval International Airport and Toronto's L.B. Pearson International Airport. These airports have constructed centralized aircraft deicing facilities that include storage tanks and filling stations for aircraft deicing/anti-icing agents and control towers for monitoring deicing operations and controlling traffic flow. The Montreal pad accommodates up to seven aircraft at a time and has a laser guidance system to assist pilots in maneuvering and parking aircraft on the deicing pad (36).

The Toronto pad consists of four deicing bays, but is currently being expanded to six bays. Once the expansion is completed, the deicing facility will be able to accommodate up to six Boeing 747s and will cover an area of 65 acres. Each deicing bay is approximately 328 feet wide and 780 feet long. A high-density polyethylene liner, installed underneath the deicing bays, collects any fluid that seeps through the concrete pad. Inset lighting assists pilots in positioning

aircraft on the pad, while surveillance cameras are used to record activities on the pad. An electronic sign board system provides pilots with deicing operational information, minimizing verbal communication requirements. Wastewater from aircraft deicing/anti-icing operations is collected in 14 diversion vaults, which are equipped with automated diversion valves. A pump located in the bottom of each diversion vault pumps samples of the wastewater to a small, on-site laboratory, where the glycol concentration is measured. If the glycol concentration is less than the Canadian voluntary guideline of 100 mg/L (see Section 13.3.1), the wastewater is discharged through the storm water drainage system. If the glycol concentration is greater than 100 mg/L, the operator diverts the wastewater to one of three underground storage tanks. The storage tanks have a combined capacity of approximately 3.5 million gallons. The stored wastewater is either trucked to a glycol recycling plant or discharged to a local POTW (37).

Although the principal environmental advantage of deicing pads is their ability to collect a high percentage of the aircraft deicing fluid sprayed, the wastewater they collect has a high glycol content, an important advantage for airports considering glycol recovery/recycling. For example, at Denver International Airport, aircraft deicing pads collect wastewater with glycol concentrations of approximately 20 percent (20). By collecting wastewater with high glycol concentrations, Denver's aircraft deicing pads make its on-site glycol recycling economically viable.

Aside from their environmental benefits, deicing pads provide several operational and safety advantages. First, they allow aircraft to move away from the gate area so that arriving flights have access to gates. Second, they allow for much more efficient spraying of aircraft, especially for aircraft with wide wing spans, such as the new Boeing 777. Third, they ease ramp and gate area vehicle congestion. Fourth, they improve safety and working conditions for baggage handlers, maintenance engineers, and other airline personnel working in the gate area. Finally, they improve passenger safety by enabling aircraft to be deiced closer to the departure runway, decreasing the time between deicing and takeoff and reducing the potential for an aircraft to exceed its holdover time.

Despite these advantages, some airlines have been reluctant to use aircraft deicing pads. Airlines are primarily concerned that aircraft deicing pads may create a bottleneck, resulting in departure delays. To prevent unnecessary delays, the FAA recommends deicing pads be constructed with bypass taxiways that allow aircraft not requiring deicing to proceed without hindrance to active runways. Airports serving a wide range of aircraft types can often reduce congestion by constructing separate aircraft deicing pads for general aviation, cargo, commuter aircraft, and large passenger jets. For example, Pittsburgh International Airport has constructed five aircraft deicing pads: two for large passenger jets, one for cargo carriers, and two smaller pads for commuter aircraft (20).

Airlines also complain of congestion on aircraft deicing pads caused by the presence of deicer trucks from several different airlines. Currently, most passenger airlines deice their aircraft using their own deicer equipment. The presence of multiple deicer trucks increases the potential for collisions with aircraft or other airport vehicles. This problem can be solved by air carriers allowing their aircraft to be deiced by a single carrier or a fixed-based operator. At Dorval International Airport in Montreal, for example, aircraft deicing/anti-icing is performed exclusively by the airport's FBO, Aeromag 2000. Similarly, aircraft deicing/anti-icing at the L.B. Pearson International Airport's new central deicing facility is conducted by Hudson General Aviation Services, Inc. However, due to liability issues and concerns over equitable access to deicing pads, airlines often have difficulty agreeing on who should provide aircraft deicing services at deicing pads and which fluid formulations should be used. These issues are particularly difficult to resolve at airports that have no dominant carrier and a large number of competing airlines.

Although not limited to aircraft deicing pads, one environmental problem encountered by airports is the tracking of aircraft deicing and anti-icing fluids from the pad onto nearby taxiways and runways. This problem is caused primarily by fluids dripping from aircraft after they have left the deicing pad, but may also be caused by jet blast, drippage from aircraft undercarriages, and the wheels of airport vehicles carrying fluid across the pad's threshold.

For some airports, deicing pads may be impractical due to their physical size and capital and operational costs. The construction costs for aircraft deicing pads vary with the size and complexity of the system. For example, Denver International Airport constructed three deicing pads with drainage collection systems for approximately \$2 million per pad (1). Dorval International Airport's pad, complete with storage facilities, new deicer equipment, laser guidance system and control tower, cost approximately \$22 million.

6.3.2 ADF Collection Systems for Ramps and Passenger Terminal Gate Areas

At most airports, aircraft deicing operations are performed on aircraft parking ramps or at the passenger terminal gates. To collect wastewater generated at these locations, some airports have installed new collection systems or modified existing storm water drainage systems. The typical collection system consists of graded concrete pavement with trench or square drains connected to a wastewater storage facility via a diversion box. The storage facility may consist of detention ponds (covered or uncovered), tanks, or underground concrete basins. The diversion box allows uncontaminated storm water to be diverted to storm water outfalls.

The construction or modification of drainage collection systems with their associated underground piping, diversion boxes, and storage facilities can be extremely expensive, especially for larger airports that have several passenger terminals and a large number of gates. In addition to the expense, these projects are often disruptive to airline operations. Many U.S. airports already experience delays due to congestion, and temporary gate closures would exacerbate the situation. Similar to deicing pads, ADF may be tracked outside the containment area onto nearby runways and taxiways.

Because of the large drainage area typical of passenger terminals and aircraft parking ramps, large volumes of very dilute wastewater are collected. Airports located in urban areas may not have sufficient land available to construct storage facilities large enough to accommodate the volume of wastewater generated. The relatively low glycol concentrations typical of wastewater collected by these systems make glycol recycling/recovery difficult and

expensive; however, low glycol concentrations can be an advantage to airports that discharge their wastewater to a POTW.

The principal advantage of installing ADF collection systems at aircraft parking ramps and passenger terminals is that they enable airports to collect wastewater from aircraft deicing and anti-icing without requiring airlines to alter their winter operating practices. Many airlines believe that deicing and anti-icing aircraft at these locations is an unavoidable part of winter operations, because aircraft can be damaged by taxiing prior to being deiced. For example, aircraft engines may be damaged by ingesting ice shed from aircraft surfaces during taxiing. Aircraft with engines mounted on the rear fuselage, such as the MD-80, are particularly at risk. Consequently, most airports with deicing pads (discussed in Section 6.3.1) allow airlines to conduct some limited gate and ramp deicing. Several U.S. airports, such as Kansas City International, Greater Rockford, Bradley International, Minneapolis-St. Paul International, and Albany International, have installed new collection systems or modified existing storm water drainage systems to enable them to collect ADF-contaminated storm water from these areas. Several example systems are described below. Additional information about ADF collection systems, including the systems used at Dallas-Ft. Worth International and Albany International Airports, is provided in Section 7.1.

Kansas City International Airport, Kansas City, MO (KCI)

Kansas City International Airport is currently constructing a new collection system at its passenger terminals. The new system consists of trench drains strategically located 240 feet from the face of the terminal buildings. Wastewater from aircraft deicing/anti-icing operations combines with small amounts of storm water runoff, enters the trench drains, and is conveyed through underground pipes to a two-celled, concrete storage basin. Due to the large size of the drainage area, the storage basin was constructed with a capacity of 2 million gallons. The collected wastewater is discharged at a controlled rate to a POTW.

Greater Rockford Airport, Rockford, IL (RFD)

At the Greater Rockford Airport in Rockford, Illinois, UPS has constructed an aircraft parking ramp with two separate drainage areas, each with its own collection system. Both drainage collection systems are connected through diversion boxes to the airport's treatment facility and to the airport's storm water outfall on the Rock River. The drainage system on the southern part of the ramp drains approximately 33% of the UPS ramp. During the winter, aircraft deicing/anti-icing operations are typically restricted to the southern part of the ramp. At peak traffic times, such as the Christmas season, UPS can expand the area used for aircraft deicing/anti-icing to the northern part of the ramp by diverting the wastewater from that area to the airport's treatment system (discussed in Section 7.2.1). The treatment system has a combined storage capacity of 21 million gallons.

The separate drainage areas provide UPS with maximum operational flexibility, while also providing the airport with the flexibility needed to efficiently manage the wastewater generated. The principal advantage of this design is that it enables the airport to minimize the dilution of the wastewater during precipitation events by reducing the drainage collection area. Storm water that is not contaminated with ADF is discharged directly to the Rock River.

Bradley International Airport, Windsor Locks, CT (BDL)

Construction plans for a new passenger terminal at Bradley International Airport near Hartford, Connecticut, include two independent drainage collection systems, one for clean storm water and one for ADF-contaminated storm water. Rectangular drains (one for each drainage system) will be installed side by side in the gate areas. During aircraft deicing operations, the clean storm water drains will be closed using drain inserts (discussed in Section 6.3.4) to prevent ADF-contaminated storm water from entering the clean storm water drainage system. Drains for the ADF-contaminated storm water drainage system will be opened, allowing the wastewater to be collected in underground storage tanks. Although the dual drainage system is expensive, airport personnel believe it will be more efficient and require less monitoring than

single drainage systems where contaminated storm water tends to remain in storm water pipes long after deicing/anti-icing operations have ceased and be washed out during periods of heavy rainfall.

Minneapolis-St. Paul International Airport, Minneapolis-St. Paul, MN (MSP)

Minneapolis-St. Paul International Airport has avoided the large capital expenditures associated with construction of a new collection system by using existing infrastructure to collect ADF-contaminated storm water. At this airport, storm water pipes located at the passenger terminal are turned into temporary retention systems by inserting specially designed compression plugs. The plugs are installed prior to the beginning of the deicing season and removed in late spring. The contaminated storm water is pumped out periodically and transferred by truck to the airport's detention ponds. Careful management of the retention systems enables the airport to collect enough wastewater with high glycol concentrations to make glycol recycling/recovery economically viable. Inland Technologies, Inc., under a contract with Northwest Airlines, currently operates an on-site glycol recycling/recovery system, which is described in detail in Section 6.4.

6.3.3 Temporary Aircraft Deicing Pads

Temporary aircraft deicing pads are specially designed platforms used to collect contaminated wastewater generated during aircraft deicing and anti-icing operations. They are constructed from reinforced rubber or polypropylene mats and sometimes use inflatable air or foam berms to contain contaminated wastewater. The temporary pads cost less than permanent structures, are portable, and can be assembled on taxiways close to departure runways. Although EPA does not know of any U.S. airports using this collection method, four types of temporary aircraft deicing pads are currently available and are discussed in detail below.

Ro-Mat™

Ro-Mat™ is manufactured by the Danish company A/S Roulunds Fabriker and consists of a thick rubber mat that can tolerate temperatures ranging from -50° C to 50° C. The mat is grooved and reinforced with steel cables. The grooves are designed to channel wastewater to existing drainage systems, such as open trenches or trench drains, located at the sides of the mat. The mat can be placed on an asphalt or concrete taxiway and can be moved if necessary. The Ro-Mat™ costs approximately \$22 per square foot (5, 38).

The Ro-Mat™ is currently in use at Copenhagen International Airport in Denmark, where it is located on a taxiway close to the departure runway. The system was installed in 1992 at a cost of approximately \$1.6 million, and consists of the Ro-Mat™, a drainage collection system, and wastewater storage tanks. The system is reportedly capable of collecting up to 75% of sprayed aircraft deicing fluid. The glycol concentration of the collected wastewater is relatively high, typically ranging from 25.8% to 32.5% (5, 38).

Latimat™

Environmental Cleaning Systems, Inc. has developed a containment pad system called Latimat™, which consists of a pad with inflatable air or foam berms. The containment pad is portable and can be manufactured in a variety of sizes to meet customer requirements. The largest Latimat™ available can accommodate a Boeing 747 aircraft (39).

Pure Mat™

Recovery Systems, Inc. manufactures a containment system similar to Latimat™ called Pure Mat™. The Pure Mat™ consists of a pump and a chemically resistant mat attached to a flexible berm. The pump transfers wastewater from the containment area to a storage tank for future treatment, recycling, or disposal. The system can be used for either aircraft deicing or washing (5).

Remote Aircraft Wash Platform and Portable Evacuation System™

Aviation Environmental, Inc. manufactures a containment system designed for use as an aircraft deicing pad and wash rack. The system consists of a chemical and sun-resistant polypropylene liner, a foam berm, and an 18-horsepower pump. It can be situated on either concrete or asphalt and is attached to the surface using a batten-bar fastening system made from aluminum. Aircraft enter the containment area by compressing the berm. Collected wastewater is pumped from the containment area to storage tanks. The system is custom-made to meet individual customer requirements (5, 40).

6.3.4 Storm Drain Inserts

Storm drain inserts or plugs are used by some airports to close storm drains and prevent glycol-contaminated wastewater from entering storm water drainage systems. Some airports, such as Minneapolis-St. Paul International Airport, have designed their own inserts, while other airports use manufactured inserts.

One company that manufactures storm drain inserts is AR Plus. This company manufactures inserts that consist of a steel plate with a gate valve, a mounting bracket with sealing mastic, and a detachable valve driver. The inserts are mounted directly beneath the storm drain grate with the steel plate bolted to the mounting bracket. During periods of aircraft deicing/anti-icing, the valves are closed manually using the detachable valve driver, thereby preventing ADF-contaminated storm water from entering the storm water drainage system. The valves can be opened when deicing/anti-icing activities cease, allowing uncontaminated storm water to pass through the drain. The steel plate containing the valve is removed for maintenance by removing the bolts that attach the plate to the mounting bracket (41).

AR Plus manufactures the inserts in standard valve diameters of 6, 8, and 10 inches. The 6-inch valve is the most commonly used. The inserts cost between \$1,200 and

\$1,800 and have a life expectancy of approximately 7 years. AR Plus also manufacture custom-made inserts for drains of unusual shape or size or to meet individual customer specifications.

Drain inserts are often used in conjunction with glycol vacuum vehicles (discussed in Section 6.3.5) to collect contaminated storm water. To enable the vacuum trucks to efficiently collect fluid retained above the insert, the drain inserts are typically mounted approximately 2 inches below the storm drain grate. Although the inserts may be mounted lower to allow the storm drains to be used as sumps, AR Plus does not recommend this practice because the valves are more difficult to inspect and maintain. In addition, residual ADF retained in the drain after evacuation may be washed into the storm water drainage system when the valve is opened.

The inserts may also be used in an emergency to prevent fuel and other spills from entering storm water drainage systems. The sealant used in the inserts was specially selected for its chemical resistance to both glycol and aviation fuel.

In response to customer comments, AR Plus is currently developing a new system that will automate the valves so that an operator could close or open several valves by pushing a single button.

6.3.5 Glycol Vacuum Vehicles

Specially designed vacuum vehicles provide an alternative approach to the collection of wastewater generated by aircraft deicing/anti-icing operations. Vacuum vehicles offer a number of advantages over traditional collection systems: (1) they are versatile, enabling wastewater to be collected at gate areas, ramps, aircraft parking aprons, taxiways, and aircraft holding pads; (2) they are cost-effective, enabling airports to avoid the high capital costs of installing traditional drainage collection systems or deicing pads; and (3) they can collect spent aircraft deicing fluid in high concentrations, making glycol recovery/recycling economically feasible. Critics of vacuum vehicles state that they are slow moving, have insufficient collection capacity, require regular maintenance by trained personnel, and cause ramp and gate area

congestion. Some airports also believe that the airport-wide use of vacuum vehicles is impractical and prohibitively expensive for airports with high traffic volumes because a large number of units would be necessary to efficiently collect the wastewater generated.

Vacuum vehicles are typically used in conjunction with storm drain inserts or valves that prevent ADF-contaminated storm water from entering storm water drainage collection systems. The contaminated storm water ponds around the closed drain grates or surface depressions and vacuum vehicles collect the ponded fluid. Aircraft parking ramps and gate areas must be cleared of snow prior to vacuum vehicle use, since collecting large quantities of clean snow along with contaminated storm water significantly lowers the efficiency of vacuum vehicles.

Several U.S. airports currently use vacuum vehicles, including Minneapolis-St. Paul International Airport, Baltimore Washington International Airport, Indianapolis International Airport, Bradley International Airport, Portland International Airport, Washington Dulles International Airport, Ronald Reagan Washington National Airport, and General Mitchell International Airport. The U.S. Air Force has also experimented with glycol vacuum vehicles and currently uses them at several bases. During deicing operations most military aircraft must be deiced prior to starting their engines; therefore, military aircraft are typically deiced where they are parked. For the military, glycol vacuum vehicles represent a low-cost collection alternative to the installation of expensive underground drainage collection systems for large aircraft parking ramps (5, 42).

Suppliers of specialized glycol vacuum vehicles for the collection of aircraft deicing fluids include Vactor Manufacturing, Tennant, Tymco, and VQuip/AR Plus. Products manufactured by these companies are discussed in detail below.

Vactor Manufacturing

Vactor Manufacturing of Streator, Illinois, has developed a vacuum truck specially designed for glycol collection called the Glycol Recovery Vehicle (GRV™). The GRV™ consists

of a front-mounted spray bar and a rear-mounted vacuum pick-up nozzle. A preheated emulsifying agent is applied to pavement surfaces using the spray bar. The emulsifying agent helps to break the cohesion between the deicing fluid and the pavement. The fluid is then vacuumed from the pavement surface by the 8-foot-wide vacuum pick-up nozzle. Once inside the collection chamber, changes in air pressure and differences in density cause the deicing fluid droplets and other debris to fall to the bottom of the chamber. The air stream is passed through a cyclonic separator to remove any fine droplets remaining in the air stream before it is released to the atmosphere (3). GRVs™ cost approximately \$262,000.

Three GRVs™ are currently used at Minneapolis-St. Paul International Airport, primarily to collect wastewater from aircraft deicing operations performed at remote locations on the airfield. The GRVs™ are owned by the glycol recycler Inland Technologies, Ltd, but are leased, operated, and maintained by Northwest Airlines. Other airports using GRVs™ include Cincinnati-Northern Kentucky International Airport, Baltimore Washington International Airport, Milwaukee's General Mitchell International Airport, Toronto's L.B. Pearson International Airport, Washington Dulles International Airport, Portland International Airport, Detroit International Airport, Des Moines International Airport, and Ronald Reagan Washington National Airport (beginning winter 1999).

Tennant

Tennant, based in Minneapolis, Minnesota, manufactures pavement scrubbers and street sweepers. The company currently offers two models that are specially adapted for collecting ADF-contaminated wastewater from aircraft deicing operations. Both models are similar in design; however, the smaller model has a collection capacity of 120 gallons, while the larger model has a collection capacity of 510 gallons. Dual high-speed brushes scrub off stains, spills, and dirt, while picking up other debris at the same time. The debris hopper is made of heavy-duty stainless steel. The optional Solution Recovery System on each model allows the operator to scrub for longer periods of time. An optional squeegee attachment is also available for picking up spills. Both units have a cleaning path width of 50 inches. The smaller model

costs approximately \$57,000, depending on the specifications of the unit, while the larger model costs approximately \$89,000. These scrubbers are also used to collect debris and spills during the nondeicing season (43).

Tennant's scrubbers are effective in small- to medium-sized airports. Both Niagara Falls Air Reserve Station in New York and the Groton-New London Airport in Connecticut currently use Tennant scrubbers (5). The Connecticut Department of Transportation first used Tennant scrubbers at Bradley International Airport but found their limited capacity was better suited to the smaller Groton-New London Airport.

Tymco, Inc.

Tymco, based in Waco, Texas, manufactures regenerative air street sweepers that use a high-velocity air jet to blast debris from pavement surfaces. The air is then drawn into a hopper where the air stream loses velocity and the heavier pieces of debris are collected. The top of the hopper is fitted with a screen to prevent light-weight materials, such as paper, from escaping from the hopper. The air stream then enters a centrifugal dust separator before being returned to the compressor. The centrifugal separator removes small particles from the air stream (44).

Tymco manufactures its sweepers in a variety of sizes, the smallest being Model 210, which is designed for use in parking lots. Tymco's largest and most powerful sweeper is Model 600, which is used by airports and the U.S. Air Force to collect debris on runways, aprons, and ramps. Tymco also sells a modified version of this sweeper, equipped with the company's Liquid Recovery System (LRS). The LRS system enables the sweeper to collect fluids from pavement surfaces, including wastewater from aircraft deicing operations. The modified sweeper has a 700-gallon storage capacity and costs approximately \$75,000. Tymco also sells retrofit kits that allow existing models to be equipped with an LRS. The kit costs approximately \$8,500. Tymco sweepers equipped with the LRS have been used at Indianapolis International Airport and at the Niagara Falls Air Reserve Station in New York. Personnel at Indianapolis International

Airport have reportedly expressed dissatisfaction with the efficiency of the LRS-equipped sweeper, which in their opinion tends to leave a large amount of residual fluid on pavement surfaces. In contrast, personnel at the Niagara Falls Air Reserve Station are reportedly pleased with the performance of their LRS-modified sweepers (5, 44).

AR Plus and VQuip

In the early 1990s, VQuip, in association with AR Plus, developed a vacuum truck specially designed to collect glycol-contaminated wastewater from aircraft deicing/anti-icing activities. A prototype unit was tested at Toronto's L.B. Pearson International Airport in 1992 (45). Unfortunately, this prototype tended to leave behind a residue and had difficulty picking up Type II fluids because of their thickening agents. Based on this experience, VQuip added a higher volume vacuum fan and a spray boom designed to remove residual fluid from pavement surfaces (1).

Today, AR Plus markets two types of VQuip vacuum units: the truck-mounted Ramp Ranger™ and larger trailer-mounted units. Both types are currently in use at Bradley International Airport in Hartford, Connecticut. The truck-mounted Ramp Ranger™ uses a high-pressure water spray, rotating brooms, and a rear-mounted, 8-foot, vacuum nozzle with squeegee to collect contaminated wastewater and other debris. Wastewater is collected in a 875-gallon storage tank mounted on the rear of the truck. Debris is swept into a hopper that has a capacity of 5 cubic yards of material. The Ramp Ranger™ travels at between 2 and 3 miles per hour and has a cleaning width of 120 inches. By using the high-pressure water spray, the Ramp Rangers™ can clean residual ADF from airfield pavements. Tests conducted by VQuip showed that the first pass of the Ramp Ranger™ reduced residual glycol on pavement surfaces to less than 100 mg/L (46).

The trailer-mounted units are towed by closed-cab tractors. These units do not have brooms or a debris hopper, but have a large-capacity collection tank. The original trailer-mounted Ramp Rangers™ were equipped with an 1,800-gallon wastewater storage tank. The

Ramp Ranger™ costs approximately \$250,000. AR Plus also rents the units to airports and airlines for approximately \$100 to \$110 per hour of operation (47).

In response to customer comments, AR Plus and VQuip developed a new high-capacity vacuum unit with a 1,000-gallon-per-minute collection rate and a larger storage tank. The new unit is similar to the trailer-mounted unit described above, but has a 4,000-gallon wastewater storage tank and two self-priming hydraulic pumps located in front of a 12.5-foot vacuum nozzle. To remove residual ADF from pavement surfaces, the new unit is equipped with three independent rotary jets supplied with water from a storage tank mounted on the rear of the tractor. The new unit operates at 2 to 3 miles per hour when water blasting and 5 miles per hour when collecting fluid.

In addition to ADF, the Ramp Ranger™ collects slush and debris from airfield pavements. In previous models, collected slush tended to form a separate layer in the storage tank. To help mix the tank contents and hasten melting of the slush, the new model is equipped with a built-in 100-gallon-per-minute recirculation pump. Debris from airfield pavements is collected in the wastewater storage tank rather than in a separate debris collection hopper. The storage tank is equipped with a discharge pump specially designed for handling fluids containing solids. A rotating blade mounted in front of the pump intake protects the pump from any large pieces of debris.

AR Plus and VQuip successfully completed field trials using a prototype of the high-capacity vacuum unit during the 1998-1999 winter season and began marketing the new model in June 1999. The unit price is approximately \$250,000.

6.3.6 Mobile Pumping Station with Fluid Concentration Sensor

AR Plus and VQuip have developed a trailer-mounted, computer-controlled pumping unit capable of measuring the glycol concentration of the wastewater and diverting it, based on glycol content, to one of three designated storage tanks. The unit, called the

Interceptor™, is currently in use at Bradley International Airport in Connecticut and Washington Dulles International Airport in Virginia. The Interceptor™ is particularly useful for airports engaging in glycol recovery/recycling programs.

The Interceptor™ consists of a diesel engine, two pumps, a microprocessor, two refractometers, two temperature probes, three flow meters, and three fluid discharge ports with automated valves. The wastewater enters the unit through two flexible hoses attached to ports at the rear of the unit. The hoses are connected to two submersible, self-priming, hydraulic pumps. The pumps may be used to pump ADF-contaminated wastewater from sumps, tanks, or dammed storm water drainage pipes. Each pump has a capacity of 400 gallons per minute and can be operated independently (47).

After entering the unit, the wastewater passes through a refractometer and temperature probe. The refractometer measurements are used to calculate the glycol concentration of the wastewater. Measurements are made once per second and recorded by the microprocessor. Wastewater temperature is measured continuously by the temperature probe, recorded by the microprocessor, and used for making temperature compensations in calculations of glycol concentration. The microprocessor analyzes the data once every 15 seconds and opens and closes valves to the discharge ports based on the glycol concentration. The unit has three discharge ports, two of which have diameters of 4 inches, while the third has a diameter of 3 inches. The 4-inch discharge ports are used for discharging wastewater with low and medium glycol concentrations. The 3-inch discharge port is used for discharging wastewater with high glycol concentration (typically greater than 15 percent). The glycol concentration ranges for the discharge ports are set by the manufacturer, but can be adjusted to meet customer requirements. Flow meters are used to measure the volume of wastewater discharged through each port.

The Interceptor™ is designed to be operated with minimum operator supervision and has a self-diagnosis system for identifying problems. When problems are encountered, the unit automatically closes all discharge ports, shuts off the unit, and activates a flashing blue beacon located on the top of the unit.

The Interceptor™ can be used for ethylene glycol- or propylene glycol-contaminated wastewater and can measure glycol concentrations between 10,000 ppm and 500,000 ppm with an accuracy of 10,000 ppm. AR Plus and VQuip hope to improve the refractometer so that glycol concentrations of 500 ppm can be detected.

6.3.7 Containment and Collection Practices for Snow Contaminated with Aircraft Deicing/Anti-icing Fluids

U.S. airports that experience heavy snowfalls typically collect snow from aircraft parking ramps and aprons, and transport it to designated collection areas referred to as snow dumps. Because most aircraft deicing/anti-icing operations are conducted at passenger terminals and aircraft parking ramps, snow collected from these locations may be contaminated with ADF, as well as small amounts of pavement deicing/anti-icing agents. Consequently, snow dumps that are used for disposal of contaminated snow should include provisions for collecting or containing the contaminated melt water. At Albany International Airport, for example, two concrete pads, each with its own drainage collection system, are used to store snow contaminated with deicing/anti-icing chemicals. As the snow melts, the melt water flows into the drains and is conveyed to the airport's wastewater storage units (32). A similar system is currently under construction at Buffalo-Niagara International Airport (7). EPA believes that collection of melt water at snow dumps used for ADF-contaminated snow has not yet become common practice.

An alternative approach taken by several North American airports is the use of specially designed, high-performance snow melters. The units may be stationary or portable, and typically consist of a tank which is equipped with a heating system and filled with water. Snow is dumped into the tank using a front-end loader. At Chicago O'Hare International Airport, for example, portable snow melters are strategically positioned at the passenger terminals and cargo aprons so that the snow melt generated drains to the airport's storm water collection system. The snow melters are manufactured by Aero Snow and are powered by jet fuel. Each unit is capable of melting 600 tons of snow per hour. The snow melters cost approximately \$14 million each, but can be leased for \$6,000 per hour per unit.

A similar system is used at Toronto's L.B. Pearson International Airport, where snow melters manufactured by Trecan Combustion Limited are used to melt ADF-contaminated snow collected from the passenger terminals. Discharge from the snow melters is collected in underground storage tanks (also used for storing wastewater from aircraft deicing/anti-icing operations) and discharged to a local POTW (5, 48). The principal disadvantages associated with snow melters are the air emissions and the operating costs.

6.4 Glycol Recycling

Due to the high biochemical oxygen demand exerted by glycol-based ADFs, many POTWs either refuse to accept ADF-contaminated wastewater from airports or charge high fees for its treatment. To alleviate this problem and meet NPDES permit requirements, several U.S. airports now recover glycol from ADF-contaminated wastewater. Although a variety of on-site treatment systems are available (see Section 7.2), glycol recycling offers airports the additional benefit of offsetting some of their treatment costs by generating revenue from the sale of the recovered glycol.

Recycling systems rely on a series of standard separation techniques to remove water and suspended solids and, in some cases, surfactants, corrosion inhibitors, and other additives from ADF-contaminated wastewater. The typical glycol recycling system is operated as a batch process due to the variation in influent composition. The glycol recycling process generally consists of several steps, which may include filtration, ion exchange, nanofiltration, flocculation, reverse osmosis, evaporation, and distillation. Filtration is the first step in all glycol recycling systems because it removes suspended solids and prevents plugging of subsequent processing units. Once filtered, the wastewater may be passed through a series of ion-exchange columns to remove dissolved solids such as chlorides and sulfates. Nanofiltration and/or flocculation may be used to remove polymer-based additives, such as thickening agents, corrosion inhibitors, and surfactants. Water may be removed using distillation, evaporation, or reverse osmosis. Recycling systems that use distillation to remove water can produce products with glycol concentrations as high as 98 percent. However, because distillation is an energy-intensive

separation method, distillation-based recycling systems have relatively high annual operating costs (49). Consequently, several recycling companies have developed less energy-intensive recycling systems that remove water using evaporation, vapor recompression, or reverse osmosis. Typical products from evaporation-based systems contain between 50 and 60% glycol, whereas those from reverse osmosis-based systems contain only about 10% glycol.

Glycol recovery systems also generate process wastewater containing small amounts of glycol and, in some cases, ADF additives. All glycol recovery systems currently in operation in the U.S. discharge their process wastewater to a POTW via a storage tank or detention pond.

Although most recycling systems can successfully recover glycol from ADF-contaminated storm water with glycol concentrations as low as 2.5% (50), airports involved in glycol recycling strive to collect wastewater with the highest possible glycol concentration. ADF-contaminated wastewater with low glycol concentration is segregated from that with high glycol concentration and stored in tanks or ponds. Ponds are sometimes equipped with covers to reduce glycol degradation by sunlight. In situations where the glycol concentration of the collected wastewater is very low, preconcentration techniques, such as reverse osmosis, can be used to increase the glycol concentration. Preconcentration methods, however, must be followed by additional steps and generally have higher capital and operating costs. In addition, reverse osmosis systems are easily fouled and may require considerable maintenance (20).

The first U.S. airport to experiment with glycol recycling was Stapleton Airport in Denver, Colorado. Prior to Stapleton's closure in 1995, Continental Airlines operated an aircraft deicing pad where storm water runoff consistently contained glycol concentrations of more than 20 percent. The runoff from this pad was collected and the glycol recovered for profit, thereby demonstrating the financial feasibility of glycol recycling from aircraft deicing/anti-icing operations. Since that time, interest in glycol recovery has increased, and today on-site recycling of ADF-contaminated wastewater is successfully performed at several U.S. airports, including Denver International Airport, Bradley International Airport, and Minneapolis-St. Paul

International Airport. Some U.S. airports collect a portion of their wastewater from aircraft deicing/anti-icing operations for off-site glycol recycling, including Newark International Airport, Des Moines International Airport, Cleveland Hopkins International Airport, Pittsburgh International Airport, Detroit Wayne County Metropolitan, and Albany International Airport. Salt Lake City International Airport and Washington Dulles International Airport will begin on-site recycling during the 1999-2000 deicing season, while T.F. Green State Airport in Providence, Rhode Island, and General Mitchell International Airport in Milwaukee, Wisconsin, are planning pilot recycling programs for the 1999-2000 deicing season. Buffalo Niagara International Airport in Buffalo, New York, plans to begin an ADF recycling program during the 2000-2001 deicing season.

6.4.1 Glycol Recyclers

There are currently five principal companies providing glycol recycling services for airports and airlines. These include Aircraft Deicing Services, Inc., The Environmental Quality Company, Inland Technologies, Ltd., AR Plus, and Deicing Systems AB. Each company's recycling system is discussed in detail below.

Aircraft Deicing Services, Inc.

Aircraft Deicing Services, Inc. (ADSI) designed and constructed the on-site glycol recycling facility currently in operation at Denver International Airport. The ADSI recycling system uses distillation to remove water from the fluid, but cannot separate mixtures of ethylene glycol and propylene glycol. Consequently, the airport allows airlines to use only propylene glycol-based ADFs.

Denver International Airport collects ADF-contaminated storm water with high glycol concentrations (up to 25%) from aircraft deicing pads. The contaminated wastewater is stored in detention ponds and tanks prior to treatment at the on-site glycol recycling facility. The fluid is preheated using a heat exchanger prior to entering an 8,000-gallon flocculation tank. The

fluid is treated with chemicals designed to speed the flocculation of surfactants, wetting agents, corrosion inhibitors, and thickening agents. The flocculation tank is cleaned annually and only trace amounts of residual solids accumulate in the tank. After flocculation, the fluid passes through two additional heat exchangers before entering a series of three packed vacuum distillation towers. Vapor from the distillation towers is condensed in an air-cooled chiller. The condensate, which typically contains about 15 to 40 ppm glycol, is discharged to a holding pond prior to discharge to a POTW. The product, which typically contains approximately 98% propylene glycol, is sold to various secondary markets. The glycol concentration of the product can be varied to meet customer needs. The profits from the sale of the recovered propylene glycol are shared between the City of Denver (who owns and operates the airport) and ADSI.

The facility can process wastewater at a rate of between 7 to 24.5 gpm for influent glycol concentrations above 10 percent. Although wastewater with glycol concentrations above 10% is preferable, this system is capable of treating wastewater with glycol concentrations as low as 2.5 percent. ADSI is also considering investing in additional equipment that would allow treatment of storm water with glycol concentrations as low as 20 ppm. The facility is capable of processing 12 to 15 million gallons of wastewater each year, and recovered 245,000 gallons of recovered propylene glycol during the 1997/1998 deicing season (50).

The Environmental Quality Company

The Environmental Quality Company (EQ) is an environmental management company based in Wayne, Michigan, that assists airports in managing wastewater from aircraft deicing operations. The company currently recycles wastewater collected at Pittsburgh International Airport and the Detroit Wayne County Metropolitan Airport. Wastewater collected at these airports is trucked to Michigan Recovery Systems, Inc., a subsidiary of EQ based in Romulus, Michigan. The plant can produce a 99% pure glycol product, but cannot separate mixtures of propylene glycol and ethylene glycol. The recycling system is operated as a batch process and can process wastewater with glycol concentrations as low as 1 percent. The water is removed using a high-efficiency evaporator followed by distillation. The product is treated with a

proprietary polishing process prior to sale. Process wastewater is discharged to a POTW, while solid wastes are disposed of off site as a RCRA nonhazardous waste. The facility processes approximately 5 million gallons of wastewater per year (51).

EQ has also developed a glycol recycling system capable of separating mixtures of ethylene glycol and propylene glycol. In 1997, the company was approached by Salt Lake City Airport Authority to design, construct, and operate a glycol recycling facility at Salt Lake City International Airport. The recycling system was constructed in 1998-1999 and is scheduled to begin operating in January 2000.

The recycling system installed at Salt Lake City International Airport is a two-step process. In the first step, a high-efficiency evaporator will concentrate the glycol to a concentration of approximately 80 percent. In the second step, vacuum distillation will remove additional water and separate ethylene glycol from propylene glycol. The glycol concentration of the influent will be approximately 2%, while the purity of the recovered glycol will be approximately 99 percent. The plant is designed to handle 72,000 gallons of wastewater per day and is expected, based on fluid usage logs and anticipated wastewater capture rates, to operate for about 280 days each year. EQ is responsible for marketing the product, which will be sold to secondary markets. Process wastewater generated by the plant will be held in storage tanks and discharged to the local POTW.

The capital costs for construction of the recycling facility were approximately \$4.5 million, of which approximately \$1 million was the cost of the distillation column required to separate ethylene glycol and propylene glycol mixtures. In addition to capital costs, the Airport Authority also incurs the plant's annual operating expenses, which are projected to be \$760,000. The revenues from sale of ethylene glycol and propylene glycol are estimated to be \$460,000 per year, leaving a shortfall of \$300,000, which will be covered by an increase in landing fees. The airport's tenants were consulted during the planning and decision-making process and agreed to pay higher landing fees, provided the Airport Authority continued to allow airlines to use both ethylene glycol- and propylene glycol-based ADFs.

Inland Technologies, Ltd.

Inland Technologies, Ltd. (Inland) is a waste management company based in Truro, Nova Scotia, specializing in the disposal and treatment of a wide range of liquid and solid wastes. In 1992, following Environment Canada's introduction of its 100 mg/L voluntary glycol guideline (discussed in Section 13.3.1), Inland was approached by a number of Canadian airports to dispose of glycol-contaminated wastewater generated during aircraft deicing/anti-icing operations. After considering the available disposal options and evaluating the secondary markets, Inland concluded that glycol recycling could provide a cost-effective means by which Canadian airports could meet the new guideline.

The recycling system developed by Inland removes water from ADF-contaminated wastewater using mechanical vapor recompression. The principal components of the system are a heat exchanger, an evaporation tank, a cyclone, and a steam compressor. The recovery process is monitored and controlled by computer. To conserve energy and improve efficiency, the influent is preheated in a heat exchanger using heat from the hot distillate and recovered product. The influent is then evaporated in the evaporation tank. Following evaporation, the glycol/steam mixture enters the cyclone where steam is separated from the recovered glycol product. The steam is then compressed and used as a heat source for the evaporation tank and heat exchanger. The recovered glycol passes through the heat exchanger before being further purified by proprietary polishing filters. The distillate is typically discharged to a POTW, while the recovered glycol may be sold to secondary markets or reformulated into a Type I fluid (52).

Inland has designed its recycling system to be self-contained and portable. The units are mounted on trailers and are capable of processing 264 gallons of wastewater per hour. The typical influent contains at least 5% glycol, which may be either ethylene glycol or propylene glycol. Because the boiling points of ethylene glycol and propylene glycol are very close, the system cannot separate mixtures of these glycols. The typical recovered product is approximately a 50% glycol and 50% water solution, although the process can achieve concentrations as high as 60% glycol. The distillate (i.e., process wastewater) typically contains 0.5% glycol (25, 52).

Inland's first recycling unit was installed at Montreal's Dorval International Airport in Quebec, Canada in 1996. Inland does not currently recover glycol from spent aircraft deicing fluids collected at Dorval International Airport because the airport is able to inexpensively dispose of wastewater at a nearby wastewater treatment plant. The facility instead recovers glycol from spent aircraft deicing fluids collected at several other Canadian airports (Montreal-Mirabel International Airport, Quebec City Airport, Ottawa International Airport, Thunder Bay Airport, and Winnipeg International Airport) and trucks it to the Dorval facility for recycling. Inland currently operates four skid-mounted processing units at Dorval.

Inland's first U.S.-based glycol recycling facility was installed in the spring of 1997 at the Minneapolis-St. Paul International Airport in Minnesota. At this airport, Inland processes glycol-contaminated storm water from aircraft deicing/anti-icing operations under a contract with Northwest Airlines. Inland charges Northwest a fixed fee for use of the glycol recycling system, while Northwest receives a portion of the revenues from the sale of the recovered product. The fee charged by Inland is based in part on the unit operating costs for the glycol recycling system, which are approximately \$0.10 to \$0.20 per gallon of recovered product. For the three years that the facility has been operational, the sale of the recovered product has always covered the operating costs. The Minneapolis-St. Paul facility also recovers glycol from spent deicing fluid collected at Des Moines International Airport in Iowa. Approximately 4,000 to 5,000 gallons of ADF-contaminated wastewater is trucked from the Des Moines airport to the recycling facility at the Minneapolis-St. Paul International Airport each winter.

Currently, Inland has glycol recycling facilities at four North American airports (Dorval International Airport in Montreal, L.B. Pearson International Airport in Toronto, Minneapolis-St. Paul International Airport in Minnesota, and Washington Dulles International Airport in Virginia). Inland's Canadian facilities typically recover ethylene glycol, while its facilities at Minneapolis-St. Paul International Airport and Washington Dulles International Airport recover the more profitable propylene glycol. In all cases, Inland personnel operate the glycol recycling system and market the recovered product. Because the demand for pure, concentrated glycol product is generally greater than the demand for its 50% glycol solutions,

Inland sells most of its product to Consolidated Recycling based in Troy, Indiana, where it is concentrated and purified using distillation. Inland has also developed a method for producing a reformulated Type I fluid by blending their 50% glycol product with additives such as wetting agents, corrosion inhibitors, and flame retardants. Inland expects to begin marketing its reformulated Type I fluid in the near future.

AR Plus

AR Plus is an aviation focused environmental firm based in Ontario, Canada that collects and recycles aircraft deicing fluid for airlines, and provides assistance to airports in managing wastewater from aircraft deicing operations. AR Plus manages a glycol collection and recycling process at Bradley International Airport in Windsor Locks, Connecticut, as well as several other North American locations.

The recycling system developed by AR Plus uses reverse osmosis to remove water from ADF-contaminated storm water. The system consists of three processing steps: (1) flocculation to remove additives and suspended solids; (2) reverse osmosis to remove water; and (3) microfiltration as a final polishing step. The system installed at Bradley International Airport is capable of processing 20,000 gallons of wastewater per day and is operated as a batch process. The glycol concentration of all wastewater received by the recycling facility is measured using a digital refractometer. This initial analysis enables AR Plus to segregate wastewater based on glycol content. Wastewater with glycol concentrations of less than 10% is processed by the system's two reverse osmosis units, which increase the glycol concentration to between 8 and 10 percent. The type of membrane used in the reverse osmosis units was selected by AR Plus for its ability to resist fouling by polymeric additives and other contaminants found in ADF-contaminated storm water. The membranes are cleaned periodically to enhance operational efficiency. Concentrate from the reverse osmosis units and collected streams with glycol concentrations above 10% are processed through a proprietary process, which removes additional contaminants. The process wastewater from the reverse osmosis units contains less than 100 ppm glycol and is discharged to a POTW.

As part of the sampling program for this study, EPA collected grab samples of the influent to wastewater treatment, effluent from the first reverse osmosis unit, and the process wastewater discharged to the POTW. As shown in the following table, the reverse osmosis treatment system was able to remove most of the pollutants detected in the influent sample, including tolyltriazole. Data provided by AR Plus show that the glycol concentration in the effluent discharged to the POTW ranges from <2 mg/L to 120 mg/L, while the chemical oxygen demand ranges from 30 mg/L to 180 mg/L. The average glycol concentration is approximately 70 mg/L, while the average chemical oxygen demand is approximately 112 mg/L.

Pollutant	Influent to First RO Unit	Effluent from First RO Unit	Effluent to POTW
Propylene Glycol (mg/L)	160,000	8,720	62.7
Ethylene Glycol (mg/L)	3,010	27.0	ND(10)
Tolyltriazole (mg/L)	90	5.9	0.13
Phenol (ug/L)	277	45.9	ND(10)
Total Organic Carbon (mg/L)	35,300	1,320	11.3
Ammonia as Nitrogen (mg/L)	22.7	4.7	0.29
Hexane Extractable Material (mg/L)	173	ND(6)	ND(5)

ND - Not detected (followed by the detection limit).

Although the AR Plus glycol recycling system can process either propylene glycol or ethylene glycol, it cannot separate mixtures of these chemicals. Due to the higher value and greater demand for recovered propylene glycol, AR Plus processes propylene glycol-based ADF at Bradley International Airport. At other locations, however, AR Plus handles storm water contaminated with ethylene glycol-based fluids. The recovered glycol may be sold to secondary markets or reformulated into ADF. AR Plus in association with Octagon Process, Inc. (Octagon), has developed a method for producing a reformulated Type I fluid by blending their glycol product with concentrated propylene glycol and additives (e.g., wetting agents, flame retardants, corrosion inhibitors). AR Plus and Octagon have begun marketing their reformulated fluid to domestic airlines and FBOs. AR Plus charges Bradley International Airport a fee for processing

wastewater with glycol concentrations less than 10%, but shares the revenue from the sale of the recovered glycol.

Deicing Systems AB

Deicing Systems AB (DSAB) is a leading European glycol recycler based in Kiruna, Sweden. The company markets a closed aircraft deicing system in which spent ADF is collected from aircraft deicing pads, reprocessed into Type I fluid at an on-site plant, and reapplied to aircraft. DSAB currently operates glycol recycling facilities at the Munich Airport in Germany, the Oslo Airport in Norway, and the Lulea Airport in Sweden (14).

The DSAB system was designed to collect wastewater from aircraft deicing and anti-icing operations with the highest possible glycol concentration by minimizing dilution from precipitation. The system installed at the Munich Airport, for example, collects runoff with an average glycol concentration of 18.6 percent. Once collected, the fluid is passed through filters and cationic and anionic ion exchange columns to remove suspended solids and dissolved salts, respectively. The fluid is then preheated by heat exchangers before entering the facility's two distillation towers. The distillation towers are operated in series, with the resulting process wastewater containing less than 1.5% (15,000 ppm) glycol. The glycol concentration of the product is monitored using a densitometer and typically contains approximately 55% glycol. The product is reformulated on site into a Type I fluid by adding additives such as wetting agents and corrosion inhibitors. The recycling process is controlled and monitored by computer, and DSAB conducts an extensive quality control program to ensure that the reformulated fluids meet the European standards for Type I fluids established by the International Organization for Standardization (i.e., ISO 11075, Aircraft Deicing/Anti-icing Newtonian Fluids ISO Type I) (5, 14). One disadvantage of DSAB's recycling/reformulation process is that it can successfully recycle only Type I fluids. DSAB reportedly experienced problems processing anti-icing fluids, whose polymer-based thickening agents tend to clog filters (5, 14).

DSAB's largest recycling/reformulation facility is located at the Munich Airport and can process 1,320 gallons/hour. The systems installed at the Lulea and Oslo airports are smaller than the Munich system and have capacities of 80 gallons/hour and 530 gallons/hour, respectively. Currently, no North American application of the DSAB recycling/reformulation system is known (49).

6.4.2 Current Uses for Recovered Glycol

Most glycol recovered from aircraft deicing/anti-icing operations is sold to chemical manufacturers for use in other glycol-based products. Recovered propylene glycol is used in several industries, including coatings, paints, and plastics. Recovered ethylene glycol is used primarily as anti-freeze in the automobile and coal industries and as a feedstock in the manufacture of polyester fibers for the garment industry. At some European airports, recovered glycol is reused as an aircraft deicing fluid after the addition of wetting agents and corrosion inhibitors.

In contrast to European practices, recovered glycol is not currently reused for aircraft deicing/anti-icing in the U.S. or Canada. North American airlines have been reluctant to use fluids made from recycled ADF due to safety issues and liability concerns. Despite this reluctance, two Canadian recyclers, Inland and AR Plus, have developed methods that enable recovered glycol to be reformulated at on-site facilities and reused as Type I fluids.

Before the reformulated fluids can be used on aircraft, recyclers must demonstrate that their fluids meet the same aerodynamic, corrosion, and performance standards required for new fluids. These standards are set by The Society for Automotive Engineers (SAE) (see Section 13.5) and, for Type I fluids, can be found in Aerospace Material Specification (AMS) 1424. The certification process involves independent laboratory testing, which is conducted at the Scientific Material International (SMI) laboratory in Miami and the Anti-Icing Materials Laboratory (AMIL) of the University of Quebec in Chicoutimi, Canada. The testing consists of material comparability tests, aerodynamic performance tests, and stability tests.

To date, Inland's reformulated fluid has been independently tested by the AMIL and SMI laboratories. According to Inland, the results show that the reformulated fluid conforms to SAE specifications. Inland plans to conduct trials to ensure that their fluid meets SAE fluid quality standards under field conditions. The company hopes to receive SAE certification for its recycling/reformulation process, which will allow Inland to sell its reformulated fluid without having each batch of fluid independently certified (25, 52).

As mentioned earlier, the AR Plus recycling/reformulation process is a collaborative effort with Octagon, an ADF formulator. AR Plus processes spent ADF in batches and sends a sample of each batch of recovered glycol to Octagon for analysis. Based on the results, Octagon calculates the correct amount of each additive needed to reformulate the fluid to meet SAE Type I specifications. AR Plus blends the recycled glycol with additives and concentrated propylene glycol provided by Octagon to produce a reformulated Type I fluid, a sample of which is sent to Octagon for analysis and certification. The blending process is conducted at the AR Plus on-site recycling facility at Bradley International Airport.

Both Inland and AR Plus expect the reformulation of the recovered glycol into a Type I fluid to greatly improve the profitability of the recycling process, particularly in Canada where use of ethylene glycol-based ADF predominates.

6.4.3 Operational and Economic Issues

Several factors affect the profitability of glycol recycling, including: (1) volume of fluid used; (2) glycol concentration of collected wastewater; (3) frequency of wastewater generation; (4) transportation costs for the wastewater and/or recovered glycol; (5) processing costs; and (6) commercial value of the recovered product. For the recycling process to be profitable, the revenues generated from the sale of the recovered glycol must equal or exceed the costs of collection and recovery. However, because glycol recycling reduces the amount and strength of wastewater, which reduces wastewater disposal costs, recycling may represent a cost-effective method of disposal even when the revenues from the sale of recovered glycol do not

offset the costs of collection and recovery. For example, airports with very high POTW discharge costs may benefit from reduced BOD and hydraulic loading surcharges.

One of the most important factors affecting the cost-effectiveness of glycol recycling is the amount of glycol in the wastewater. In general, the higher the glycol concentration of the wastewater, the easier and more cost-effective it is to process. The concentration of glycol in aircraft deicing/anti-icing runoff varies widely and is dependent on the method of collection and prevailing weather conditions. Currently, airports collect wastewater with 5% to 20% glycol concentrations using glycol vacuum vehicles (described in Section 6.3.5), storm drain inserts (described in Section 6.3.4), and/or aircraft deicing pads with drainage collection systems (described in Section 6.3.1). In the early 1990s, wastewater with glycol concentrations above 15% were thought necessary to make glycol recycling economically viable (49). Over the last two to three years, ADF recyclers have improved their processing capabilities, so that today wastewater with glycol concentrations of greater than 5% are generally considered economically feasible to recycle (20).

The value of the recovered glycol depends on the type of glycol and its concentration and purity. The market demand for ethylene glycol is generally lower and more volatile than the demand for propylene glycol. A 50% solution of propylene glycol sells for between \$0.75 and \$1.10 per gallon, while a 50% solution of ethylene glycol sells for between \$0.38 and \$0.68 per gallon. This difference is most likely because the range of industrial uses for ethylene glycol is narrower than that for propylene glycol. Consequently, most recyclers prefer to process propylene glycol-based ADF.

Although 50% glycol solutions can be sold for use as antifreeze in the automotive industry, most other industries require concentrated glycol feedstocks with high purity. As a result, the concentrated product produced by distillation-based recycling systems has a higher value than the 50% glycol solutions produced by reverse osmosis, vapor recompression, and evaporation-based systems. A highly purified propylene glycol product currently sells for between \$2.00 and \$2.50 per gallon.

As mentioned previously, mixtures of ethylene glycol and propylene glycol are difficult and expensive to separate due to the similarity of their boiling points. Recovered product that contains a mixture of propylene glycol and ethylene glycol may be difficult to sell. Mixtures of glycols are typically sold for the same price as recovered ethylene glycol products, even when the percentage of ethylene glycol is low. As a result, most airports and airlines currently recycling ADF either allow only one type of fluid to be used (Denver International Airport and Bradley International Airport) or segregate the waste streams (Minneapolis-St. Paul International Airport). The only exception is Salt Lake City International Airport, where the on-site recycling facility was designed to separate mixtures of ethylene glycol and propylene glycol.

In the past, glycol recycling was considered applicable only for major airports where large volumes of aircraft deicing and anti-icing fluids are sprayed throughout the winter season and which had the capital to invest in large on-site distillation-based systems. Recent developments have shown that on-site recycling can be successful at smaller airports, such as Bradley International Airport. In addition, some small airports have been able to transport their wastewater to nearby recycling facilities, often with the transportation costs paid for by the recycler. As a result, several U.S. airports are reported to be considering incorporating glycol recycling into their wastewater management plans, including Ronald Reagan Washington National Airport, Dallas-Ft. Worth International Airport, Buffalo Niagara International Airport, and Dayton International Airport. Nevertheless, glycol recycling may not be feasible at all U.S. airports. The volume of fluid used at very small commercial airports and U.S. Air Force bases, for example, may still be insufficient to make recycling economically viable for these facilities (42). Glycol recycling may also be uneconomical for airports located far from secondary glycol markets (e.g., Anchorage International Airport); however, recent developments in the reformulation of recovered product into Type I fluids may make on-site reuse possible.

6.5 Pollution Prevention Practices for Airfield Pavement Deicing/Anti-icing Operations

This section discusses the pollution prevention practices currently in use or under development for airfield pavement deicing/anti-icing operations. These practices include: (1) use of alternative pavement deicing/anti-icing agents; (2) implementation of alternative pavement deicing/anti-icing methods; and (3) adoption of pavement deicing/anti-icing agent minimization practices.

6.5.1 Alternative Airfield Pavement Deicing/Anti-icing Agents

Historically, urea, ethylene glycol, or a combination of the two were the pavement deicing/anti-icing agents most commonly used by U.S. airports for deicing/anti-icing airfield pavements. Propylene glycol was approved by the FAA for runway deicing/anti-icing in October 1990. Although these chemicals are very effective deicing/anti-icing agents, they have long been recognized as having an impact on the environment. This concern led to the development of several alternative pavement deicing/anti-icing products that have low aquatic and mammalian toxicities, biodegrade readily in the environment, and exert lower biochemical oxygen demand than glycol-based products. New products include solid and liquid pavement deicers/anti-icers that contain potassium acetate, sodium acetate, sodium formate, potassium formate, or calcium magnesium acetate (CMA) as the freezing point depressant. The solid pavement deicers/anti-icers are applied using the same mechanical spreaders used for urea, while the liquid deicers/anti-icers are applied using the same spray booms used for glycol-based products.

U.S. airports were initially apprehensive about replacing traditional pavement deicers/anti-icers with the new products because of higher purchase costs and concern that some of these products may contribute to the corrosion of airfield electrical systems (e.g., runway lights). An industry workgroup is currently investigating this issue. Today, many U.S. airports have phased out urea and glycol-based products, most replacing them with potassium acetate-based deicers/anti-icers. The U.S. Air Force, which banned the use of ethylene glycol-based

aircraft and pavement deicing/anti-icing products in 1992, now uses potassium acetate, sodium acetate, and sodium formate on runways and taxiways at its bases. Although urea is still widely used both by commercial airports and the U.S. Air Force, several major U.S. airports have recently discontinued its use, including Dayton International Airport, Minneapolis-St. Paul International Airport, Bradley International Airport, Newark International Airport, and Duluth International Airport.

6.5.2 Alternative Airfield Pavement Deicing/Anti-icing Methods

One method for eliminating pavement deicing and anti-icing chemicals is heating the pavement to maintain its temperature above the freezing point of water, thereby preventing ice formation. In addition to the environmental benefits associated with eliminating discharges of potentially harmful chemicals to the environment, heated pavement systems have the potential to improve passenger safety.

The leading manufacturer of heated pavement systems is Superior Graphite Company, a Chicago-based manufacturer of graphite and carbon products. In the early 1990s, this company developed the SNOWFREE™ Heated Pavement System, which uses an electrical current as the heat source. The system includes a base layer consisting of copper cables, installed perpendicular to the runway surface, embedded in a 2-inch thick conductive material composed of a mixture of synthetic graphite and asphalt. The pavement surface consists of a 2-inch layer of asphalt. Electricity passing through the conductive layer generates enough heat to maintain the temperature of the pavement surface slightly above freezing, preventing ice from forming and melting any snow that may accumulate. The system may be used on runways, taxiways, highway bridges, and ramps.

Superior Graphite Company believes the system will be effective at aircraft touchdown points and high-speed turnoffs. The system was tested at the Chicago O'Hare International Airport during the 1994 and 1995 winter seasons, where a prototype was installed on one of the airport's taxiways. The system reportedly performed well with little maintenance

required, but was expensive to operate. The cost to heat a 10,000-foot runway is estimated at approximately \$3,000 per hour. Installation costs are approximately \$15 per square foot. Although the system is expensive to operate, the company believes that these costs are largely offset by savings in deicing/anti-icing chemicals, application equipment, and labor costs. The New Jersey Department of Transportation plans additional tests of the system during the 1999/2000 winter, with an evaluation report published the following summer. No commercial application of the SNOWFREE™ system is currently known (5, 53).

A similar heated pavement system is reportedly being developed by Thermacore, Inc., based in Lancaster, Pennsylvania. The Thermacore system would use heated pipes to maintain the pavement temperature above the freezing point of water. The heating system would be activated automatically by pavement temperature sensors (discussed in Section 6.5.3) installed on the runway. The current status of this project is unknown (54).

Thermal Power Corporation, based in Almont, Michigan, manufactures a truck-mounted pavement heating system called the Heat Master™. The system was initially developed for preheating asphalt pavements for repair work, and consists of a heating panel capable of emitting 120,000 BTUs. The Heat Master™ was tested in 1994 on a runway at a general aviation airport located near Pontiac, Michigan. The test results reportedly show that the unit can melt ice layers as thick as 1.5 inches without damaging the runway surface, painted lines, or in-pavement lights. EPA currently knows of no commercial application of the Heat Master at a U.S. airport (5).

6.5.3 Airfield Pavement Deicing/Anti-icing Minimization Practices

Applying deicing/anti-icing agents in conditions where ice and snow adheres to pavement surfaces is extremely important for the safe operation of aircraft and ultimately for passenger safety. Unnecessary or over-application of pavement deicing/anti-icing agents, however, is not only harmful to the environment but also wasteful of airport resources. This section describes the methods used by U.S. airports to minimize the amount of agents applied to

airfield pavements, including: (1) adopting good winter maintenance practices; (2) using preventative anti-icing when icing conditions are forecast; and (3) using runway surface monitoring systems to provide detailed information about runway conditions.

6.5.3.1 Good Winter Maintenance Practices

Airport managers that follow good winter maintenance practices can prevent unnecessary or over-application of pavement deicing/anti-icing chemicals. Good winter maintenance practices for airports are outlined in the FAA Advisory Circular, AC 150/5200-30A, Airport Winter Safety and Operations (31). These practices include:

- Prompt treating of airfield pavements using either mechanical methods (i.e., sweepers, displacement plows, rotary plows) or anti-icing chemicals to prevent strong bonds from forming between the frozen precipitation and the pavement surface;
- Using mechanical methods to remove dry snow from airfield pavements, rather than applying deicing/anti-icing chemicals;
- Applying pavement anti-icing chemicals prior to a storm event or icing conditions, when weather forecasts indicate that ice or snow will bond to pavement surfaces;
- Applying pavement deicing/anti-icing chemicals at rates recommended by the manufacturer;
- Frequently recalibrating chemical and abrasive spreading equipment to ensure an optimal application rate;
- Monitoring weather conditions and obtaining accurate weather forecasts from the National Weather Service or a private contractor;
- Preventing snow from drifting across runways and taxiways by installing snow fences or constructing snow trenches;
- Avoiding heavy applications of sand, which can insulate ice and snow from solar radiation and deicing chemicals;

- Storing solid pavement deicing/anti-icing chemicals in enclosed buildings to prevent product degradation and leaching by storm water; and
- Wetting solid deicing/anti-icing chemicals prior to application to increase their effectiveness and reduce the potential for light-weight particles to be blown off the pavement by strong winds and/or jet blast.

These practices also improve airport safety and minimize delays for airport tenants.

6.5.3.2 Preventive Anti-Icing

By applying pavement anti-icing chemicals, such as aqueous potassium acetate, prior to the onset of freezing conditions or a storm event, airport managers can prevent strong bonds from forming between the pavement surface and ice molecules, enabling snow and ice accumulations to be removed easily using sweepers and plows. The FAA estimates that the correct application of pavement anti-icing chemicals can reduce the overall quantity of pavement deicing and anti-icing agents used at an airport by between 30 and 75 percent (55).

Correctly timing the application of anti-icing chemicals is extremely important. To be effective, anti-icing chemicals should be applied to a clean pavement while the pavement surface temperature is still above freezing. Accurate weather forecasts, combined with pavement surface temperature data, are essential for airport managers to correctly time the application of pavement anti-icing chemicals. Advanced weather forecast systems, such as the Weather Support to Deicing Decision Making system (discussed in Section 6.2.2) and runway surface condition monitoring systems (discussed in Section 6.5.3.3) are particularly useful tools for assisting airport managers with these decisions.

6.5.3.3 Runway Surface Condition Monitoring Systems

One of the best means of preventing unnecessary application of pavement deicing/anti-icing agents is using runway surface condition monitoring systems. These devices measure the pavement temperature and detect surface contamination, such as water, ice, snow,

and residual deicing/anti-icing chemicals. The typical system consists of several remote sensors embedded in the runway pavement that collect and transmit data to a control center where the data are processed by computer and displayed on monitors (55).

By enabling airport maintenance staff to continuously monitor runway surface conditions, sensors improve passenger safety and prevent unnecessary application of pavement deicing/anti-icing agents. Maintenance staff can predict freezing conditions by tracking changes in pavement temperature and can apply pavement anti-icing chemicals in a timely manner. At Dallas/Ft. Worth International Airport, for example, runways and taxiway bridges are equipped with temperature sensors, which let airport personnel monitor pavement conditions and apply anti-icing agents before pavement temperatures dip below the freezing point.

Although air temperature can be used to predict the onset of freezing conditions, it is far less reliable than pavement condition sensors. Changes in pavement temperature generally lag behind changes in air temperature and can be affected by other factors, such as humidity, wind velocity, and traffic intensity. Consequently, airports that rely solely on air temperature to decide when and how anti-icing chemicals should be applied may not be using these chemicals effectively and may apply chemicals when they are not needed (31, 55).

The FAA provides guidance to airports considering installing or updating runway monitoring systems in Advisory Circular 150/5220-13B, Runway Surface Condition Sensor Specification Guide (55). In this document, FAA recommends installing remote sensors at three locations on runways: (1) the aircraft touchdown area; (2) the midpoint; and (3) runways exits. Runways that are 3,000 feet in length need at least three sensors; longer runways need additional sensors. The FAA also recommends that sensors be installed on taxiways and aprons (55). In general, the remote sensors are expensive to install and require frequent maintenance by specially trained personnel. The cost of installation depends on the number of sensors and the complexity of the system required. For commercial airports, installing these systems typically costs more than \$100,000 (5).

One of the leading manufacturers of pavement condition monitoring systems in the U.S. is Surface Systems, Inc. (SSI), which developed the Road/Runway Weather Information System (RWIS™) for use by highway maintenance agencies and airport authorities. RWIS™ consists of surface condition sensors, atmospheric sensors, subsurface temperature probes, a data processing unit, and display software. Data on current pavement conditions is provided by SSI's FP2000 sensors, which are installed flush with, and colored to match, the pavement surface. The FP2000 sensor measures the pavement temperature and can detect surface water and measure its freezing point, depth, and deicing/anti-icing chemical concentration. Subsurface probes, installed approximately 17 inches below the FP2000 sensors, are used to measure the ground temperature; these data are used to predict future pavement surface temperatures. Atmospheric sensors are installed at the side of the runway and measure air temperature, relative humidity, wind velocity and direction, and the type and rate of precipitation. Data collected by the atmospheric and FP2000 sensors are transmitted to a data processing unit, which evaluates and stores the data at 1-minute intervals. The processed data are displayed graphically on monitors with pavement conditions color-coded. The system can also provide weather forecasts that predict pavement conditions up to 24 hours in advance. These forecasts are derived by evaluating data provided by the National Weather Service and SSI's remote sensors. SSI sensors are currently used at St. Louis' Lambert International Airport in Missouri, Springfield's Capital Airport in Illinois, Albuquerque International Airport in New Mexico, Ft. Wayne Airport in Indiana, Akron/Canton Regional Airport in Ohio, and Cincinnati/Northern Kentucky International Airport in Kentucky (56).

A similar system, called ICELERT™, has been developed by Findlay Irvine and is currently used at commercial airports, military bases, and on highways in Finland, Austria, Canada, Spain, Italy, Hungary, Britain, and Ireland. ICELERT™ is a surface condition monitoring system that uses information from pavement surface sensors, ground temperature probes, and atmospheric sensors to predict icing conditions. ICELERT™'s sensors measure pavement surface temperature, concentration of deicing/anti-icing chemicals in surface water, ambient air temperature, barometric pressure, dew point, wind velocity and direction, and

precipitation. The system uses these data together with information from local meteorological agencies to provide 24-hour forecasts of pavement conditions (57).

The principal disadvantage of these systems is the high capital and operating costs associated with installing and maintaining the remote sensors. These costs can be avoided by using portable sensors, mounted on airport maintenance vehicles. These devices use infrared-based technology to measure the pavement temperature and display the results on a monitor or gauge mounted on the vehicle dashboard. Companies currently manufacturing portable pavement temperature sensors include Sprague Heavy Duty Technology Group and Control Products, Inc. The portable sensors cost between \$2,500 and \$2,700, and are used at some U.S. Air Force bases (5).

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7.0 WASTEWATER CONTAINMENT AND TREATMENT

Many airports have installed wastewater containment and treatment systems, often in combination with pollution prevention controls described in Section 6.0, to comply with discharge requirements for storm water contaminated with deicing agents. This section describes the types of containment and treatment technologies used by airports and available treatment performance data for these technologies. Table 7-1, at the end of this section, summarizes the airport systems described in this section; costs for these systems are included in Section 11.0. Note that the glycol recycling systems described in Section 6.4 also serve as “wastewater treatment” in that they remove glycol and other pollutants of concern from airport deicing/anti-icing fluids (ADF)-contaminated wastewater. Appendix A contains information regarding the location of airports referenced in this section.

7.1 Wastewater Containment

Of significant concern for contaminated storm water discharges, both directly to surface waters and indirectly to publicly owned treatment works (POTWs), is the high variability and unpredictability in hydraulic and pollutant loading. Airports have large impervious areas for gates, aprons, ramps, taxiways, runways, roads, and parking lots, which contribute to hydraulic loading. Major winter storms can require application of large amounts of aircraft and pavement deicing chemicals within a short period of time that can result in a “slug” loading of these chemicals in storm water discharges. To help mitigate storm water flow variability and slug discharges, many airports have constructed storm water containment systems either as part of the original airport design or in response to more recent storm water discharge requirements. Common types of storm water containment at airports are retention ponds, underground storage basins, and storage tanks.

The cost of these structures and their associated drainage systems is directly proportional to the size of the area serviced by the system and the volume of precipitation expected. As a result, at most airports, these systems service only those areas where aircraft

deicing operations are performed. Furthermore, many airports also incorporate diversion devices (e.g., valves and gates) such that deicing operation areas are only serviced when glycol or a surrogate parameter is detected in storm water, which further reduces the size and cost of the containment system. EPA identified several airports that use containment systems to control discharges of ADF-contaminated wastewater to surface waters and POTWs (described below), and believes other airports may have constructed containment systems.

Runoff from runways and other large paved areas are generally discharged without treatment because of the high cost of controls. However, discharges from these areas may contain high pollutant loadings. For example, during a 1998 conference and exposition sponsored by the American Association of Airline Executives and the Airport Council International - North America, a consultant working for Portland International Airport indicated that runway deicing operations contributed one-third of total deicing-derived biochemical oxygen demand (BOD) discharges to surface waters. Although many airports have stopped using glycol-based chemicals for pavement deicing, their increased use of Type IV deicing fluids, designed to shear from aircraft surfaces during takeoff, may contribute to pollutant loadings discharged from runway areas. EPA currently knows of only one U.S. airport, Chicago's O'Hare International Airport, and two European airports, Munich Airport in Germany and Stockholm-Arlanda Airport in Sweden, that collect a portion or all of the contaminated storm water from runways and taxiways. Airport wastewater containment systems are also described below.

Portland International Airport, Portland, OR (PDX)

Currently, ADF-contaminated wastewater from the gate areas is discharged directly to the Columbia Slough via nine major outfalls. The Columbia Slough flows to the Willamette River (1).

A long-term plan being developed jointly between the airport and the airlines, in accordance with a NPDES permit issued by the Oregon DEQ, includes an airport-wide deicing runoff containment system. The system will use in-line BOD meters to monitor glycol

concentrations in runoff. Higher-strength ADF-contaminated wastewater collected near the terminal areas will be conveyed to storage tanks followed by controlled discharge to a POTW. Lower strength wastewater will be diverted to a 13-million-gallon, aerated retention pond for biological pretreatment prior to controlled discharge to the Columbia Slough in compliance with the waste load allocations for BOD₅ specified in the Columbia Slough TMDL. See Section 13.2.2 for a description of Portland's TMDL-based permit (1, 2).

Billings Logan International Airport, Billings, MT (BIL)

Storm water contaminated with ADF enters the storm drain system that flows to four detention ponds operated in series. Storm water enters the first pond, which overflows to the second pond, and so forth. Overflow from the fourth pond is discharged to a nearby creek. In general, the first pond is large enough to contain all glycol-contaminated wastewater generated during the winter. Spring precipitation then usually fills all four ponds, resulting in the eventual discharge of the collected glycol-contaminated wastewater. Airport personnel indicated that most of the glycol has biodegraded in the ponds prior to discharge.

Chicago O'Hare International Airport, Chicago, IL (ORD)

Deicing/anti-icing fluids from all of the aircraft deicing/anti-icing areas and 50% to 70% of the pavement enter Chicago O'Hare International Airport's storm water drainage systems and are collected and retained in one of the airport's two storm water detention ponds, the South Detention Pond and the North Airfield Detention Pond. The South Detention Pond has a capacity of approximately 1,120 acre-feet and services the southern part of the airfield, which includes wastewater from aircraft deicing/anti-icing operations conducted at the airport's passenger terminals and cargo ramps. The Northern Detention Pond has a capacity of 45 acre-feet and services an aircraft deicing pad storm water drainage system. Both ponds discharge at a controlled rate to local POTWs. Total wastewater discharge fees range from \$800,000 to \$1 million per year and are based on the volume of wastewater treated, BOD₅, and suspended solid loadings.

Contaminated storm water from the northern part of the airfield, including portions of two runways and their associated taxiways, drains into nearby creeks. Airport managers are working on plans to construct a storm drainage system around these runways and taxiways, which will collect the contaminated storm water and convey it through underground pipes to a detention pond for eventual discharge to a POTW.

Minneapolis-St. Paul International Airport, Minneapolis, MN (MSP)

Minneapolis-St. Paul International Airport uses compression plugs in their storm water system (discussed in Section 6.3.2) to collect ADF-contaminated wastewater for subsequent glycol recycling/recovery. The airport estimates that more than 40% of all fluid applied is collected in the storm water retention system. However, some collected wastewater is too dilute for economically viable glycol recycling/recovery. Dilute wastewater is evacuated as needed using pump trucks and transported to one of two 1-million-gallon, nonaerated storage ponds dedicated for lower strength wastewater. (Three ponds and associated equipment, including a boiler and recirculation system to protect against pond freezing, were constructed in 1993 at a cost of \$1 million.) The ponds are alternately filled and then slowly discharged to the POTW. On average, the low-strength ponds contain wastewater with propylene glycol concentrations of 2 percent. Wastewater discharge fees include \$0.056 per pound of chemical oxygen demand (COD) for concentrations greater than 500 mg/L, as well as sewerage fees assessed by wastewater volume, for a total annual cost ranging from \$150,000 to \$200,000.

Dallas/Ft. Worth International Airport, Dallas, TX (DFW)

In 1999, the Dallas/Ft. Worth International Airport constructed nine deicing pads at a cost of over \$16 million for deicing/anti-icing operations with a total of 53 aircraft positions. The airport is now able to collect and contain all ADF runoff generated on these pads. The deicing pads are strategically located around the airport near both runway thresholds and terminal egress taxiways. All pads are common use facilities, and each airline is free to select the pad that

best suits its needs. Operational experience has shown that the airlines primarily use the threshold pads during intense periods of deicing.

When deicing/anti-icing activities are occurring, the runoff from the pads is directed to collection tanks located at each deicing pad. The collection tanks have a combined volume of over 1.5 million gallons and can be emptied by tank trucks within 24 hours. Precipitation and runoff from the pads immediately after deicing is also collected to ensure that no residual deicing fluid remains.

The airport has contracted the collection of deicing runoff to Inland Technologies. Inland is obligated to pick up by tank truck all fluid collected in the collection tanks. Depending on the concentration of the runoff, or their system capacity, Inland may either recycle, biologically treat on site, or ship off site the fluid they collect. For biological treatment, Inland will use the airport's detention ponds which were constructed in 1997 at a cost of \$1.7 million. The ponds are covered and lined with membranes. The combined capacity of the detection ponds is 6 million gallons. Following biological treatment, the fluid may be discharged to the POTW, which requires the wastewater to have a BOD₅ of less than 250 mg/L. The POTW charges a hydraulic loading fee of \$1.07/1,000 gallons.

Following completion of deicing/anti-icing operations, the airport ensures that any ADF runoff remaining on the pads is removed prior to directing runoff to the airport's pretreatment system. This system is specially designed to collect "first flush" precipitation contaminated with oil and grease from spills on ramps and gate areas. Specifically, storm water enters drains and flows to diversion boxes that each contain an inflow pipe and two outflow pipes positioned one above the other. The lower outfall pipes drain to the airport's pretreatment plant. The upper outfall pipes discharge to the airport's general storm water collection system and ultimately to U.S. surface waters during periods of high storm flow (3).

Denver International Airport, Denver, CO (DIA)

At Denver International Airport, aircraft deicing operations are performed primarily at specially designed deicing pads (discussed in Section 6.3.1) where large volumes of high concentration ADF-contaminated wastewater are collected for glycol recycling/recovery. In addition, limited aircraft deicing is performed in the gate areas. Airport personnel estimate that approximately 70% of all ADF applied at the deicing pads and gate areas is subsequently collected. Runoff from the gates flows by gravity to the east and west detention ponds, which have a combined capacity of 12 million gallons. The ponds are a component of a large wastewater collection system project constructed in 1995 at a total cost of \$36 million. (Airport construction was completed in 1994, and airfield operations began in 1995.) One of the ponds is separated into two cells. When the first cell is full, the wastewater is pumped to the second cell, where it is mixed for 12 hours to homogenize the wastewater prior to discharge. Since the other pond has only one cell, this pond is not mixed prior to discharge. The wastewater from each pond is tested to determine its characteristics and discharged at a controlled rate to the POTW. The POTW places surcharges on excess BOD, total Kjeldahl nitrogen, and hydraulic flow. Airport personnel stated that these surcharges total approximately \$550,000 per year.

Salt Lake City International Airport, Salt Lake City, UT (SLC)

Salt Lake City International Airport has constructed specially designed aircraft deicing areas where runoff is collected for subsequent glycol recycling/recovery (see Section 6.4.1, Environmental Quality Company (EQ)). However, some collected wastewater is too dilute for economically viable glycol recycling/recovery. EQ dedicated one of three, newly constructed, 3-million-gallon detention ponds for lower-strength wastewater, which is discharged to a POTW. The ponds are part of a large wastewater collection system and glycol recycling/recovery project constructed in 1998 at a total cost of \$28 million. Each detention pond is lined with clay and a membrane liner, and covered with a floating membrane to reduce degradation of glycol by ultraviolet light and bacterial action. Currently, wastewater with BOD concentrations greater than 200 mg/L are subject to a POTW surcharge of \$0.05/lb BOD.

Buffalo-Niagara International Airport, Buffalo, NY (BUF)

In areas where aircraft deicing/anti-icing operations are performed, Buffalo-Niagara International Airport installed storm water collection systems equipped with diversion valves to direct storm water to either an underground storage basin (ADF-contaminated wastewater) or an underground storm water detention basin (non-ADF-contaminated wastewater). The ADF-contaminated wastewater storage basin is lined with a membrane and has four chambers, each with a capacity of 50,000 gallons. Wastewater from the storage basin is discharged to a POTW, which requires the airport to meter their discharge based on glycol loading. Wastewater with BOD concentrations greater than 250 mg/L is subject to an additional surcharge of between \$0.10 and \$0.105 per gallon. The annual BOD surcharge ranges from \$1,800 to \$2,400.

Kansas City International Airport, Kansas City, MO (MCI)

In the main gate and terminal areas where aircraft deicing/anti-icing operations are performed, Kansas City International Airport is upgrading their existing storm water collection systems to include diversion valves to direct storm water to either a concrete storage basin (ADF-contaminated wastewater) or a series of storm water retention ponds (non-ADF-contaminated wastewater). The storage basin consists of two, 1-million-gallon chambers operated in parallel with one filling while the second is discharging to the POTW. Wastewater is discharged at a controlled rate based on flow and BOD₅ loading.

The Federal Aviation Administration (FAA) and Kansas City International Airport funded modifications to the POTW to handle the ADF-contaminated wastewater discharged from the airport. The total capital cost of upgrading the storm water collection system, installing the storage basin, and upgrading the POTW is estimated to be \$8.5 million, of which 75% will be funded by the FAA and the remainder by the airport.

Baltimore/Washington International Airport, Baltimore, MD (BWI)

Baltimore/Washington International Airport has invested approximately \$22 million on deicing control facilities including three deicing pads, each equipped with runoff drainage and collection systems, storm water diversion trenches at multiple locations at the passenger terminal gates, and glycol vacuum trucks. Under nondeicing conditions, storm water is directed to the airport storm water drainage system. During deicing events, diversion valves are actuated to direct ADF-contaminated wastewater to collection vaults for transfer to temporary storage tanks. Two of the three deicing pads each include two 20,000-gallon, above-ground temporary storage tanks. Wastewater from these tanks is transported to the third deicing pad via tank truck. The third deicing pad includes a lift station to transfer wastewater from all three deicing pads to a central wastewater storage area, which includes a 600,000-gallon, above-ground storage tank surrounded by a 5- to 6-foot concrete containment wall. From the central storage area, wastewater is discharged at a controlled rate to the POTW based on BOD loading. Wastewater discharge fees are \$0.0024 per gallon (4).

Des Moines International Airport, Des Moines, IA (DSM)

All aircraft deicing operations are performed on an apron rebuilt in 1995 to allow collection of all runoff from this area. The airport collects approximately 30% of all ADF applied. The airport is currently constructing a 4-million-gallon storage tank (cost: \$8 million) to contain runoff from the apron beginning in the 1999/2000 deicing season (2). During the winter months, when deicing events are likely to occur, wastewater from the tank will be discharged at a controlled rate to the POTW. For the remainder of the year, the tank contents will be discharged directly to surface waters. The tank will be equipped with a TOC analyzer to indicate the presence of glycol.

Hopkins International Airport, Cleveland, OH (CLE)

Hopkins International Airport uses compression plugs (discussed in Section 6.3.2) in their storm water system to collect ADF-contaminated wastewater for subsequent glycol recycling/recovery. However, they consider some of the collected wastewater to be too dilute (i.e., less than 11% glycol content) for economically viable glycol recycling/recovery. Dilute wastewater is evacuated as needed using pump trucks and transported to one of eight 21,000-gallon storage tanks dedicated for lower-strength wastewater. Dilute wastewater from the storage tanks is then discharged at a controlled rate to the POTW. Wastewater discharge fees are \$0.04 per gallon.

Washington Dulles International Airport, Herndon, VA (IAD)

Washington Dulles International Airport is implementing an ADF-contaminated wastewater collection and storage system for use beginning in the 1999/2000 deicing system. Wastewater will be collected from deicing operation areas using glycol vacuum vehicles (see Section 6.3.5) and transferred to storage tanks. Wastewater with high glycol content (7% or greater) will be stored in a 500,000-gallon storage tank and in twenty 20,000-gallon storage tanks for eventual transport for on-site glycol recycling/recovery. Dilute wastewater (<7%) will be stored in a 300,000-gallon storage tank for discharge at a controlled rate to a POTW. The airport plans to begin discharging to the POTW in January 2000.

Prior to implementing this system, most storm water runoff at Washington Dulles International Airport, including that from the primary and two of the three secondary deicing areas, drained into Horsepen Lake, a man-made impoundment, either by overland flow or through storm drains after traveling three to four miles. The total drainage area for the lake is 23 square miles. Water from the lake is discharged to Broad Run, a tributary to the Potomac River.

Munich Airport, Germany (MUC)

At Munich Airport, a system of drainage channels connected to underground pipes is used to collect contaminated storm water from the runways and convey it to a wastewater storage complex. The storage complex consists of an underground concrete storage basin with a capacity of 16 million gallons and a lined detention basin with a capacity of 21 million gallons. Wastewater from the storage complex is discharged at a controlled rate to a local wastewater treatment plant. Contaminated storm water from the airport's taxiways is also collected and treated on site as described in Section 7.2.3 (5).

Stockholm-Arlanda Airport, Sweden (ARN)

Stockholm-Arlanda Airport installed a high-density polyethylene membrane with a bentonite and sand lining beneath the airport's new runway to prevent seepage of aircraft and pavement deicing/anti-icing chemicals into an aquifer that lies directly beneath the runway. The membrane collects storm water from the runway and diverts it to a storm water drainage system. The membrane is monitored using leak detection equipment and groundwater monitoring wells (5).

7.2 Wastewater Treatment

This section describes on-site wastewater treatment used by airports to control deicing chemical discharges to surface waters and POTWs.

7.2.1 Biological Treatment

Because of the high oxygen demand of ADF-contaminated wastewater, many airports rely on biological treatment as a cost-effective and efficient treatment technology. The principle advantages of biological treatment specific to airport deicing operations include: (1) capability to treat both high-strength and dilute wastewaters, (2) capability to treat wastewater

containing ethylene glycol, propylene glycol, or a mixture of both, (3) capability for use with any wastewater collection system (systems described in Sections 6.3 and 7.1), and (4) competitive treatment costs as compared to glycol recycling. Where feasible, airports generally choose off-site biological treatment via discharge to a POTW. Table 13-1, at the end of this section, lists facilities known to discharge to a POTW and their discharge requirements. However, several airports choose on-site biological treatment for a variety of reasons including: (1) limited hydraulic or loading capacity at the POTW, (2) high POTW wastewater treatment and/or conveyance fees, (3) inability of local POTW to handle highly variable pollutant loadings, and (4) airport infrastructure constraints. Wastewater treatment at these airports is described below.

Airport biological treatment systems generally include a means of wastewater equalization to avoid system upset by flow variability and slug loadings. Airports using pond-based biological treatment systems generally use their ponds for both wastewater equalization and wastewater treatment (see discussion of Greater Rockford Airport below). Other airports use ponds solely for wastewater equalization. For example, Albany International Airport, discussed below, operates extensive wastewater equalization in ponds prior to biological treatment.

Note that any airport operating contaminated storm water containment systems, where wastewater is retained through warmer spring months, likely achieves some degree of natural biological degradation of glycol prior to discharge. One example is Billings Logan International Airport discussed earlier in this section.

Greater Rockford Airport, Rockford, IL (RFD)

Greater Rockford Airport operates an aerobic biological treatment system consisting of a 16-million-gallon aerated detention pond, a settling pond, a recycling pump, and a chemical addition building. The system was constructed in 1994 at a capital cost of \$1.8 million. Estimated annual operating costs (i.e., electricity, chemicals) are \$108,000 and estimated annual labor costs are \$60,000 to \$75,000. Contaminated storm water enters a detention pond, which is lined and fitted with four mechanical and 12 aspirating aerators. Wastewater is retained in the

detention pond during the deicing season, and released in spring or early summer. During this time, microorganisms present in the pond biodegrade ethylene and propylene glycols. The biodegradation of glycol is temperature-dependent and mainly occurs during the spring and early summer months when ambient temperatures are higher. Airport personnel estimate that the BOD₅ of contaminated storm water entering the detention pond during the deicing season may reach a high of 2,000 mg/L. By midsummer, biodegradation has reduced the BOD₅ to less than 30 mg/L (typically 10 mg/L). Prior to discharge, the treated wastewater is transferred to the 5-million-gallon settling pond and then slowly discharged to the Rock River over a two- to three-week period.

The pond system has operated for five years with minor sludge buildup that has not required removal. Airport personnel anticipate that any sludge removed from the ponds in the future would be land-applied on site.

The table below presents EPA's sampling data for Greater Rockford Airport's wastewater treatment system. Note that during the 1998-1999 deicing season (when EPA collected samples at Greater Rockford Airport), BOD₅ concentrations in the pond did not exceed 100 mg/L. In addition, during the three-week period immediately preceding collection of the influent sample, ambient temperatures were unseasonably warm with daily highs reaching above 70°F on five separate days. Consequently, EPA believes that some treatment had already occurred prior to collection of the influent sample. This conclusion is further supported by the analytical data, which shows that glycols, known to biodegrade rapidly, were not detected in the influent sample. Note that the treatment system removed toxic additives (e.g., tolyltriazole).

Pollutant	Influent Concentration	Effluent Concentration
Propylene Glycol (mg/L)	ND (5)	ND (5)
Ethylene Glycol (mg/L)	ND (10)	ND (10)
Tolyltriazole (mg/L)	0.12	0.013
Phenol (ug/L)	ND (10)	ND (10)
Total Organic Carbon (mg/L)	12	9.0
Ammonia as Nitrogen (mg/L)	46	0.27
Hexane Extractable Material (mg/L)	100	ND (6)

ND - Not detected (followed by the detection limit).

The airport submitted weekly monitoring data for the wastewater treatment facility detention pond for September 28, 1998 through July 7, 1999. The airport also submitted daily discharge monitoring data for July 20, 1999 through August 26, 1999. These data are summarized below.

Pollutant	Detention Pond Concentration		Discharge Concentration	
	Average	Range	Average	Range
Biochemical Oxygen Demand, 5-Day (mg/L)	37	ND (10) - 98	5.3	3 - 10
Ammonia as Nitrogen (mg/L)	24	ND (0.5) - 82	0.5	0.5 - 0.55
Total Suspended Solids (mg/L)	38	ND (5) - 325	7.1	ND (5) - 12

Duluth International Airport, Duluth, MN (DLH)

Duluth International Airport operates storm water retention ponds equipped with aeration systems to biologically degrade glycol and improve water quality prior to discharge to surface waters. The airport plans to upgrade the aeration system to include filtration and chlorination.

Albany International Airport, Albany, NY (ALB)

Albany International Airport operates an anaerobic biological treatment system consisting of two fluidized bed biological reactors currently operated in parallel with the capability of operating in series when required. Each unit is 14 feet in diameter, 35 feet in height (including a 4-foot freeboard), and packed with 10 tons of granular activated carbon. The treatment system was constructed in 1998 at a capital cost of \$3.2 million and is preceded by a total of 11 million gallons of deicing storm water retention and equalization (retention ponds and a storage tank). The airport collects and treats approximately 70% of all ADF applied.

The treatment system was designed and constructed by EFX Systems, Inc. and Clough-Harbour Technical Services, LLC to meet the Airport Authority's design-build performance specifications. These requirements included: (1) a minimum influent flow rate of 100 gallons per minute (an annual total of 31 million gallons), (2) reduction of the propylene glycol concentration from an average of between 4,800 and 7,500 mg/L to below the detection limit of 1 mg/L, and (3) reduction of COD by greater than 90 percent.

Deicing storm water is recirculated through the unit to increase the residence time and equalize influent characteristics. Under anaerobic operating conditions, glycol is converted primarily to methane gas, carbon dioxide, and biomass. Some glycol is also converted to propionic acid. The system is self-sustaining by reusing methane for process and space heating. Final effluent is stored prior to either commercial spray irrigation to the airfield or discharge to the POTW during winter months. The system includes separators to capture and return carryover bed carbon. Excess biomass, which is too fine to be removed by the separators, exits with effluent for discharge through airfield spray irrigation.

EPA's sampling data for Albany International Airport are presented below. Note that the treatment system removed toxic additives (e.g., tolyltriazole) as well as glycol. This analysis was conducted prior to establishment of aerobic polishing filtration units, which reportedly reduce effluent to below threshold limits for all permit parameters.

Pollutant	Influent Concentration	Effluent Concentration
Propylene Glycol (mg/L)	2,700	ND (5)
Ethylene Glycol (mg/L)	ND (10)	ND (10)
Tolyltriazole (mg/L)	>2.00	0.107
Phenol (ug/L)	109	ND (10)
Total Organic Carbon (mg/L)	2,420	ND (10)
Ammonia as Nitrogen (mg/L) (a)	88.1	87.2
Hexane Extractable Material (mg/L)	ND (6)	ND (5.5)

ND - Not detected (followed by the detection limit).

(a) According to airport personnel, the ammonia concentration indicates an anomaly condition not representative of typical deicing wastewater at Albany International Airport. Subsequent ammonia analysis conducted by the airport established maximum effluent concentrations of less than 45 mg/L. Subsequent to EPA's sampling episode, the airport installed an aerobic polishing filtration unit, which reportedly reduces ammonia concentrations to less than 5 mg/L.

The airport installed and began operating the EFX biological treatment system during the 1998-1999 deicing season. The system was required to undergo an acceptance period where the system was operated 30 consecutive days at an average daily applied loading rate of 3,500 kg COD/day (10% above the design maximum loading rate). The results from this acceptance period are presented below.

Pollutant	Influent Concentration		Effluent Concentration	
	Average	Range	Average	Range
Propylene Glycol (mg/L)	4,400	3,400 - 5,500	0.28	ND (0.05) - 0.85
Biochemical Oxygen Demand, 5-Day (mg/L)	NA	NA	57	39 - 75
Chemical Oxygen Demand (mg/L)	8,600	420 - 9,300	110	70 - 610

NA - Not available.

Airborne Air Park, Wilmington, OH (ILN)

Airborne Air Park operates a pilot-scale reciprocating subsurface aerobic/anaerobic biological treatment system in which glycol-contaminated wastewater flows through beds of gravel that is planted with wetland plants. The reciprocating design, whereby wastewater is alternately transferred between pairs of partner cells, enhances biological degradation. The full-scale system is currently under construction for use beginning in the 2000-2001 deicing season to

treat all dry-weather flows and nonpeak wet-weather flows from areas where aircraft deicing is performed. Airport personnel estimate that 90% of ADF-contaminated wastewater will be treated by the system. The cost of the treatment system is not known.

Biological degradation occurs primarily via bacteria attached to the gravel and secondarily by the wetland plants. Bacteria populations are both aerobic and anaerobic, with aerobic bacteria degrading glycols and anaerobic bacteria degrading excess biological solids. Performance data for the pilot-scale treatment system are presented below.

Subsurface Treatment System Type	Removal Rate (lb COD per mgal per ft ³ of substrate)	Average Influent COD (mg/L)	Average Effluent COD (mg/L)	Range of Influent COD Treated (mg/L)	Range of Effluent COD (mg/L)
Conventional	0.6	959	783	100 to 500	24 to 380
Reciprocating	7.5	1960	383	260 to 12,000	42 to 2,990

7.2.2 Oil/Water Separation

Some airports operate oil/water separators to mitigate any potential petroleum spill. Chicago O'Hare International Airport operates an oil/water separator consisting of a skimmer and underflow weir at each inlet to its storm water retention pond. Greater Rockford Airport operates a static inclined plate oil/water separator prior to the inlet to its aerated detention pond. Seattle/Tacoma International Airport in Washington State separately conveys contaminated storm water collected from areas where aircraft deicing operations are performed and industrial wastewater generated at the airport to an on-site industrial waste treatment system. The system consists of storage/equalization, settling, and dissolved air flotation prior to its discharge to the Puget Sound. (Note that the airport plans to discharge to a POTW in the future.) Dallas/Ft. Worth International Airport incorporates baffles in storm water diversion boxes to separate any oil and grease. In addition, ADF-contaminated wastewater is routed through a grit chamber and oil skimmer prior to entering the airport's new detention basins. Anchorage International Airport in Alaska operates watershed protection stations which include (in addition to other controls described in Section 7.2.3) oil/water separators to skim and remove petroleum

products from drainage ditches flowing to nearby lakes. Oil/water separation is not useful in removing glycol and other dissolved pollutants in ADF-contaminated wastewater.

7.2.3 Land Application

Albany International Airport disposes of some of its effluent from their on-site anaerobic biological treatment system via airfield spray irrigation as a cost-effective alternative to discharging to the POTW. Installation of the irrigation pipe gallery array covering approximately 40 acres cost less than \$110,000 plus airfield maintenance labor. Spray irrigation is performed at a rate of 150 gallons per minute and BOD loading of less than 10 pounds of BOD per acre per day. Their New York State discharge permit allows irrigation discharge of up to 500 pounds of BOD per acre per day when soil temperatures are above 50° F. Biological treatment plant effluent is continuously monitored via a 24-hour composite sampler to ensure adherence to permit requirements.

Almost all U. S. airports maintain vegetative swales between impervious areas to help mitigate storm water runoff and allow deicing chemicals to degrade naturally. For example, Anchorage International Airport maintains oversized open drainage swales to allow natural biodegradation, filtration, settling, and evaporation of storm water runoff. To a limited extent, existing wetland receive some of the ADF-contaminated storm water for natural degradation. Duluth International Airport conveys some ADF-contaminated storm water to retention areas that do not drain to surface waters, where the storm water is allowed to evaporate and infiltrate the ground.

Baltimore/Washington International Airport has constructed infiltration facilities throughout its airfield designed to temporarily store and infiltrate runoff from the first one-half inch of each rain event into the underlying soils. The infiltration facilities consist of gravel-filled trenches installed parallel to runways and taxiways. Excess water overflows the trenches and is directed either to storm water retention areas or to specially designed overland flow through grass meadow strips and a shrub bed prior to discharge (6).

At the Munich Airport, contaminated storm water from the airport's taxiways is collected and treated by a specially designed biodegradation system installed approximately 1 foot beneath the taxiway surface. This system consists of two layers of impervious fabric enclosing a 1-mm thick layer of bentonite powder. The top fabric layer is overlain with a layer of loosely packed sand, which is seeded with bacteria to biodegrade aircraft and pavement deicing/anti-icing chemicals (4).

7.3 **References**

1. Letter from Cheryl R. Koshuta, Port of Portland, to Shari H. Zuskin, U.S. EPA. November 1, 1999 (DCN T11067).
2. Letter from Scott F. Belcher, Air Transport Association, to Shari Zuskin Barash, U.S. EPA. November 4, 1999 (DCN T11063).
3. Letter from Darcy Zarubiak, Dallas/Ft. Worth International Airport, to Shari Zuskin, U.S. EPA. December 22, 1999 (DCN T11085).
4. Maryland Aviation Administration. Aircraft Deicing Plan Update, Baltimore/Washington International Airport. August 1998 (DCN T10697).
5. U.S.A.F. Air Combat Command. Literature and Technology Review Report for Aircraft and Airfield Deicing. September 1997 (DCN T10450).
6. Maryland Aviation Administration. Interim Report, Mass Balance Study Aircraft Glycol Deicers, Baltimore/Washington International Airport. September 1998 (DCN T10698).

Table 7-1**Summary of Wastewater Containment and Treatment at Airports**

Airport	ADF-Contaminated Wastewater Collection/Treatment
Portland International Airport (PDX)	High strength to POTW Low strength to pond and direct discharge
Billings Logan International Airport (BIL)	Retained in a series of ponds; direct discharge in spring
Chicago O'Hare International Airport (ORD)	Retained in ponds; discharge to POTW
Minneapolis-St. Paul International Airport (MSP)	High strength to glycol recycling Low strength to ponds; discharge to POTW
Dallas/Ft. Worth International Airport (DFW)	Retained in detention basins; discharge to POTW
Denver International Airport (DIA)	Deicing pad runoff to glycol recycling. Gate runoff to detention ponds; discharge to POTW
Salt Lake City International Airport (SLC)	High strength to glycol recycling Low strength to detention pond; discharge to POTW
Buffalo-Niagara International Airport (BUF)	Retained in underground storage basins; discharge to POTW
Kansas City International Airport (MCI)	Retained in storage basins; discharge to POTW
Baltimore/Washington International Airport (BWI)	Retained in storage tanks; discharge to POTW Runway and taxiway runoff to infiltration system
Des Moines International Airport (DSM)	Retained in storage tank; discharge to POTW
Hopkins International Airport (CLE)	High strength to glycol recycling Low strength to storage tanks; discharge to POTW
Washington Dulles International Airport (IAD)	High strength to glycol recycling Low strength to storage tank; discharge to POTW
Munich Airport (MUC)	Runway runoff to basins; discharge to POTW Taxiway runoff to on-site biodegradation treatment system
Stockholm-Arlanda Airport (ARN)	Runway runoff drainage system to direct discharge
Greater Rockford Airport (RFD)	Retained in aerated detention pond; direct discharge in summer
Duluth International Airport (DLH)	Retained in aerated retention pond; direct discharge
Albany International Airport (ALB)	Retention ponds and storage tank to on-site anaerobic fluidized bed reactor; discharge to POTW or land application
Airborne Air Park (ILN)	Drainage to on-site reciprocating aerobic/anaerobic treatment system; direct discharge

8.0 WASTEWATER CHARACTERIZATION

As part of the characterization of airport deicing operations, EPA assessed what constituents may be present in airport deicing/anti-icing fluid (ADF)-contaminated wastewater. Information presented in this section is based on data provided by the industry, EPA's compliance data, and EPA's site visit and sampling programs. Section 8.1 presents industry self-monitoring data; Section 8.2 presents data from EPA's permit compliance system (PCS) database; Section 8.3 presents wastewater characterization data collected during EPA's sampling program; and Section 8.4 discusses multi-sector general permit application data. All tables appear at the end of this section. Appendix A contains information regarding the location of airports referenced in this section.

8.1 Industry Self-Monitoring Data

During the course of the study, EPA obtained storm water sampling data from five airports. In general, these data represent discharges of ADF-contaminated wastewater; however, some airports submitted data for nondeicing season discharges. Although the length of the deicing season may vary among airports and also from year to year at a given airport, EPA analyzed only data collected during the airport's reported deicing season (e.g., October through March). These data are described and summarized in this section.

EPA also received storm water monitoring data from Transport Canada and Environment Canada for five Canadian airports. These data were collected as part of a study designed to assess the effectiveness of the Canadian voluntary glycol guideline (discussed in Section 13.3.1), to identify problems in wastewater management, and to develop better storm water monitoring programs. These data are also described and summarized in this section.

In general, each airport monitored a unique set of parameters, which were generally dictated by state and local permit requirements. In addition, some parameters can be analyzed by multiple analytical methods, making it difficult to directly compare data submitted by

different airports. For example, glycols are analyzed by several different methods, the detection limits of which vary from 1,000 mg/L to less than 1 mg/L. Therefore, a nondetect value at an airport using an analytical method with a high detection limit may in fact have a higher glycol concentration than a detected value at an airport using an analytical method with a low detection limit.

The data presented in this section generally represent discharges from the winter of 1997-1998 and/or the winter of 1998-1999, with some exceptions. EPA recognizes that some of the pollutant discharge concentrations presented in this section may not represent current pollutant discharges from the airports because several of the airports discussed in this section have recently implemented pollutant control technologies (e.g., Milwaukee's General Mitchell International Airport).

EPA recognizes that the data presented in this section may have several limitations. First, the data represent only a small subset of wastewater discharges from airport deicing/anti-icing operations. Second, the data submitted by some airports were collected during only one deicing season. Third, some of the data submitted by airports include samples collected on days when no deicing/anti-icing operations were conducted. However, like the PCS data presented in Section 8.2, EPA considers the effluent monitoring data a "snapshot" of pollutant discharges to surface waters that may occur at airports. The data submitted by each airport are summarized below.

Bradley International Airport, Windsor Locks, CT (BDL)

Bradley International Airport submitted analytical data for storm water outfall and in-stream samples for the winters of 1990-1991, 1993-1994, 1996-1997, 1997-1998, and 1998-1999. The outfall samples were collected from 13 different outfalls. The in-stream data were not included in this summary because they do not represent ADF-contaminated wastewater discharges. The discharge data summarized in Table 8-1 are presented by general location and outfall. Some outfalls were sampled hourly for eight consecutive hours while a single grab sample

was collected at other outfalls. Outfall data are presented as either an average of hourly sampling data or as the single grab sample result as applicable. As shown by the data in Table 8-1, most ADF-contaminated wastewater discharges at BDL occur at Outfalls 2 and 3, which service the passenger terminal and aircraft deicing pad areas.

Washington Dulles International Airport, Herndon, VA (IAD)

Washington Dulles International Airport submitted analytical data for samples collected at the outfall from Horsepen Lake, a man-made impoundment located at the airport's northern property boundary. In general, the airport collected samples twice per day for 90 days between December 1998 and April 1999. Sampling generally coincided with deicing operations; however, EPA assumes, based on nondetect glycol values, that minimal deicing/anti-icing occurred in April. The following data summarize the Horsepen Lake outfall data, excluding the April 1999 data.

	Average Concentration (mg/L)	Range (mg/L)	Number of Data Points
Propylene Glycol	<61.1	ND (5) - 986	124
Ethylene Glycol	<5.52	ND (5) - 34	124

< - Maximum concentration.

ND - Not detected (followed by detection limit).

Logan International Airport, Boston, MA (BOS)

Logan International Airport submitted analytical data for storm water sampling performed as part of its National Pollutant Discharge Elimination System (NPDES) storm water permit application. The airport collected samples in March 1991, January 1992, and March 1992. The airport also collected samples in June 1991; however, these data are not included in this summary because they do not represent storm water discharges during deicing operations. Although the data were collected from several years ago, EPA believes they represent current deicing operation conditions at Logan.

Storm water runoff samples were collected and analyzed for several parameters, including BOD₅, ammonia, metals, ethylene glycol, and propylene glycol. Samples were collected at the north and west outfalls, which directly drain to the adjacent harbor. The following data summarize the results of storm water sampling during deicing events.

Date	North Outfall (mg/L)				West Outfall (mg/L)			
	PG	EG	BOD ₅	Ammonia	PG	EG	BOD ₅	Ammonia
3/15/91	120	110	8,320	2.3	240	95	5,500	2.9
1/23/92	ND (1)	1,100	592	5.3	130	280	531	3.8
3/19/92	<141	<641	N/A	N/A	<218	481	N/A	N/A
Avg.	<87.3	<617	4,456	3.8	<196	285	3,016	3.35

< - Maximum concentration.

PG - Propylene glycol.

EG - Ethylene glycol.

ND - Not detected (followed by the detection limit).

N/A - Not available.

Baltimore/Washington International Airport, Baltimore, MD (BWI)

Baltimore/Washington International Airport performed a glycol mass balance study using data collected during the 1997-1998 deicing season. The goal of the study was to determine the percentage of glycol discharged relative to the volume of glycol sprayed on aircraft. The airport collected daily grab samples between October 24, 1997 and April 30, 1998 from two watersheds that receive storm water discharges from the airport. The following table summarizes the glycol and COD results for the Kitten Branch Watershed and Muddy Bridge Branch Watershed.

1997-1998 Season	Kitten Branch Watershed	Muddy Bridge Branch Watershed
Average glycol concentration (mg/L)	<10	<8.7
Range of glycol concentrations (mg/L)	ND (6) - 630	ND (6) - 30
Range of COD concentrations	ND (10) - 400	ND (10) - 690
Range of ammonia concentrations (mg/L)	ND (1)	ND (1) - 1.3
Number of Data Points	159	159

< - Maximum concentration

ND - Not detected (followed by detection limit).

General Mitchell International Airport (MKE)

General Mitchell International Airport submitted analytical data from a study conducted during the winter of 1996-1997. The purpose of the study was to assess the water quality impacts that aircraft deicing fluids have on receiving streams. From November 1996 through April 1997, the airport conducted a monitoring program for flow, water quality parameters (e.g., BOD₅, glycols), and toxicity from 10 sampling stations, including two sampling stations that directly measured runoff from the airport. The remaining sampling stations were located in receiving streams both upstream or downstream of the airport. Because the other sampling stations may not represent contaminated storm water discharges, only data for the two airport sampling stations are summarized below.

	Outfall #1	Outfall #7
Average EG Concentration (mg/L)	170	123
Average PG Concentration (mg/L)	5,080	1,460
Average BOD ₅ Concentration (mg/L)	3,510	917
Number of Data Points	4	4

EG - Ethylene glycol.

PG - Propylene glycol.

The airport also conducted acute and chronic whole effluent toxicity (WET) tests for both fathead minnows and *Ceriodaphnia dubia* for one sampling event on April 11, 1997.

Data from this event were used to establish acute and chronic toxic criteria for the fathead minnow and *Ceriodaphnia dubia* as follows:

Species	Duration	Aircraft Deicing/Anti-icing Fluid Concentration (mg/L)
Fathead minnow	96-hour LC ₅₀	1,650
	7-day IC ₂₅	90
<i>Ceriodaphnia dubia</i>	48-hour LC ₅₀	3,150
	7-day IC ₂₅	1,015

LC₅₀ - Lethal concentration at which 50% of the test population dies.

IC₂₅ - Concentration at which 25% of the test organisms had inhibited growth, reproduction, or survival of the young.

Transport Canada/Environment Canada

Five Canadian airports were studied as part of the Transport Canada/Environment Canada joint study of storm water monitoring at airports. For two of the airports, Quebec City and Victoria, samples were collected at two outfalls. EPA believes the Canadian data are relevant since some U.S. airports experience weather conditions that are similar to those experienced by the Canadian airports. Note that Canada has a voluntary glycol guideline of 100 mg/L. The following table summarizes the analytical data.

Airport	Range of Total Glycol Concentration (mg/L)	% of Samples that Exceeded 100 mg/L	Range of Ammonia Concentration (mg/L)	Range of BOD ₅ Concentration (mg/L)
St. John's	ND (1) - 120	1	ND (1) - 1.85	ND (1) - 89
Quebec City (A)	ND (1) - 30,200	17.2	ND (0.03) - 197	ND (1) - 3,900
Quebec City (B)	ND (1) - 2	0	ND (0.02) - 4.63	3 - 47
Thunder Bay	ND (1) - 437	5.9	ND (0.03) - 106	ND (1) - 703
Victoria (A)	ND (1) - 7	0	ND (0.03) - 27	ND (1) - 29
Victoria (B)	ND (1) - 77	0	ND (0.03) - 11	ND (1) - 28
Halifax	ND (5) - 130,000	28	ND (0.05) - 55	1 - 31

ND - Not detected (followed by detection limit).

Based on the data available to EPA, the range of glycol concentrations at these Canadian airports is generally lower than those at U.S. airports presented in this section. This is most likely a result of Canada's voluntary guideline. The ammonia concentrations at Canadian airports are significantly higher than those at the U.S. airports presented in this section. This is most likely because the Canadian airports use urea as a pavement deicer, which many U.S. airports are eliminating in favor of alternate pavement deicing agents.

8.2 Permit Compliance System (PCS)

EPA's PCS database contains compliance, enforcement, and permitting information for facilities that hold an NPDES permit. NPDES, which is authorized under Section 402 of the CWA, requires permits for the discharge of pollutants from any point source into waters of the United States.

The PCS database includes the following information for each facility included in the database:

- Facility NPDES permit number;
- Facility name;
- Pipe number and description (i.e., code and description of each NPDES-permitted discharge point);
- Name and description of analyzed parameters;
- Average quantity and/or concentration limit (and maximum and minimum limits, if applicable);
- Units of measurement for limits;
- Average quantity and/or concentration of parameter during monitoring period (and maximum and minimum measurements, if applicable); and
- Units of measurement for monitoring parameters.

In 1998, EPA's Office of Compliance extracted PCS records for Standard Industrial Classification (SIC) code 4185 (Airports, Flying Fields, and Airport Terminal Services) for the 1997-1998 deicing season (i.e., September through March) for EPA's Office of Water. EPA recognizes that the pollutant discharge concentrations from this period may not represent current industry pollutant discharges because several airports have recently implemented contaminated storm water collection and/or treatment techniques and/or POTW discharge that would not be reflected in the 1997-1998 data.

The PCS database excerpt for SIC code 4185 contained information for 42 different airports from across the U.S. However, some of these airports are small or general aviation airports or are in southern locations, where few deicing operations are expected to occur. EPA compared the airports in the PCS database to the list of airports thought to have potentially significant deicing/anti-icing activities (see discussion in Section 4.3.1) and determined that 14 of the airports in the PCS database were on this list.

Using information in the PCS database for the 14 airports, EPA evaluated each permitted outfall and types of parameters to determine whether the outfall discharges wastewater containing deicing/anti-icing chemicals. For example, if an airport is required to collect and analyze storm water for glycol at a particular outfall, then EPA considered the outfall as discharging wastewater containing deicing/anti-icing chemicals. In contrast, if an airport is required to analyze only for oil and grease and volatile organic pollutants at a particular outfall, then EPA considered the outfall as not discharging wastewater containing deicing/anti-icing chemicals and eliminated it from further analyses.

After EPA edited the database using the above criteria, information from 10 airports remained in the database. These airports include:

- Chicago O'Hare International (ORD);
- Louisville International - Standiford Field (SDF);
- Baltimore/Washington International (BWI);
- Minneapolis-St. Paul International (MSP);

- Newark International (EWR);
- Westchester County (HPN);
- Tompkins County (ITH);
- Syracuse Hancock International (SYR);
- Nashville International (BNA); and
- Salt Lake City International (SLC).

Table 8-2 summarizes effluent monitoring data for direct discharges for these airports, grouped by discharge location and/or similar discharge characteristics (e.g., runway or terminal outfalls).

It is important to recognize that the data presented in Table 8-2 have certain limitations, such as: 1) EPA was not able to verify for all airports that the outfalls presented in Table 8-2 are representative of wastewater discharges containing deicing/anti-icing chemicals, 2) the data represent only a small subset of wastewater discharges from airport deicing/anti-icing operations, 3) the data were collected during only one deicing season (the winter of 1997-1998), and 4) the data may not represent current deicing/anti-icing operations at these airports. However, EPA considers the effluent monitoring data a “snapshot” of pollutant discharges to surface waters that may occur at airports.

8.3 EPA Sampling Data

To supplement the analytical data available from the industry, EPA undertook a sampling program consisting of six sampling episodes. The goals of the sampling program were to: (1) identify pollutants present in wastewater from aircraft deicing and anti-icing operations; (2) determine the possible range of concentrations for each pollutant identified; and (3) assess the effectiveness of different wastewater treatment methods currently used at U.S. airports. To achieve these goals, EPA collected the following samples:

- Ethylene glycol-based aircraft deicing fluid (i.e., a Type I fluid);
- Propylene glycol-based aircraft deicing fluid (i.e., a Type I fluid);

- Influent to and effluent from an anaerobic biological treatment system used to treat ADF-contaminated wastewater at Albany International Airport;
- Wastewater discharge to a POTW from a retention basin used to collect ADF-contaminated wastewater at Kansas City International Airport;
- Influent to and effluent from a reverse osmosis system at Bradley International Airport used to recover glycol from low-strength ADF-contaminated wastewater for further processing;
- Storm water outfall which drains aircraft deicing/anti-icing areas at Bradley International Airport (sample collected during the deicing season, but not concurrent with a deicing event); and
- Influent to and effluent from an aerobic biological treatment system used to treat ADF-contaminated wastewater at Greater Rockford Airport.

These samples were analyzed for a large number of conventional and nonconventional pollutants and, in a few cases, for whole effluent toxicity. Table 8-3 lists the classes of pollutants analyzed as well as the analytical methods used.

The analytical data for the wastewater recovery and treatment systems, including an assessment of their efficiency, is presented in Section 6.4.1 for Bradley International Airport and Section 7.2.1. for Albany International Airport and Greater Rockford Airport. This section presents the analytical results for the two Type I fluids (Section 8.3.1) and for several raw wastewater samples and one storm water outfall sample (Section 8.3.2). Section 8.3.3 discusses the analytical results.

8.3.1 Type I Aircraft Deicing Fluids

Based on data provided by the industry, EPA estimates that more than 90% by volume of all ADF fluids sprayed in a given deicing season are Type I, with Type IV fluids comprising most of the remaining 5% to 10% and Type II fluids being largely obsolete. Since Type I fluids are used in much greater quantities than Type II and Type IV fluids, EPA analyzed samples of two Type I formulations as control or background samples for the sampling program.

There are currently three principle manufacturers/formulators of Type I fluids in the U.S.: Union Carbide, Lyondell (formerly ARCO), and Octagon Process. Union Carbide's Type I fluids contain ethylene glycol as the freezing point depressant, while those of Lyondell and Octagon contain propylene glycol. In recent years, the mammalian toxicity of ethylene glycol, combined with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting requirements (see Section 13.2.1) and the proliferation of propylene glycol recovery, have made propylene glycol-based fluids dominant in the U.S. However, some carriers continue to use ethylene glycol-based products, and, at a few U.S. airports, the volume of ethylene glycol-based fluid applied to aircraft exceeds that of propylene glycol-based fluid. Consequently, EPA decided to analyze both an ethylene glycol-based Type I fluid (trade name UCAR™ Aircraft Deicing Fluid Concentrate, Union Carbide) and a propylene glycol-based Type I fluid (trade name Octaflo™ Concentrate, Octagon Process).

The samples were collected directly into sample containers and shipped to EPA contract laboratories for analysis. Chemical preservation was not required for these samples, although they were shipped on ice to maintain a sample temperature of 4° C. The samples were diluted with reagent grade water to a 50% solution prior to analysis to represent fluid as applied to aircraft. EPA recognizes that airlines sometimes dilute Type I fluid concentrate to solutions containing less than 50% ADF, but believes the 50% dilution is most typical of industry practices.

The samples were analyzed for volatile organics, semivolatile organics (including tolyltriazoles), metals, total organic carbon (TOC), and ammonia as nitrogen. Table 8-4 lists analytes detected in the diluted samples as well as their concentrations. EPA did not analyze the ADF samples for glycols, biochemical oxygen demand, or acute toxicity. Some of this information is available from fluid formulators, who collect environmental data both to comply with Society of Automotive Engineers' fluid certification reporting requirements (see Section 13.5) and to assist customers with waste management issues. Table 8-5 summarizes the data provided by the fluid manufacturers/formulators.

Table 8-4 should not be viewed as a comprehensive list of all pollutants present in wastewater from aircraft deicing/anti-icing operations. The fluids are known to contain a variety of additives, including wetting agents, fire suppressants, and potentially toxic corrosion inhibitors, many of which could not be included on the list of analytes because their identity was unknown and is considered proprietary by the fluid manufacturers.

8.3.2 Characterization of Wastewater from Aircraft Deicing/Anti-icing Operations

To characterize raw wastewater from aircraft deicing/anti-icing operations, EPA collected samples from a variety of airport wastewater storage facilities. These samples included wastewater from a portable storage tank at Bradley International Airport, an uncovered concrete basin at Kansas City International Airport, a storage tank and two detention ponds at Albany International Airport, and an aerated detention pond at Greater Rockford Airport. EPA also collected one storm water outfall sample at Bradley International Airport to characterize direct discharge of ADF-contaminated storm water. Sample fractions were preserved as specified by the analytical methods, packed in ice, and shipped overnight to EPA contract laboratories for analysis. All samples were analyzed for semivolatile organics (including tolyltriazoles), glycols, metals (including potassium), TOC, ammonia as nitrogen, BOD₅, hexane extractable material (HEM), and silica-gel hexane extractable material (SGT-HEM). Whole effluent toxicity (WET) tests were performed on samples collected at Kansas City International Airport and Bradley International Airport. The sample from Albany International Airport was also analyzed for volatile organic compounds.

Each sampling point and the sample collection method are briefly described below. Table 8-4 lists the analytes detected in the wastewater samples as well as their concentrations.

Albany International Airport, Albany, NY (ALB)

Aircraft deicing/anti-icing at Albany International Airport is performed using only propylene glycol-based fluids, and is permitted only in designated areas where a drainage

collection system consisting of graded pavement surfaces, catch basins, trench drains, and wet wells are installed. Wastewater collected in the wet wells is pumped through force mains to the airport's wastewater storage area, which consists of a 6-million-gallon lagoon, a 2.3-million-gallon lagoon, and a 2.5-million-gallon above-ground tank. The lagoons are equipped with piping systems and blowers to provide gross diffusion aeration and a recirculation pump to move wastewater from the pond center to the edge. The primary purpose of the aeration and recirculation systems is to reduce glycol stratification within the lagoons. On March 24, 1999, EPA collected a grab sample of wastewater from the small lagoon and a composite sample from the storage tank and large lagoon. Grab samples were also collected from the large lagoon and the storage tank for analysis of HEM and SGT/HEM. EPA also analyzed a sample of effluent from the treatment system. The analytical data for the effluent sample of is provided in Section 7.2.1.

Kansas City International Airport, Kansas City, KS (KCI)

At Kansas City International Airport, airlines and fixed-base operators use either ethylene glycol- or propylene glycol-based fluids for aircraft deicing/anti-icing. Wastewater from aircraft deicing and anti-icing operations are collected at the passenger terminal using a trench drain system specifically designed for this purpose. The wastewater, combined with any storm water runoff, enters the trench drains and is conveyed by underground pipes to a concrete storage basin. The storage basin consists of two 1-million-gallon cells: the west cell and the east cell. The storage cells are operated in parallel, with one filling while the other is discharging to a local POTW. Because the storage cells are uncovered, rain water dilutes the wastewater and sunlight helps to degrade the glycols present. EPA collected a grab sample of wastewater from the west cell on February 25, 1999. The cell was approximately half-full at the time of sampling and had received wastewater from aircraft deicing/anti-icing operations since February 15, 1999.

Bradley International Airport, Windsor Locks, CT (BDL)

At Bradley International Airport, aircraft deicing and anti-icing operations are performed using propylene glycol-based fluids and are conducted on the airport's aircraft deicing pad, at the passenger terminal, and on the cargo ramps. Wastewater is collected at the passenger terminal and cargo ramps using vacuum trucks, while wastewater generated at the deicing pad drains into a sump. The collected wastewater is transferred to several 20,000-gallon temporary storage tanks located at the airport's glycol recycling facility (discussed in Section 6.4.1). The wastewater is segregated based on the glycol concentration, which typically varies between 1% and 30% (i.e., between 10,000 mg/L and 300,000 mg/L), depending on the volume of fluid used and the type of precipitation. EPA collected a wastewater grab sample from one of the temporary storage tanks on March 9, 1999. EPA also analyzed a sample of effluent from the treatment system. The analytical data for the effluent sample are provided in Section 6.4.1.

Storm water from the southern areas of the airfield, including the passenger terminal areas and the remote deicing pad (with the exception of that collected as described above), flows to Outfalls 3-1 and 3-2. On March 9, 1999, EPA collected a grab sample of the combined outfalls from an above-ground channel at a point down stream from the outfalls where the two streams combine. Although the sample was collected during the deicing season, it was not collected concurrent with a deicing event.

Greater Rockford Airport, Rockford, IL (RFD)

Aircraft deicing/anti-icing operations are performed at the airport's deicing pad and on a ramp at the cargo facility, where wastewater collection systems have been installed. Although the airport authority allows its tenants to use either propylene glycol- or ethylene glycol-based fluids, most of the fluid used at the airport is ethylene glycol-based. The wastewater collected at the airport's deicing pad and the cargo facility is conveyed via underground pipes and a diversion box to a 16-million-gallon aerated detention pond, where aerobic biological treatment takes place. Wastewater collected during the deicing season is retained in the detention pond

until midsummer, when the treated fluid is discharged to a nearby river. The rate of biodegradation is dependent on temperature; biodegradation occurs primarily in spring and summer months when ambient temperatures are above 40° F.

EPA collected a grab sample of wastewater from the detention pond on April 14, 1999, following the close of the deicing season. During the three weeks immediately preceding the sampling episode, ambient temperatures were unseasonably warm, with daily highs reaching above 70° F on five separate days. A review of analytical data provided by the airport indicates that some treatment had already occurred prior to the sampling episode. This conclusion is further supported by EPA's data, which show that glycols, known to biodegrade rapidly, were not detected in the wastewater sample. Consequently, the sample is not representative of raw wastewater from airport deicing/anti-icing operations, at least with respect to glycol levels. EPA also analyzed a sample of effluent from the treatment system. The analytical data for the effluent sample of is provided in Section 7.2.1.

8.3.3 Discussion of Sampling Results

Analytical results for the Type I fluids show that the composition of Type I fluids varies considerably. For example, three volatile organic compounds (ethylbenzene, toluene, and m- + p-xylene) and three metals (antimony, manganese, and thallium) were detected in the propylene glycol-based fluid, but were not detected in the ethylene glycol-based fluid. Similarly, two semivolatile compounds (di-n-butyl phthalate and n-dodecane) and one metal (chromium) were detected in the ethylene glycol-based fluid, but not in the propylene glycol-based fluid.

The concentrations of the analytes that were detected in both fluids also differed. The ethylene glycol-based fluid contained higher concentrations of bis(2-ethylhexyl) phthalate, aluminum, boron, cadmium, and sodium, while the propylene glycol-based fluid contained higher concentrations of 5-methyl-1H-benzotriazole, arsenic, barium, calcium, copper, iron, lead, tin, zinc, and ammonia. Pollutant concentrations that differed by more than an order of magnitude

include those for bis(ethylhexyl) phthalate, 5-methyl-1H-benzotriazole, arsenic, boron, cadmium, and thallium.

In general, pollutants detected in the Type I fluids were also detected in the raw wastewater samples. However, a number of analytes were detected in at least one of the Type I fluids, but were not detected in any of the raw wastewater samples. These analytes include ethylbenzene, toluene, m- + p-xylene, di-n-butyl phthalate, n-dodecane, antimony, boron, selenium, and thallium. There are several possible reasons for these results. First, wastewater from aircraft deicing/anti-icing operations is typically diluted by storm water, which may mask the presence of these pollutants. Second, the Type I fluids analyzed for this study may not have been used at the airports that were sampled. Third, biological activity in the storage units may have degraded some pollutants.

Several analytes were detected in at least one of the raw wastewater samples but not in either of the Type I fluids analyzed. These analytes include n-hexadecane, phenol, n-tetradecane, magnesium, silver, titanium, and vanadium. Other analytes were detected in both Type I fluids and in all raw wastewater samples; however, the concentration of the analyte was generally greater in the raw wastewater samples. These analytes include aluminum, barium, calcium, iron, sodium, and ammonia as nitrogen. There are several possible sources of these pollutants. First, they may be constituents of anti-icing fluids (i.e., Type II and Type IV fluids) or other Type I formulations. Second, they may be present in the water used at the airport to dilute the Type I fluid concentrate. Third, they may be present in precipitation. Fourth, they may be constituents present in pavement deicing/anti-icing agents. Fifth, they may be pollutants rinsed from aircraft or pavement surfaces during aircraft deicing operations. Pollutants were generally detected in higher concentrations in the raw wastewater sample collected at Bradley International Airport because the airport purposely attempts to collect wastewater with the highest possible ADF concentration for processing through its on-site glycol recycling system.

Although pavement deicing/anti-icing was not the primary focus of the sampling program, EPA included ammonia as nitrogen, potassium, magnesium, sodium, and calcium on the

list of analytes measured in raw wastewater samples. Ammonia is a common degradation product of urea (a solid pavement deicer), while potassium acetate, calcium magnesium acetate, sodium acetate, and sodium formate (common pavement deicer/anti-icers) are potential significant sources of the remaining pollutants.

Ammonia concentrations in the raw wastewater samples ranged from 3.9 mg/L to 88 mg/L. Ammonia concentrations greater than 5 mg/L are known to be toxic to aquatic organisms, including the test species used in the whole effluent toxicity tests. The highest ammonia concentrations were found in wastewater samples collected at Albany International Airport, which reported using urea for deicing a newly constructed apron near the passenger terminal. Urea was used on this apron during the 1998-1999 winter, because application of potassium acetate (i.e., the pavement deicing/anti-icing typically used at Albany) would have voided the manufacturer's one-year warranty on the apron construction. Bradley International Airport and Greater Rockford Airport both reported using urea for runway and taxiway deicing. Note that the ammonia concentration in the storm water outfall from Bradley International Airport, 1.1 mg/L, was significantly less than 5 mg/L.

Concentrations of potassium in the raw wastewater samples varied considerably. The highest concentrations were detected in wastewater samples collected at Albany International Airport and Greater Rockford Airport, where potassium levels were approximately 60,000 $\mu\text{g/L}$. All of the airports sampled reported using potassium acetate on airfield pavements, mostly applied to runways and taxiways. None of the airports sampled reported using sodium acetate, calcium magnesium acetate, or sodium formate for airfield deicing/anti-icing.

In general, pollutants detected in the raw wastewater sample from Bradley International Airport were also detected in the storm water outfall. However, many pollutants detected in the outfall were not detected in the raw wastewater sample, likely because the outfall is diluted by storm water from non-deicing areas. Two pollutants, antimony and boron, were detected in the outfall but not in the raw wastewater. These pollutants may be contributed by natural sources.

8.4 Multi-Sector General Permit Application Data

As described in Section 13.1.3, Part 2 of the Multi-Sector General Permit application includes quantitative data based on samples collected during storm events from outfalls containing storm water discharges associated with industrial activity. The American Association of Airport Executives submitted a group permit application on behalf of 700 airports. Part 2 of the application included sampling data for 59 airports considered to be representative of the group. Sampling parameters included oil and grease, pH, BOD₅, COD, total suspended solids (TSS), total phosphorus, total Kjeldahl nitrogen, and nitrate plus nitrite nitrogen. Data from only one airport are relevant to airport deicing operations. The remaining data were collected during summer rain events when potential sources of pollutants consisted of aircraft fueling, cleaning, and maintenance.

Table 8-1

**Summary of Storm Water Monitoring Data from
Bradley International Airport**

Group	Location	Date	Average BOD Concentration (mg/L)	Average Ammonia Concentration (mg/L)	Average Ethylene Glycol Concentration (mg/L)	Average Propylene Glycol Concentration (mg/L)
Southeast drainage	Outfall 1A	2/14/91	28	2.6	11.2	NA
		2/27/91	560	6.1	43.8	NA
		3/13/91	11	0.33	0.12	NA
		3/4/97	30	0.36	ND (10)	ND (10)
		3/14/98	NA	NA	ND (50)	ND (50)
		2/2/99	76	2.7	ND (10)	ND (10)
		3/15/99	>190	0.87	ND (10)	ND (10)
	Outfall 1B	2/14/91	31	2.5	10.4	NA
		2/27/91	520	6.1	20.8	NA
		3/13/91	3	0.11	ND (0.1)	NA
		3/14/98	NA	NA	ND (50)	ND (50)
	Outfall 14	3/14/98	NA	NA	ND (50)	ND (50)
Terminal drainage (South)	Outfall 2	2/14/91	8,300	2.3	11,700	ND (500)
		2/27/91	6,700	1.9	6,600	ND (50)
		3/13/91	32	0.24	10.5	ND (10)
		1/28/94	NA	<1.8	<150	17,000
		3/9/94	NA	3.1	<103	370
		3/4/97	69	0.61	40	9.1
		3/14/98	NA	NA	ND (50)	ND (50)
		2/2/99	>87	21	ND (10)	<280
		3/15/99	50	2.2	ND (10)	<29
	Outfall 3-1	2/14/91	22,000	4.6	22,500	13,000
		2/27/91	3,200	3.7	24,000	12,000
		3/13/91	2	0.32	0.29	ND (10)
		1/28/94	NA	<0.7	ND (100)	17,000
		3/9/94	NA	3.2	<99	11,000
		3/4/97	>304	1.13	ND (10)	700
		3/14/98	NA	NA	ND (100)	250
		2/2/99	>94	12	ND (10)	1,400
		3/15/99	>190	1.6	<1,700	<340
	Outfall 3-2	3/14/98	NA	NA	ND (1,000)	3,600
		2/2/99	>94	29	ND (10)	1,200
		3/15/99	>190	3.8	ND (10)	180

Table 8-1 (Continued)

Group	Location	Date	Average BOD Concentration (mg/L)	Average Ammonia Concentration (mg/L)	Average Ethylene Glycol Concentration (mg/L)	Average Propylene Glycol Concentration (mg/L)
West drainage	Outfall 5	3/14/91	6	1.2	1.9	NA
		2/27/91	ND (2)	0.18	ND (0.1)	NA
		3/13/91	ND (2)	0.22	ND (0.1)	NA
		3/4/97	5.6	0.76	ND (10)	ND (10)
	Outfall 7	2/2/99	ND (2)	0.22	ND (10)	ND (10)
		3/15/99	ND (15)	0.14	ND (10)	ND (10)
	Outfall 8	2/2/99	10	7.7	ND (10)	ND (10)
		3/15/99	ND (15)	0.71	ND (10)	ND (10)
	Outfall 9	3/4/97	1.2	0.16	ND (10)	ND (10)
		3/14/98	NA	NA	ND (50)	ND (50)
		2/2/99	ND (2)	1.5	ND (10)	ND (10)
		3/15/99	ND (15)	0.33	ND (10)	ND (10)
	Outfall 10	2/14/91	ND (2)	1.2	ND (0.1)	NA
		2/27/91	ND (2)	0.92	ND (0.1)	NA
		3/13/91	2	0.75	ND (0.1)	NA
		3/14/98	NA	NA	ND (50)	ND (50)
		2/2/99	ND (2)	0.65	ND (10)	ND (10)
		3/15/99	ND (15)	0.53	ND (10)	ND (10)
Northeast drainage	Outfall 13-1	2/14/91	8	0.54	1.7	NA
		2/27/91	ND (2)	0.23	ND (0.1)	NA
		3/13/91	ND (2)	0.2	ND (0.1)	NA
		3/4/97	7.8	19.6	ND (10)	ND (10)
		3/14/98	NA	NA	ND (50)	ND (50)
		2/2/99	7.6	0.46	ND (10)	ND (10)
		3/15/99	>190	1.1	ND (10)	2,100
	Outfall 13-2	2/14/91	2	0.47	ND (0.1)	NA
		2/27/91	ND (2)	0.13	ND (0.1)	NA
		3/13/91	2	0.51	0.17	NA
		3/14/98	NA	NA	ND (50)	ND (50)

> - Minimum concentration.

< - Maximum concentration.

NA - Not available.

ND - Not detected (followed by detection limit).

Table 8-2

**Summary of PCS Data for Airports with EPA-Estimated Potentially
Significant Deicing/Anti-Icing Operations**

Airport	Discharge Point(s)	Parameter	Average Effluent(a)	Range of Data Points	# of Data Points
Chicago O'Hare International (ORD)	0110, 0210, 0310, 0410, 0610, 0810, 081A - Storm water (NW drainage)	BOD ₅ (mg/L)	111	1.1 - 1,650	36
		pH (S.U.)	NA	6.9 - 7.6	36
		NH ₃ - N (mg/L)	10.8	0.2 - 50	36
		TDS (mg/L)	1,080	232 - 3,370	36
	0910, 1010, 1110, 1120, 1130, 1140 - Storm water (N drainage)	BOD ₅ (mg/L)	134	1 - 2,150	34
		pH (S.U.)	NA	6.0 - 7.6	34
		NH ₃ - N (mg/L)	11.2	0.2 - 50	34
		TDS (mg/L)	645	227 - 1,620	34
	1210 - Storm water (NE drainage)	BOD ₅ (mg/L)	40.2	2.5 - 141	6
		pH (S.U.)	NA	6.9 - 7.5	6
		NH ₃ - N (mg/L)	3.4	0.6 - 10	6
		TDS (mg/L)	1,200	105 - 2,080	6
	1410 - Storm water (SE drainage)	BOD ₅ (mg/L)	117	9.2 - 342	6
		pH (S.U.)	NA	6.7 - 7.6	6
		NH ₃ - N (mg/L)	35.1	2.6 - 85	6
		TDS (mg/L)	1,050	624 - 1,340	6
	3720, 3730, 4710 - Storm water (SW drainage)	BOD ₅ (mg/L)	291	0.9 - 3,100	17
		pH (S.U.)	NA	6.8 - 7.6	17
		NH ₃ - N (mg/L)	8.28	0.7 - 37.5	17
		TDS (mg/L)	1,740	211 - 8,470	17
	091A, 091B - drainage from deicing activities	BOD ₅ (mg/L)	381	264 - 497	2
		pH (S.U.)	NA	7.3	2
		NH ₃ - N (mg/L)	50	50	2
		TDS (mg/L)	727	616 - 837	2
Louisville International - Standiford Field (SDF)	011, 021, 031, 041, 061 - Storm water/ deicing fluid runoff	Benzene (ug/L)	<7.62	<5 - 97	27
		BOD ₅ (mg/L)	77.7	3 - 1,250	27
		Ethylbenzene (ug/L)	<8.48	<5 - 127	27
		Naphthalene (ug/L)	<15.2	<5 - 361	27
		NH ₃ - N (mg/L)	<17.2	<0.03 - 171	27
		Oil and grease (mg/L)	<1.27	<1 - 3.5	27
		DO (mg/L)	7.9	0.270 - 13.0	27
		pH (S.U.)	NA	7.0 - 9.1	27
		TSS (mg/L)	473	2.00 - 3,530	27
		Toluene (ug/L)	<5	<5	27
		Xylene (ug/L)	<5	<5	27

Table 8-2 (Continued)

Airport	Discharge Point(s)	Parameter	Average Effluent(a)	Range of Data Points	# of Data Points
Baltimore/ Washington International (BWI)	306A and 307A - Outfall 003 (runway, terminal, and deicing pad drainage)	BOD ₅ (mg/L)	1,010	23 - 2,510	4
		EG (mg/L)	<10	<10	4
		TKN (mg/L)	12.8	2 - 27	4
		pH (S.U.)	NA	6.7 - 7.5	4
	007A and 703A - Storm water runoff (from taxiway, terminal, and ramps)	BOD ₅ (mg/L)	412	197 - 769	4
		EG (mg/L)	<10	<10	4
		Petroleum			
		Hydrocarbons (mg/L)	1	1	1
		TKN (mg/L)	2.25	2 - 3	4
		pH (S.U.)	NA	6.7 - 7.1	4
Minneapolis- St. Paul International (MSP)	010M and 01AM - Mother Lake and Duck Lake drainage (runways and taxiways)	BOD ₅ (tons/mo)	0.1	<0.001 - 0.5	10
		BOD ₅ (mg/L)	90.9	1 - 694	10
		BOD ₄₀ (mg/L)	5.50	2 - 10.0	4
		PG (mg/L)	137	9.4 - 596	5
		EG (mg/L)	14.4	4.1 - 32.6	3
		COD (mg/L)	243	6 - 1,880	10
		NH ₃ - N (mg/L)	11.5	0.09 - 50.6	10
		NH ₃ (mg/L)	0.638	0.002 - 5.27	10
		TKN (mg/L)	20.2	0.3 - 75	9
		Oil and grease (mg/L)	2.28	0.8 - 7.7	7
		DO (mg/L)	7.02	1.8 - 9.7	10
		pH (S.U.)	NA	7.1 - 8.5	10
		P (mg/L)	0.329	0.07 - 0.83	8
		TSS (mg/L)	15.3	2 - 76	10
		Toluene (mg/L)	0.002	0.002	1
	020M, 030M, 03AM - Minnesota River North and Snelling Lake drainage (terminal, runway, and taxiway drainage)	BOD ₅ (tons/mo)	14	0.1 - 83	18
		BOD ₅ (mg/L)	497	5 - 2,140	18
		BOD ₄₀ (mg/L)	319	8 - 676	12
		PG (mg/L)	313	3.2 - 1,660	14
		EG (mg/L)	95.8	2.6 - 561	10
		COD (mg/L)	763	2.9 - 4,320	18
		NH ₃ - N (mg/L)	19.4	0.48 - 124	18
		NH ₃ (mg/L)	0.671	0.02 - 10.7	18
		TKN (mg/L)	48.4	1.3 - 290	18
		Oil and grease (mg/L)	3.90	1.2 - 9.6	17
		DO (mg/L)	4.82	0.9 - 9.6	18
		pH (S.U.)	NA	6.8 - 8.1	18
		P (mg/L)	0.114	0.01 - 0.41	16
		TSS (mg/L)	15.6	5 - 54	18
		Benzene (ug/L)	4.7	0.1 - 12	4
		Ethylbenzene (ug/L)	2.7	0.2 - 5	4
		Toluene (ug/L)	6.2	0.2 - 23	6
		Xylene (ug/L)	16.3	3 - 30	4

Table 8-2 (Continued)

Airport	Discharge Point(s)	Parameter	Average Effluent(a)	Range of Data Points	# of Data Points
Minneapolis-St. Paul International (cont.)	040M - Minnesota River South drainage area (terminal and cargo areas)	BOD ₅ (tons/mo)	10	0.001 - 41	6
		BOD ₅ (mg/L)	641	5 - 1,210	6
		BOD ₄₀ (mg/L)	26.0	18 - 34	2
		PG (mg/L)	853	137 - 1,830	4
		EG (mg/L)	27.9	1.7 - 54.2	4
		COD (mg/L)	1,250	37 - 3,170	6
		NH ₃ - N (mg/L)	44.2	0.04 - 172	6
		NH ₃ (mg/L)	8.18	0.003 - 42.7	6
		TKN (mg/L)	77.5	1 - 235	6
		Oil and grease (mg/L)	15.8	2.8 - 67	6
		DO (mg/L)	4.72	1.9 - 7.6	6
		pH (S.U.)	NA	8.2 - 8.7	6
		P (mg/L)	0.378	0.18 - 0.73	6
		TSS (mg/L)	32.8	10 - 67	6
		Benzene (ug/L)	0.45	0.3 - 0.6	2
		Ethylbenzene (ug/L)	1.7	1.7	1
Newark International (EWR)	006A - Storm water from terminal	TOC (mg/L)	16	9 - 23	7
		Hydrocarbons (mg/L)	2.45	1 - 3.9	7
		pH (S.U.)	NA	6.1 - 7.0	7
		TSS (mg/L)	11.3	3 - 38	7
	008A, 009A, 013A, 014A, 014B, 015A - Storm water from runway	TOC (mg/L)	83.5	7 - 1,120	32
		COD (mg/L)	189	49 - 338	7
		Hydrocarbons (mg/L)	<1.98	<0.4 - 8.8	39
		pH (S.U.)	NA	5.1 - 7.5	39
		TSS (mg/L)	<12.5	<2 - 64	39
Westchester County (HPN)	001A and 003A - Storm water from ponds	BOD ₅ (mg/L)	2.82	2 - 7.2	14
		PG (mg/L)	32.8	0.05 - 220	12
		Oil and grease (mg/L)	5	5	14
		pH (S.U.)	NA	6.9 - 8.6	14
	004A, 008A, 009A - Storm water from buildings and hangars	BOD ₅ (mg/L)	4.92	2 - 37	21
		PG (mg/L)	0.134	0.05 - 0.82	18
		Oil and grease (mg/L)	5	5	21
		pH (S.U.)	NA	6.3 - 8.8	21
	005A, 006A, 007A - Storm water from taxiways and ditch drainage	BOD ₅ (mg/L)	2.53	2 - 8.4	19
		PG (mg/L)	0.213	0.05 - 1.3	17
		Oil and grease (mg/L)	5	5	19
		pH (S.U.)	NA	6.0 - 8.0	19
Tompkins County (ITH)	001M, 004M, 005M - Storm water runoff	BOD ₅ (mg/L)	<3	<3 - 3	18
	002M - Storm water from deicing/fueling pad	Oil and grease (mg/L) pH (S.U.)	<0.5 NA	<0.5 - 0.5 6.8 - 7.5	7 7

Table 8-2 (Continued)

Airport	Discharge Point(s)	Parameter	Average Effluent(a)	Range of Data Points	# of Data Points
Syracuse Hancock International (SYR)	001M, 003M, 004M, 005M, 006M, 007M - Storm water runoff	BOD ₅ (mg/L)	<334	<4 - 3,500	30
		Oil and grease (mg/L)	<6.18	<4 - 26	36
		pH (S.U.)	NA	6.8 - 8.2	36
		TSS (mg/L)	<11.5	<4 - 19	6
		NH ₃ - N (mg/L)	7.3	0.17 - 24.3	14
		Benzene (ug/L)	<2.5	<1 - <5	12
Nashville International (BNA)	002G - Effluent from treatment basin	BOD ₅ (mg/L)	38.1	3 - 98	7
		HEM (mg/L)	<6.71	<1 - 14	7
		COD (mg/L)	<69.6	<20 - 130	7
		DO (mg/L)	8.64	6.4 - 11.9	7
		pH (S.U.)	NA	7.2 - 8.6	7
		TSS (mg/L)	32.7	18 - 55	7
Salt Lake City International (SLC)	001A, 002A, 003A - Storm water discharge from terminal, runway, apron, and cargo areas	BOD ₅ (mg/L)	332	11 - 1,050	11
		Nitrate/Nitrite (mg/L)	4.73	0.9 - 9	5
		Oil and grease (mg/L)	9	8 - 10	2
		COD (mg/L)	835	104 - 3,880	12
		pH (S.U.)	NA	6.6 - 9.5	21

(a) Data represent only the 1997-1998 Deicing Season.

Key:

BOD ₅	-	5-day biochemical oxygen demand.
BOD ₄₀	-	40-day biochemical oxygen demand.
COD	-	Chemical oxygen demand.
DO	-	Dissolved oxygen.
EG	-	Ethylene glycol.
HEM	-	Hexane extractable material (i.e., oil and grease).
NA	-	Not applicable.
NH ₃	-	Ammonia - un-ionized.
NH ₃ -N	-	Ammonia as Nitrogen.
P	-	Phosphorus.
PG	-	Propylene glycol.
TDS	-	Total dissolved solids.
TKN	-	Total kjeldahl nitrogen.
TSS	-	Total suspended solids.
<	-	Not detected or maximum concentration.

Table 8-3

**Standard Analytical Methods for Parameters Included in EPA's
Airport Deicing Sampling Program**

Parameter	Method Number
Ammonia as nitrogen	350.2
Biochemical oxygen demand (5-day)	405.1
Total organic carbon	415.1
Glycols	624
Metals (including potassium)	1620
Volatile organic compounds	1624C
Semivolatile organic compounds (including tolyltriazoles)	1625C
Hexane extractable material	1664
Silica-gel treated hexane extractable material	1664
Whole effluent toxicity: Fathead Minnow (<i>Pimephales promelas</i>) Cladoceran (<i>Ceriodaphnia dubia</i>)	NA

NA - Method number not applicable. Analytical methods per Methods for Measuring the Acute Toxicity of Effluents and Receiving Water to Fresh Water and Marine Organisms, U.S. EPA, August 1993.

Table 8-4

**Analytical Results for Analytes Detected in Type I Aircraft Deicing Fluids (50% Solution), Raw Wastewater
from Airport Deicing/Anti-Icing Operations, and a Stormwater Outfall
EPA Sampling Data**

Priority Pollutant Code	Analyte	Type I Deicing Fluids (50% Solution)		Albany International Airport		Raw Wastewater Samples			Storm Water Outfall Samples
		Ethylene Glycol- Based Fluid	Propylene Glycol- Based Fluid	Small Lagoon	Composite of Large Lagoon and Tank	Kansas City International Airport	Bradley International Airport	Greater Rockford Airport	Bradley International Airport
	VOLATILE ORGANICS ($\mu\text{g/L}$)								
P038	ETHYLBENZENE	ND(100)	580	ND(10)	NA	NA	NA	NA	NA
P086	TOLUENE	ND(100)	620	ND(10)	NA	NA	NA	NA	NA
	M- + P-XYLENE	ND(100)	2,800	ND(10)	NA	NA	NA	NA	NA
	SEMIVOLATILE ORGANICS ($\mu\text{g/L}$)								
	N-HEXADECANE	ND(500)	ND(100)	ND(10)	ND(10)	ND(10)	110	ND(10)	ND (10)
P066	BIS(2-ETHYLHEXYL) PHTHALATE	7,200	350	>200	ND(10)	ND(10)	ND(100)	ND(10)	ND (10)
P068	DI-N-BUTYL PHTHALATE	100	ND(100)	ND(10)	ND(10)	ND(10)	ND(100)	ND(10)	ND (10)
	N-DODECANE	3,000	ND(100)	ND(10)	ND(10)	ND(10)	ND(1,000)	ND(10)	ND (10)
	5-METHYL-1H-BENZOTRIAZOLE	2,000	2,200,000	>2,000	2,200	17,000	90,000	120	200
P065	PHENOL	ND(500)	ND(100)	110	64	93	280	ND(10)	ND (10)
	N-TETRADECANE	ND(500)	ND(100)	ND(10)	ND(10)	ND(10)	140	ND(10)	ND (10)
	GLYCOLS (mg/L)								
	ETHYLENE GLYCOL	NA	NA	ND(10)	ND(10)	3,200	3,000	ND(10)	ND (10)
	DIETHYLENE GLYCOL	NA	NA	ND(5.0)	ND(5.0)	>20,000	15,000	ND(5.0)	ND (5.0)
	PROPYLENE GLYCOL	NA	NA	2,700	1,200	16,000	160,000	ND(5.0)	180

ND - Analyte not detected (followed by detection limit).

NA - Not analyzed.

> - Minimum concentration.

Table 8-4 (Continued)

Priority Pollutant Code	Analyte	Type I Deicing Fluids (50% Solution)		Albany International Airport		Raw Wastewater Samples			Storm Water Outfall Samples
		Ethylene Glycol-Based Fluid	Propylene Glycol-Based Fluid	Small Lagoon	Composite of Large Lagoon and Tank	Kansas City International Airport	Bradley International Airport	Greater Rockford Airport	Bradley International Airport
	METALS ($\mu\text{g/L}$)								
	ALUMINUM	230	120	530	1,100	860	1,100	270	69
P114	ANTIMONY	ND(20)	91	ND(2.0)	ND(2.0)	ND(2.0)	ND(20)	ND(2.0)	2.3
P115	ARSENIC	24	360	ND(1.0)	ND(1.0)	2.8	ND(1.0)	3.4	ND (1.0)
	BARIUM	3.0	24	89	86	60	36	31	91
	BORON	1,400	36	ND(26)	ND(26)	ND(26)	ND(26)	ND(26)	220
P118	CADMIUM	240	6.7	1.0	1.4	3.4	11	ND(1.0)	ND (1.0)
	CALCIUM	1,100	2,000	38,000	36,000	34,000	33,000	14,000	41,000
P119	CHROMIUM	3.5	ND(1)	2.7	3.6	5.0	7.2	3.7	ND (1.0)
P120	COPPER	20	44	ND(9.0)	14	14	44	9.2	ND (9.0)
	IRON	230	670	3,500	9,200	1,200	3,400	810	7,100
P122	LEAD	53	110	6.6	9.5	15	50	4.3	ND (2.0)
	MAGNESIUM	ND(89)	ND(70)	7,100	7,400	2,500	2,000	3,000	12,000
	MANGANESE	ND(1.0)	40	1,100	1,000	170	140	360	1,600
P123	MERCURY	NQ	NQ	ND(0.2)	ND(0.2)	ND(0.2)	0.29	ND(0.2)	ND (0.2)
	POTASSIUM	20,000	NA	64,000	57,000	13,000	ND(900)	64,000	ND (900)
P125	SELENIUM	NQ	890	ND(2.0)	ND(2.0)	ND(20)	ND(20)	ND(2.0)	ND (20)
P126	SILVER	ND(5.0)	ND(4.0)	ND(5.0)	ND(5.0)	ND(5.0)	6.6	ND(5.0)	ND (5.0)
	SODIUM	36,000	24,000	62,000	63,000	11,000	10,000	7,900	75,000
P127	THALLIUM	ND(1.0)	330	ND(1.0)	ND(1.0)	ND(1.0)	ND(10)	ND(1.0)	ND (1.0)
	TIN	1,100	1,300	12	12	20	180	ND(5.0)	ND (4.0)
	TITANIUM	ND(3.0)	ND(4.0)	6.4	11	68	44	9.1	ND (5.0)
	VANADIUM	ND(11)	ND(10)	ND(10)	ND(10)	ND(10)	16	ND(10)	ND (10)

ND - Analyte not detected (followed by detection limit).

NQ - Analyte not quantified due to matrix interference.

Table 8-4 (Continued)

Priority Pollutant Code	Analyte	Type I Deicing Fluids (50% Solution)		Albany International Airport		Raw Wastewater Samples			Storm Water Outfall Samples
		Ethylene Glycol-Based Fluid	Propylene Glycol-Based Fluid	Small Lagoon	Composite of Large Lagoon and Tank	Kansas City International Airport	Bradley International Airport	Greater Rockford Airport	Bradley International Airport
P128	ZINC	190	440	110	130	140	340	45	ND (10)
	CLASSICAL WET CHEMISTRY (mg/L)								
	AMMONIA AS NITROGEN	3.0	5.4	88	84	3.9	23	46	1.1
	BIOCHEMICAL OXYGEN DEMAND (5-DAY)	NA	NA	12,000	9,800	5,100	39,000	>7.3	61
	TOTAL ORGANIC CARBON (TOC)	410,000	210,000	2,400	2,500	3,000	35,000	12	26
	SILICA-GEL TREATED HEXANE EXTRACTABLE MATERIAL	NA	NA	ND(5.0)	ND(5.0)	6.0	65	ND(6.0)	ND (5.0)
	HEXANE EXTRACTABLE MATERIAL	NA	NA	ND(6.0)	ND(6.0)	10	170	100	ND (5.0)
	WHOLE EFFLUENT TOXICITY (LC 50, endpoint (%))								
	CERIODAPHNIA DUBIA (48-HOUR ACUTE)	NA	NA	NA ¹	NA ¹	58	1.2	NA ¹	>100
	PIMEPHALES PROMELAS (96-HOUR ACUTE)	NA	NA	NA ¹	NA ¹	40	3.1	NA ¹	>100

ND - Analyte not detected (followed by the detection limit).

NA - Analyte not analyzed.

> - Minimum concentration.

1 - Wastewater expected to be toxic to aquatic life due to high ammonia concentration.

LC 50, endpoint (%) - Percentage of raw wastewater that kills 50% of the aquatic test population (i.e., the lower the percentage, the greater the aquatic toxicity). When less than 50% of the test populations dies in all sample concentrations tested up to and including the 100% raw wastewater, the results are reported as >100%.

Table 8-5

**Analytical and Toxicity Data Provided by Fluid Formulators
for Type I Aircraft Deicing Fluids**

Parameter	UCAR™ Aircraft Deicing Fluid Concentrate	Octaflo Concentrate
Ethylene glycol (% weight)	92	N/A
Propylene glycol (% weight)	N/A	88
Chemical oxygen demand (mg O ₂ /mg of fluid)	1.14	NA
Percentage biodegradation	69 (5-day)	61 (7-days)
	85 (10-days)	84 (14-days)
	96 (20-days)	93 (21-days)
Rainbow trout (LC ₅₀ , 96-hour)(mg/L)	17,100	NA
Fathead minnows (LC ₅₀ , 96-hour)(mg/L)	22,000	1,250
<i>Daphnia magna</i> (LC ₅₀ , 48-hour)(mg/L)	NA	750

N/A - Not applicable.

NA - Data not available.

9.0 TOXICITY OF DEICING/ANTI-ICING AGENTS

During aircraft and airfield deicing operations, deicing agents are released to the land, air, and surface waters. Release of these agents may adversely affect the environment, aquatic wildlife, and human health. Aircraft deicing/anti-icing fluids (ADFs) typically contain water, glycols, and additives. The toxicity exhibited by ADFs is due in part to the presence of glycols (which typically make up approximately 45% to 65% of the total fluid by weight when applied), but is also due to the additives contained in the fluids. Although additives comprise a small percentage of ADFs (e.g., less than 2%), they may be responsible for a disproportionate share of the toxicity of ADFs. The toxicity of pavement deicing agents is mainly due to the application of glycols and urea; however, there are other more benign pavement deicing agents currently used.

Several toxicity studies have been performed using pure ethylene glycol and propylene glycol but few studies have been performed using formulated ADFs. The formulations are considered trade secrets, and only limited information is currently available on the actual chemical compositions of formulated ADFs. Some information is available on the types of compounds that may be included as additives in ADFs. The fluid manufacturers indicate that their formulas change often, potentially as often as every year. In general, toxicity studies are available for pavement deicers either from literature sources or from the manufacturers.

Sections 9.1 and 9.2 discuss toxicity tests performed to determine the aquatic and mammalian (including human) health effects of pure ethylene glycol and propylene glycol and of formulated ADFs containing ethylene or propylene glycol, respectively. Section 9.3 discusses tests performed using pure diethylene glycol and formulated deicing/anti-icing fluid containing diethylene glycol, a freezing-point depressant that is commonly used in deicing/anti-icing fluids in Europe. Diethylene glycol is also a byproduct in the manufacturing of ethylene glycol. This section also discusses the toxicity of isopropanol, another possible freezing point depressant alternative. Section 9.4 discusses the toxicity of runway deicing chemicals which include urea,

potassium acetate, sodium formate, calcium magnesium acetate, and others. All tables are presented at the end of this section.

9.1 Comparison of Pure Ethylene Glycol to Pure Propylene Glycol

Ethylene glycol and propylene glycol are synthetic clear liquid substances that absorb water. Ethylene glycol is classified as a hazardous air pollutant (HAP) by Congress, and is required to be reported by users under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) if 5,000 pounds or more in a 24-hour period are released to the environment (see Section 13.2.1 for more information on CERCLA reporting). Propylene glycol is similar in chemical and physical properties to ethylene glycol, but is not classified as a HAP and is not required to be reported if released. In addition to its use as a deicing/anti-icing agent, propylene glycol is commonly used in small amounts as a food additive and in cosmetics and certain medicines to absorb moisture.

Several toxicity studies have been performed using pure ethylene glycol and propylene glycol. The results of these studies generally show that both ethylene glycol and propylene glycol are similar in aquatic toxicity and are fairly nontoxic to the aquatic environment.

Ethylene glycol has been proven to be toxic to mammals, especially humans, when directly ingested (1). It is also classified as a teratogen (likely to cause birth defects) if ingested in large doses (1). When propylene glycol is ingested in regulated amounts as a food additive, it does not have the same toxic effects as ethylene glycol (2). Neither ethylene glycol nor propylene glycol is believed to be toxic by adsorption through the skin or by breathing air containing mists or vapors of either compound.

9.1.1 Aquatic Toxicity

Both ethylene glycol and propylene glycol exhibit similar aquatic toxicity characteristics. Acute and chronic tests have been performed for both glycols. Data were

acquired from several sources, particularly individual studies that performed similar tests on both ethylene glycol and propylene glycol. Tests were performed on both freshwater and marine aquatic life. Acute tests were performed to determine the lethal concentration for 50% of the sample population (LC_{50}) over a short period of time (48 to 96 hours). Chronic tests were performed over a longer period of time (7 to 14 days).

Table 9-1 summarizes aquatic toxicity data from studies that directly compare ethylene glycol and propylene glycol under the same or similar experimental conditions. In general, the data show that ethylene glycol and propylene glycol exhibit aquatic toxicological effects at concentrations within the same order of magnitude. Although EPA does not use such a system, the U.S. Fish and Wildlife Service Classification System for Acute Exposures defines “relatively harmless” as any chemical with an LC_{50} above 1,000 mg/L (3). The test results shown in Table 9-1 indicate that ethylene glycol and propylene glycol may be classified as “relatively harmless,” as defined by the U.S. Fish and Wildlife Service.

The results show that both ethylene glycol and propylene glycol exhibit acute toxicity (LC_{50}) at a concentration above 10,000 milligrams per liter (mg/L). Toxicity values vary based on the species tested. The lowest LC_{50} for ethylene glycol and propylene glycol occurred at a concentration of 27,600 mg/L and 23,800 mg/L, respectively, among sheepshead minnow during a 96-hour test (4).

Table 9-2 lists additional aquatic toxicity studies performed using either ethylene glycol or propylene glycol. The data from these studies may not be directly comparable to other available data due to differences in experimental conditions (e.g., dissolved oxygen concentration, life stage, temperature). The results of these additional studies generally agree with the data presented in Table 9-1. Table 9-2 presents the additional data sources and their references.

9.1.2 Mammalian Toxicity

There are three main exposure routes for ethylene glycol and propylene glycol: inhalation, oral, and dermal (through skin adsorption). Inhalation and dermal exposure to ethylene glycol are not expected to exhibit toxic effects (2). Data based on human oral exposure (accidental or intentional) of ethylene glycol are available, and several animal studies have been used to corroborate the findings (2). When ingested, ethylene glycol quickly breaks down in the body. As it breaks down, it forms chemicals that crystallize and affect kidney functions, and forms acidic chemicals that alter the body's normal chemical balance (2). Inhalation, oral, and dermal exposure to propylene glycol are not expected to lead to toxic effects, although some data suggest oral exposure to propylene glycol may cause allergic reactions with minor side effects (2). Although propylene glycol is approved for use in small amounts as a food additive for human consumption, the Food and Drug Administration (FDA) recently excluded propylene glycol from its generally recognized as safe (GRAS) status in or on cat food (61 FR 19542). The FDA concluded that there are significant questions about the safety of propylene glycol in cat food based on scientific literature (5). Propylene glycol also quickly breaks down in the body but does not form crystals or acidic chemicals in the body (2).

For both ethylene glycol and propylene glycol, information on several different health effects over varying periods of time (acute and chronic) were collected. These health effects include: lethal effects, systemic effects, immunological and lymphoreticular effects, neurological effects, reproductive effects, developmental effects, genotoxic effects, and carcinogenic effects. Levels of effects are divided into two categories: no-observed-adverse-effect levels (NOAELs) and lowest-observed-adverse-effect-levels (LOAELs). LOAELs are classified into "less serious" (i.e., effects not expected to cause significant dysfunction or death) or "serious" (i.e., effects that evoke failure in a biological system and can lead to morbidity or mortality). Below is a summary of the results of several studies (e.g., inhalation, oral, and dermal) compiled by the U.S. Department of Health and Human Services on these different health effects of ethylene glycol and propylene glycol (2).

9.1.2.1 Inhalation Exposure

There are limited data available for ethylene glycol and propylene glycol that describe the human health effects associated with breathing air containing either glycol.

- Lethal - No evidence is currently available in which humans or animals died after inhalation exposure to either glycol. Clinical studies indicate that inhalation of ethylene glycol and propylene glycol is not likely to result in death.
- Systemic - Systemic effects on humans included irritation and reports of headache following inhalation exposure to ethylene glycol; no data are currently available for systemic effects on humans following propylene glycol exposure. Animals exposed to propylene glycol did not experience serious systemic effects.
- Immunological and lymphoreticular - No evidence is currently available that links immunological effects to inhalation of either ethylene glycol or propylene glycol.
- Neurological - No evidence is currently available that links neurological effects to inhalation of either ethylene glycol or propylene glycol.
- Reproductive - No evidence is currently available that links reproductive effects in humans to inhalation of ethylene glycol and propylene glycol; however, in one study, mice exposed to ethylene glycol exhibited increased postimplantation loss (i.e., exhibited increased occurrence of miscarriage). No evidence is currently available that links reproductive effects in animals to inhalation of propylene glycol.
- Developmental - No evidence is currently available that links developmental effects in humans to inhalation of ethylene glycol and propylene glycol; however, mice exposed to ethylene glycol exhibited skeletal malformations and reduced fetal body weight. No evidence is currently available that links developmental effects in animals to inhalation of propylene glycol.
- Genotoxic - No evidence is currently available that links in vivo genotoxic effects in humans or animals to inhalation of either ethylene glycol or propylene glycol.

- Carcinogenic - One study that examined health histories of workers in a chemical plant that were exposed to ethylene glycol concluded that inhalation of ethylene glycol poses negligible cancer risks. No evidence is currently available that links inhalation of propylene glycol to cancer.

9.1.2.2 Oral Exposure

Significant data exist that show the adverse effects associated with oral exposure to ethylene glycol. The main exposure route is direct ingestion. The results show that, when ingested, ethylene glycol can be considered acutely toxic because, even after one ingestion, it can significantly adversely impact human health and may even lead to death. Propylene glycol is a common additive in foods, and is not associated with serious adverse effects following ingestion at low levels.

- Lethal - In cases where humans directly ingested ethylene glycol and died, the lethal amount ranged from 2,379 to 23,786 mg/kg, although some cases exist where the amount ingested is not known. One study concluded that a dose of 1,559 mg/kg of ethylene glycol is lethal (1). Rats and dogs fed similar doses to each other resulted in at least 10% and, in some cases, 100% mortality. No cases were found in which humans died after ingesting propylene glycol. One case did report a horse dying of respiratory failure after ingesting propylene glycol. Studies of oral exposure of propylene glycol to rats resulted in no deaths.
- Systemic - Serious systemic effects in humans and animals occurred following ingestion of ethylene glycol, including cardiovascular, gastrointestinal, renal, and metabolic effects. Less serious effects in animals, including gastrointestinal, hematological, and endocrine effects, resulted after ingestion of propylene glycol.
- Immunological and lymphoreticular - No evidence is currently available that links immunological effects to ingestion of either ethylene glycol or propylene glycol.
- Neurological - Neurological effects were reported in humans, and are among the first symptoms in humans following ethylene glycol ingestion. Such effects include ataxia, slurred speech, irritation, restlessness, and disorientation and may be followed by convulsions and coma. Ingestion of

propylene glycol may also result in neurological effects in allergic individuals, including stupor and repetitive convulsions.

- Reproductive - No evidence is currently available that links reproductive effects in humans to ingestion of either ethylene glycol or propylene glycol. Reproductive studies on mice and rats following ingestion of ethylene glycol are inconclusive, and no adverse reproductive effects were found in mice after ingesting propylene glycol.
- Developmental - No evidence is currently available that links developmental effects in humans to ingestion of either ethylene glycol or propylene glycol. Ingestion of ethylene glycol caused harmful developmental effects in mice, including reduced litter sizes, reduced fetal body weight, and malformations. No evidence is currently available that links development effects in mice to ingestion of propylene glycol.
- Genotoxic - No evidence is currently available that links in vivo genotoxic effects in humans to ingestion of ethylene glycol or propylene glycol. Rats receiving oral doses of ethylene glycol exhibited no lethal mutations.
- Carcinogenic - No evidence is currently available that links cancer in humans to ingestion of ethylene glycol. In two different studies performed on mice and rats, ingesting ethylene glycol over a two-year period did not produce carcinogenic results. No information is currently available that links ingestion of propylene glycol to cancer.

9.1.2.3 Dermal Exposure

Dermal exposure of ethylene glycol and propylene glycol is not likely to cause adverse human or animal impacts.

- Death - No evidence is currently available that links death to dermal exposure of either ethylene glycol or propylene glycol.
- Systemic - No serious systemic effects in humans or animals were found following dermal exposure to ethylene glycol or propylene glycol, with one exception. Serious systemic effects were found in an infant with serious burns who was treated with a dermal dressing that included high levels of propylene glycol. The infant suffered acute respiratory acidosis and cardiorespiratory arrest. After being resuscitated, the baby was discovered to have serious neurological damage. Although the actual source of the

infant's problem could not be determined, propylene glycol cannot be ruled out as the potential harmful agent.

- Immunological and lymphoreticular - No evidence is currently available that links immunological effects in humans or animals to dermal exposure to ethylene glycol or propylene glycol. However, since propylene glycol is widely used in the pharmaceutical industry for dermally applied medications, several studies were performed to investigate its potential to irritate the skin. The results of the studies show that propylene glycol has "marginal irritant properties."
- Neurological - No evidence is currently available that links neurological effects in humans or animals to dermal exposure to ethylene glycol or propylene glycol.
- Reproductive - No evidence is currently available that links reproductive effects in humans to dermal exposure to ethylene glycol. Pregnant mice dermally exposed to ethylene glycol exhibited no adverse reproductive effects. No evidence is currently available that links reproductive effects in humans or animals to dermal exposure to propylene glycol.
- Developmental - No evidence is currently available that links developmental effects in humans to dermal exposure to ethylene glycol. Pregnant mice exposed to ethylene glycol exhibited no adverse developmental effects. No evidence is currently available that links developmental effects in humans or animals to dermal exposure to propylene glycol.
- Genotoxic - No evidence is currently available that links genotoxic effects in humans or animals to dermal exposure to ethylene glycol or propylene glycol.
- Carcinogenic - No evidence is currently available that links carcinogenic effects in humans or animals to dermal exposure to ethylene glycol. No evidence is currently available that links carcinogenic effects in humans to dermal exposure to propylene glycol. No increase in tumors was found in one study on mice after twice weekly applications of propylene glycol to skin.

Table 9-3 presents toxicity data for humans following dermal, oral, and inhalation exposure to ethylene glycol and propylene glycol. Unlike aquatic toxicity tests, tests performed on humans and animals using ethylene glycol and propylene glycol almost always focused on

either ethylene or propylene glycol, but not both, and hence were performed under various conditions. Therefore, the toxicity results are not directly comparable. Accordingly, the data in Table 9-3 show ethylene glycol results followed by propylene glycol results, and not side by side. In addition, no human toxicity data are currently available for inhalation and oral exposure to propylene glycol and dermal exposure to ethylene glycol. It is important to recognize that more studies have been performed using ethylene glycol than for propylene glycol.

9.2 Toxicity of Additives and Formulated Aircraft Deicing/Anti-Icing Fluids (ADF)

ADFs typically consist of a formulation of ethylene glycol or propylene glycol, water, and chemical additives such as flame retardants and corrosion inhibitors. The additives contribute significantly to the overall toxicity of ADFs. For example, available data demonstrate that the additives in ADFs may cause adverse aquatic toxic effects (6). For these reasons, it is important to examine the toxicity of formulated fluids in addition to that of pure ethylene glycol and propylene glycol to determine the toxicological effects of ADFs released to the environment from airport deicing/anti-icing operations. The identity of the actual chemicals used as additives is not known because the ADF manufacturers claim this information confidential; however, general information is known about the types of additives and their possible role in the toxicity of ADFs. Section 9.2.1 discusses this general information. Sections 9.2.2 and 9.2.3 provide available toxicity data for ADFs and compare toxicity among various types of ADFs.

Based on available data, the toxicity exhibited by pure ethylene glycol and propylene glycol is significantly lower, and therefore less toxic, than the corresponding formulated fluids. The reason for this difference is the toxicity of the chemicals that are added, albeit in small amounts, to formulated fluids. Test results indicate that formulated fluids are more toxic than pure glycol substances (1). For example, in a study conducted at Stapleton Airport in Denver, Colorado, a propylene glycol-based ADF exhibited significantly more acute aquatic toxicity than pure propylene glycol. In chronic studies performed at the airport, the concentration that inhibits growth and reproduction in 25% of the test organisms (IC_{25}) of pure propylene glycol for fathead

minnows was 6,941 mg/L, whereas the IC_{25} of propylene glycol-based deicing ADF (type unknown) was 112 mg/L (1). The lower the toxic concentration value, the more toxic the substance. Note, however, that both of these studies were performed several years ago, and more recent ADF formulations would likely exhibit less toxicity.

9.2.1 Aircraft Deicing Fluid Components

As stated previously, the identity of many of the chemical compounds that are added to deicing fluids is unknown; however, general information about the types of additives that may be included in fluid packages is known. For example, the Air Transport Association (ATA) prepared a list of deicing fluid constituents in 1994 (7). According to this list, typical ADF components include or have included:

- Ethylene glycol or propylene glycol;
- Water;
- Surfactants (wetting agents);
- Corrosion inhibitors (including flame retardants);
- pH buffers;
- Dyes;
- 1,4-Dioxane; and
- Complex polymers (thickening agents in Type II and Type IV ADFs).

Other common additives (or manufacturing byproducts) include diethylene glycol, ethylene oxide, and acetaldehyde (1).

Deicing fluids are composed mostly of glycol and water. The remaining components comprise approximately 1% or less of Type I fluids and 2% or less of Type II and Type IV fluids (8). ADFs are required to meet performance-based standards that are established by the Society for Automotive Engineers (SAE). SAE standards for deicing fluids can be found in Aerospace Material Specification (AMS) 1424, and for anti-icing fluids in AMS 1428. ADFs would be unable to meet SAE standards without additives. Manufacturers and formulators have attempted to reduce the toxicity of additives present in their aircraft deicing/anti-icing fluid formulations and, when possible, to use environmentally benign chemicals. For example, one

manufacturer uses a food-grade dye in its deicing fluids that is photoreactive and readily degrades in the environment. Manufacturers and formulators also stress that some additives perform multiple functions. They claim that they could replace these additives with several less toxic additives, but the combined toxicity may be greater than the toxicity of the original additive (9). As discussed in Section 13.5.3, the SAE fluids subcommittee is currently working to set an ADF toxicity standard in the near future.

The potential adverse environmental and health effects of each of the ADF components are discussed below.

9.2.1.1 Glycol

Fluid formulations contain varying amounts of glycol. Typical Type I ADFs contain approximately 90% glycol (by weight) in concentrated form. As applied, they contain between 30% and 60% glycol (typically approximately 50%), whereas Type II and Type IV ADFs contain higher percentages of glycol, closer to 65 percent. In general, by themselves, both ethylene glycol and propylene glycol are relatively nontoxic to the aquatic environment. Ethylene glycol is fairly nontoxic to mammals, except when ingested. Several documented cases show that ethylene glycol, when ingested, may be lethal. Available data indicate that propylene glycol is nontoxic to mammals. See Section 9.1 for a more detailed discussion on the toxicity of pure ethylene glycol and pure propylene glycol.

9.2.1.2 Surfactants

Surfactants, or wetting agents, are substances that reduce the surface tension of fluids and aid fluids in spreading or adhering to aircraft surfaces. They may comprise approximately 0.4% to 0.5% by volume of deicing fluids (7). Surfactants can be very toxic to aquatic organisms (1). At acutely toxic concentrations (concentration unknown), the primary effect on fish would be damage to gill tissue, although it is not known if these tests were conducted using the same surfactants that are used in deicing fluids (1).

9.2.1.3 Corrosion Inhibitors and Flame Retardants

Corrosion inhibitors act to prevent aircraft components that have been covered with deicing/anti-icing fluids from corroding, and flame retardants act to reduce the flammability hazard created when fluids are applied to metal aircraft surfaces that carry electric currents (6). Corrosion inhibitors may comprise up to 0.5% by volume of ADFs and are present at approximately 100 to 300 mg/L (6, 10). The corrosion inhibitor and flame retardant most commonly used in deicing fluids is 5-methyl-1H-benzotriazole (common name: tolyltriazole or TTZ), although 1H-benzotriazole (common name: benzotriazole or BTZ) may also be used. Aquatic toxicity data available for TTZ (summarized below) indicate that it is significantly more toxic than glycols.

Species	Duration	LC ₅₀ for TTZ (mg/L)	LC ₅₀ for Ethylene Glycol (mg/L)	LC ₅₀ for Propylene Glycol (mg/L)
Bluegill sunfish (<i>Lepomis macrochirus</i>)	96-h LC ₅₀	31	27,540	Not available
Water flea (<i>Daphnia magna</i>)	48-h LC ₅₀	74	46,300 - 54,700	43,500

Sources: References (6, 11, 12, 13).

Little mammalian toxicity data are available for TTZ, although it is considered harmful if swallowed and may cause irritation on contact (14). According to the Merck Index, it has a lethal dose at which 50% of the test organisms die (LD₅₀) of 720 mg/kg for rats (14). BTZ was identified by Environment Canada's National Water Research Institute as a potentially toxic additive in ADFs (10).

Scientists and researchers are currently studying the toxic effects of tolyltriazoles. In a study performed by D. Cancilla et al. in 1996, results verified the presence of TTZ and BTZ in deicing and anti-icing fluids (15). The results also showed that both TTZ and BTZ have significant Microtox® activity, although TTZ was more acutely toxic than BTZ. Microtox® testing was conducted using the standard method for various exposure times and temperatures.

The median effective toxicity concentration (EC_{50}) was measured as the concentration at which light lost in the sample equals the light remaining in a sample of bioluminescent bacteria. Results for TTZ and BTZ are presented below.

Compound	5-min. EC_{50} (mg/L)	15-min. EC_{50} (mg/L)
Benzotriazole	41	42
Tolyltriazole	6	6

Source: Reference (15).

Another common corrosion inhibitor includes phosphate esters, which may comprise up to 0.125% by volume of deicing fluids (7). Phosphate esters $((RO)_3PO)$ are derivatives formed by phosphoric acids and alkyl or aryl alcohols. The degree of toxicity of phosphate esters varies. Some phosphate esters can be highly toxic and even carcinogenic (17).

Other common corrosion inhibitors include sodium nitrite, sodium benzoate, and borax (17). Corrosion inhibitors are highly reactive with each other and with glycols, which can result in high biological toxicity (1). In general, corrosion inhibitors are considered toxic chemicals because of their high reactivity potential (1).

9.2.1.4 pH Buffers

pH buffers are solutions that maintain the fluid at a constant pH. The addition of alkali or acid would result in only minimal changes to fluid pH. pH buffers are thought to comprise less than 0.25% by volume of deicing fluids (7). A common pH buffer is potassium hydroxide (7), which on its own is highly caustic upon contact, may be lethal upon ingestion, and is extremely corrosive (14). It has an oral LD_{50} of 1,230 mg/kg for rats (14).

9.2.1.5 Colorants or Dyes

Colorants or dyes (organic based) are chemicals used to color deicing fluids. They are thought to comprise less than 0.25% by volume of deicing fluids (7). Deicing fluids are colored to make them visible so that deicing personnel can see where fluids have been applied and where they have fallen to the ground. In general, Type I fluids are dyed orange and Type II and IV fluids are dyed green. Due to the wide range of potential colorants used in ADFs, no useful information could be collected on the toxicity of colorants or dyes.

9.2.1.6 1,4-Dioxane

1,4-Dioxane is used as a wetting and dispersing agent and is thought to comprise less than 0.5 mg/L of deicing fluids (7). Dioxane is a suspected carcinogen and/or teratogen (1). EPA has reason to believe that some fluid manufacturers have removed 1,4-dioxane from their formulations. However, it is present in at least one ADF, although, according to the fluid's manufacturer, its source is as an impurity that occurs at extremely low levels (18). 1,4-dioxane has low acute aquatic and mammalian toxicity and may be irritating to humans on contact; however, it can exhibit significant chronic toxicity (14). Prolonged exposure to 1,4-dioxane has resulted in several human deaths (14). The oral LD₅₀ in mice and rats is 5,700 mg/kg and 5,200 mg/kg, respectively (14).

9.2.2 Aquatic Toxicity Data for ADF

Few aquatic toxicity experiments have been performed using formulated ADFs. Those that have been performed used a variety of experimental conditions, making it difficult to directly compare data. Table 9-4 summarizes toxicity data from studies that directly compare ethylene glycol-based and propylene glycol-based ADFs by fluid type under the same experimental conditions. Table 9-4 also summarizes all available data for the fathead minnow and *Ceriodaphnia dubia* because EPA selected these species for its aquatic toxicity tests (see Section 8.1). It is important to note that the formulation of these fluids frequently changes. Deicing fluid

manufacturers state that any toxicity data collected using a specific ADF are quickly outdated as they develop less toxic additives. Information provided by an ethylene glycol-based ADF manufacturer shows toxicity in current formulations to be as much as an order of magnitude less than older formulations (8). Aquatic toxicity data from two deicing fluid formulators for concentrated deicing fluid (i.e., Type I) are summarized below. Both of these formulations are currently used in the U.S.

Species	Duration and Endpoint	Type I EG-Based Deicing Fluid Concentration (mg/L)	Type I PG-Based Deicing Fluid Concentration (mg/L)
Fathead Minnow (<i>Pimephales promelas</i>)	96-h LC ₅₀	22,000	1,250
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	96-h LC ₅₀	17,100	NA
Water Flea (<i>Daphnia magna</i>)	48-h EC ₅₀	44,000	NA
Water Flea (<i>Daphnia magna</i>)	48-h LC ₅₀	NA	750

Reference: (19, 20).

NA - Not available.

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

The results above and in Table 9-4 show that, for most aquatic species, the current ethylene glycol-based Type I ADFs exhibit acute aquatic toxicological effects at higher concentrations (i.e., are less acutely toxic) than the current propylene glycol-based Type I ADFs. Note that these data were collected under laboratory conditions in compliance with SAE specifications and not under actual field conditions.

Few sources of toxicity data that directly compare Type IV ethylene glycol-based and propylene glycol-based ADFs are available. Toxicity data for Type IV ADF provided by two fluid manufacturers are presented below. Both of these formulations are currently used in the U.S. Note that these data show toxicity results similar to those for Type II ADFs and that data

were collected under laboratory conditions in compliance with SAE specifications and not under actual field conditions.

Species	Duration and Endpoint	Type IV EG-Based Deicing/Anti-icing Fluid Concentration (mg/L)	Type IV PG-Based Deicing/Anti-icing Fluid Concentration (mg/L)
Fathead Minnow (<i>Pimephales promelas</i>)	96-h LC ₅₀	370	NA
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	96-h LC ₅₀	380	NA
Water Flea (<i>Daphnia magna</i>)	48-h LC ₅₀	630	975

Reference: (19, 20).

NA - Not available.

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

In general, Type I ADFs, regardless of chemical basis, may be considered “relatively harmless” per the U.S. Fish and Wildlife Service Classification System¹. In contrast, Type II/IV ADFs, with an LC₅₀ in the range of 10 to greater than 1,000 mg/L are considered in the range of “slightly toxic” to “relatively harmless” (3).

Based on the available data, the current propylene glycol-based Type IV fluid exhibits toxicity at similar concentrations to the same manufacturer’s current Type I fluid. These results suggest that additives in propylene glycol-based Type IV fluid may not significantly impact aquatic toxicity. However, the ethylene glycol-based Type IV fluid is significantly more toxic to aquatic life than the same manufacturer’s Type I fluid.

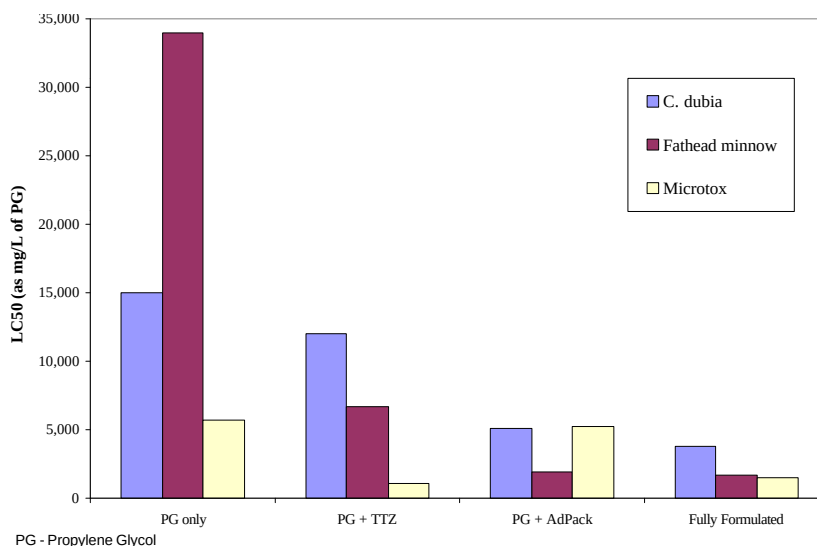
Table 9-5 lists additional toxicity studies performed using either only ethylene glycol-based or propylene glycol-based ADFs on only Type I or Type II fluids. The data from these studies may not be directly comparable due to differences in experimental conditions (e.g.,

¹Although EPA does not use such a system, the U.S. Fish and Wildlife Classification System for Acute Exposures defines “relatively harmless” as any chemical with an LC₅₀ above 1,000 mg/L (3).

temperature, pH). The results of these studies generally agree with the data provided in Table 9-4.

As discussed in Section 8.1, General Mitchell International Airport (GMIA) performed aquatic toxicity tests under actual field conditions (i.e., in-stream sample collection during a storm event). The results show an acute toxic ADF in-stream concentration to fathead minnows and *Ceriodaphnia dubia* above 1,000 mg/L (i.e., $LC_{50} > 1,000$ mg/L).

Aquatic toxicity tests performed by Cornell, Pillard, and Hernandez show different test organisms to be affected by different ADF components (6, 21). Tests were performed using pure propylene glycol, propylene glycol and TTZ, propylene glycol and the additives package excluding TTZ (e.g., only surfactants, dyes, buffers), and two propylene glycol-based fully formulated fluids (from different manufacturers). The *Ceriodaphnia dubia* (*C. dubia*) and fathead minnow were only highly affected by the propylene glycol and additives package (i.e., excluding TTZ) while Microtox® organisms were only highly affected by the propylene glycol and TTZ (i.e., excluding the additives package). In general, the two formulated fluids (shown below as an average), which yielded similar results, were the most toxic combination to all test species. However, the effects of the fully formulated fluids on each test organism were similar (within an order of magnitude) to the effects of the most highly affected component alone, indicating that the most highly affected component controls the toxicological response as shown in the chart below. These results also suggest very different toxicity mechanisms for macroorganisms (e.g., *C. dubia* and fathead minnow) and microorganisms (e.g., Microtox® organisms) (6, 21). Table 9-6 presents the results of the toxicity tests.



9.2.3 Mammalian Toxicity Data for Aircraft Deicing Fluids

No mammalian toxicity data are currently available for ADFs. However, available aquatic toxicity data for ADFs as compared to pure ethylene glycol and propylene glycol, as well as data indicating the potential for ADF additives to cause adverse health effects in mammals, indicate that ADFs will exhibit mammalian toxicity at lower concentrations than pure glycols. As discussed in Section 9.2.1, some additives are known or suspected carcinogens or teratogens.

9.3 Toxicity of Other Freezing-Point Depressants

Ethylene glycol and propylene glycol are the most commonly used freezing point depressants in ADFs, although other freezing point depressants may be used or are currently being researched for approved use by the industry. Diethylene glycol is an SAE-approved freezing point suppressant for use in ADFs; however, no ADFs that are primarily diethylene glycol are currently approved for use in the U.S. Diethylene glycol-based deicing fluids are more commonly found in Europe, although some formulations used in the United States may contain a small portion of diethylene glycol (17).

Isopropyl alcohol (isopropanol) is currently used by the U.S. Air Force as a pavement deicer, but is not currently an SAE- or FAA-approved freezing point depressant for aircraft deicing (17). Although isopropanol is highly flammable and cannot meet the SAE specifications without the addition of fire suppressants, it may be a viable alternative due to its low cost and effectiveness as a freezing point depressant. EPA believes that research is currently being performed on the use of isopropanol for aircraft deicing.

Sections 9.3.1 and 9.3.2 discuss the toxicity of diethylene glycol and isopropanol, respectively.

9.3.1 Diethylene Glycol

Diethylene glycol exhibits similar toxicity characteristics to ethylene glycol but it has a higher eutectic temperature (i.e., minimum freezing point depression temperature) (22). EPA believes that diethylene glycol is not considered a favorable alternative at this time because of these factors. However, trace amounts of diethylene glycol may be commonly found in ethylene glycol-based ADFs (17).

Diethylene glycol is a clear, colorless, syrupy liquid that may be used as an anti-freeze, but is more commonly used in the petroleum refining industry as a solvent extractor (23). In its pure form, it has a freezing point of approximately -10°C (23). The freezing point of a 40% diethylene glycol and 60% water mixture is -18°C , while that of a 50/50 mixture is -28°C (the freezing point of a 50/50 mixture of ethylene glycol and water is -35°C) (14).

Fewer sources of aquatic toxicity data are available for diethylene glycol as compared to ethylene glycol and propylene glycol. Available data are summarized in Table 9-7 and show that diethylene glycol exhibits aquatic toxicity characteristics similar to ethylene glycol and propylene glycol. Based on these data, diethylene glycol may be considered “relatively harmless,” as classified by the U.S. Fish and Wildlife Service (3).

Diethylene glycol, like ethylene glycol, can be fatal if ingested, but it is not as toxic to mammals or humans via other exposure routes (e.g., inhalation, dermal). Table 9-8 summarizes mammalian toxicity data for diethylene glycol.

Diethylene glycol is an eye and human skin irritant (24). Exposure to diethylene glycol may result in nausea, vomiting, headaches, unconsciousness, convulsions, and even death (24). It can also cause degenerative changes in the kidneys and liver, respiratory failure, cardiovascular collapse, acute renal failure, and brain damage, among others (24).

In one documented case, children were accidentally given oral medication that was contaminated with diethylene glycol (at a median concentration of 14.4%). The median estimated toxic dose of diethylene glycol was estimated at 1.34 mL/kg and caused renal failure, hepatitis, pancreatitis, central nervous system impairment, coma, and death (25).

In a study performed to document clinical signs of toxicity in time-pregnant mice, researchers found that 1,250 mg/kg/day of diethylene glycol was a no-observed-adverse effect-level for maternal and developmental toxicity. Mice fed 5,000 mg/kg/day of diethylene glycol produced significant maternal toxicity (e.g., increased water intake, increased kidney weights) but no developmental toxicity. Mice fed 10,000 mg/kg/day of diethylene glycol produced significant maternal toxicity (e.g., increased water intake, decreased food consumption, increased kidney weights and renal lesions), significant developmental toxicity (e.g., decrease in fetal body weight), and resulted in one death during the study. Researchers found that diethylene glycol was not teratogenic in mice at the doses tested in the study (26).

9.3.2 Isopropyl Alcohol (Isopropanol)

Isopropanol is a commonly used chemical, although it is not commonly used for aircraft deicing. Based on responses to EPA's 1993 screener questionnaire, 14 airports were identified as using isopropanol for aircraft deicing; however, EPA was not able to identify any airports that currently use isopropanol-based ADFs. Reportedly, the National Aeronautics and

Space Administration (NASA) is researching the use of an alcohol-based ADF. A main drawback to an isopropanol-based ADF is that it would be corrosive and highly flammable and would, therefore, need to contain significant amounts of flame retardants, corrosion inhibitors, and other potentially toxic additives. On the other hand, from a cost perspective, isopropanol is significantly less expensive than glycols (27).

Isopropanol is a colorless, flammable liquid, that has a slight odor resembling ethanol and acetone (28). It is used in many industries, including chemical manufacturing and pharmaceutical manufacturing for solvent applications (23). It is commonly used as a deicing agent in liquid fuels. In its pure form, it has a freezing point of approximately -88.5°C (23). Exposure to isopropanol can irritate the eyes, nose, mouth, and throat, and overexposure can even cause death (29). It is regulated under Toxic Substances Control Act (TSCA) and Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and must be reported under TRI only if is being manufactured by a strong acid process, which is not applicable to this industry.

Available aquatic toxicity data show that isopropanol exhibits aquatic toxicity at concentrations similar to but slightly less than glycols. The available data are summarized in Table 9-9. The data also show that isopropanol may be considered “relatively harmless,” as classified by the U.S. Fish and Wildlife Service (3).

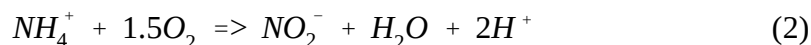
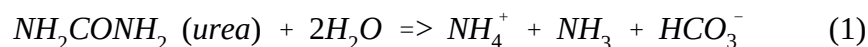
Isopropanol is considered toxic if ingested in large enough doses, or through the subcutaneous route. It is considered moderately toxic by intravenous and intraperitoneal routes, and mildly toxic by dermal contact. Human systemic effects can be the result of ingestion or inhalation. Experimentally, it has been shown to be teratogenic and cause negative reproductive effects. It is also considered an eye and skin irritant. Based on inadequate evidence, it is not classified as a carcinogen; however, there is an increased incidence of nasal sinus cancer in workers involved in the manufacture of isopropanol by the strong acid process. Exposure to isopropanol can lead to skin irritation, dizziness, nausea, lowered blood pressure, abdominal pain, and can even lead to coma and death (29). Table 9-10 summarizes mammalian toxicity data for isopropanol.

9.4 Toxicity of Pavement Deicers

Pavement deicing agents may cause significant adverse environmental impacts, although many airports are beginning to use less harmful agents. Pavement and runway deicing and anti-icing agents approved by the FAA include urea, ethylene glycol (including an ethylene glycol-based fluid known as UCAR, containing approximately 50% ethylene glycol, 25% urea, and 25% water by weight), potassium acetate, calcium magnesium acetate (CMA), sodium acetate, and sodium formate. Alternative agents that may be used for runway deicing include isopropanol and propylene glycol. Salts including magnesium chloride, sodium chloride, and potassium chloride are not approved for use in aircraft operational areas because they are corrosive to aircraft. Sand is used on some airfields to increase friction and improve aircraft braking performance. Pavement and runway deicers must meet specifications set by the SAE or the United States military (MIL-SPEC). Until recently, most commercial airports used urea and/or glycols to deice pavement areas. Due to negative environmental impacts from these agents, several airports currently use more environmentally benign agents, such as potassium acetate, sodium formate, and CMA. Corrosion inhibitors are often added to runway deicers to meet the SAE and MIL-SPEC specifications. As discussed in Section 9.2.1.3, corrosion inhibitors may exhibit high mammalian and aquatic toxicity. Each of the approved agents and resulting adverse aquatic and health effects is discussed below. Available information on the biochemical oxygen demand of deicing agents can be found in Section 10.1.2.

9.4.1 Urea

Urea is typically applied to pavement and runway areas in granular form. Urea is a common nutrient for algae and other water plants as a nitrogen source and is not considered toxic. However, urea degrades by hydrolysis to carbon dioxide and ammonia, which can be very toxic to aquatic organisms even at very low concentrations. Once ammonia is formed, it either remains in solution as ammonia or its ionized form (NH_4^+), biologically converts to other nitrogen forms (e.g., NO_3 or N_2), or volatilizes to the air. The following equations show the degradation of urea:



Urea is considered to be nontoxic to aquatic organisms but it can irritate the nose and throat, causing a sore throat, sneezing or coughing, and shortness of breath in humans (30). Chronic exposure and acute exposure in high concentrations may cause eye damage, skin redness or rash (dermatitis), or emphysema (31). Toxicity data for urea are summarized below.

Species	Duration	Concentration/Dose
<i>Barilius barna</i>	96-h LC ₅₀	>9,100 mg/L
<i>Tilapia mossambica</i>	96-h LC ₅₀	22,500 mg/L
<i>Leuciscus idus melanotus</i>	48-h LC ₅₀	>10,000 mg/L
Water Flea (<i>Daphnia magna</i>)	24-h EC ₅₀	>10,000 mg/L
Mosquito (<i>Aedes aegypti</i>)	4-h LC ₅₀	60,000 mg/L
Freshwater snail (<i>Helisoma trivolvis</i>)	24-h LC ₅₀	30,060 mg/L (adults)
	24-h LC ₅₀	18,255 mg/L (juvenile)
	24-h LC ₅₀	14,241 mg/L (egg)
Rat	LD ₅₀ (oral)	14,300 mg/kg
	LD ₅₀ (subcutaneous)	8,200 mg/kg
Mouse	LD ₅₀ (intravenous)	4,600 mg/kg

Sources: References (30, 31).

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

> - Minimum concentration.

Ammonia in its un-ionized form is one of the urea byproducts that may have significant adverse aquatic effects and reported LC₅₀ values in the range of 1 to 10 mg/L (31). Aquatic toxicity data for ammonia in its un-ionized form are summarized below.

Species	Duration	Concentration (mg/L)
Fathead minnow (<i>Pimephales promelas</i>)	96-h LC ₅₀	0.73 - 3.4; 8.2 (hard water)
Goldfish (<i>Carassius auratus</i>)	24-96-h LC ₅₀	2 - 2.5
Rainbow trout (<i>Oncorhynchus mykiss</i>)	24-h LC ₅₀ (fertilized egg)	>3.58
	24-h LC ₅₀ (0-50 days old)	>3.58
	24-h LC ₅₀ (85 days old)	0.068
	24-h LC ₅₀ (adults)	0.097
Water flea (<i>Daphnia magna</i>)	48-h LC ₅₀ (static test)	189
Water flea (<i>Daphnia pulex</i>)	48-h LC ₅₀ (static test)	187

Source: Reference (23).

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

> - Minimum concentration.

The formation of ammonia is highly dependent on the pH and temperature of a given stream. The higher the pH and temperature, the more ammonia is formed (Equation 1). Another potentially toxic byproduct of urea degradation is nitrous acid (formed from nitrite in an acidic solution), which reacts with secondary amines to form nitrosamines, many of which are known carcinogens (33).

The current ammonia criterion (i.e., allowable concentration) established by EPA for use by permit writers is based on toxicity of ammonia to fish and varies with the temperature and pH of the receiving stream. The warmer the stream and the higher its pH, the more likely ammonia will exist in its un-ionized form (i.e., toxic form), and, therefore, the lower EPA's maximum allowable concentration of ammonia should be set. The colder the stream and lower the pH, the higher EPA's maximum allowable concentration may be set. One factor affecting the maximum allowable concentration during cold seasons (i.e., deicing seasons) is that, for the most sensitive invertebrates, the toxicity of ammonia appears to decrease with decreasing temperature. Therefore, it is believed that the maximum allowable concentration of ammonia during cold seasons may be higher than other times of the year.

9.4.2 Ethylene Glycol

The use of ethylene glycol as a runway and pavement deicer is becoming less popular, due to its reporting requirements and adverse environmental impacts. However, it is an effective freezing point depressant and may still be used at airports subject to extreme temperatures. The toxicity of ethylene glycol and its potential impacts are discussed in Section 9.1.

Urea is often combined with ethylene glycol for use as a liquid runway deicer. The mixture is irritating to the eyes and skin (31). Ingestion can lead to mental sluggishness, difficulty in breathing, heart failure, kidney and brain damage, and death (31). Mammalian toxicity data for an ethylene glycol/urea mixture are presented below.

Species	Duration	Dose (mg/kg)
Rat	LD ₅₀ (oral)	4,700
	LD ₅₀ (intraperitoneal)	5,010
	LD ₅₀ (subcutaneous)	2,800
	LD ₅₀ (intravenous)	3,260
	LD ₅₀ (intramuscular)	3,300

Source: Reference (30).

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

9.4.3 Potassium Acetate

Based on EPA-sponsored site visits, potassium acetate is currently the most commonly used runway and pavement deicer, although airports have expressed concern that it may degrade insulation in electric systems (e.g., runway lights). An industry workgroup is currently investigating this issue. Potassium acetate alone is corrosive, so it is mixed with corrosion inhibitors, and is also slightly flammable. It is typically applied in its liquid form and may be combined with urea prior to application.

Potassium acetate is a common food additive and is relatively nontoxic to mammals in small doses, although it may cause eye irritation (31). The oral LD₅₀ of potassium acetate (without additives) is 3,250 mg/kg for rats (14). Data for potassium acetate-based deicers are presented below.

Species	Duration	Concentration/Dose
Fathead minnow (<i>Pimephales promelas</i>)	LC ₅₀ (duration unknown)	>500 mg/L
	7-d LC ₅₀	>1,500 mg/L
Rainbow trout (<i>Oncorhynchus mykiss</i>)	96-h LC ₅₀	>2,100 mg/L
Water flea (<i>Daphnia magna</i>)	48-h LC ₅₀	>3,000 mg/L
Rat	LD ₅₀	>5,000 mg/kg

Source: Reference (31).

> - Minimum concentration/dose.

The identity and toxicity of corrosion inhibitors typically added to potassium acetate runway deicers is not currently known. Most airports are pleased with the performance of potassium acetate deicer, despite its suspected degradation of electric system insulation and higher cost than other deicers.

9.4.4 Calcium Magnesium Acetate (CMA)

CMA is typically applied in a solid granular form. It is an effective anti-icer that is relatively nontoxic to the environment, though it can be cost-prohibitive. Unlike magnesium chloride and other salts, CMA is not corrosive and, therefore, does not contain corrosion inhibitors. Aquatic and mammalian toxicity for CMA are summarized below. In addition, the results of a 28-day oral toxicity study performed on rats showed no observable effects at daily doses of 1,000 mg/kg (31).

Species	Duration	Concentration/Dose
Rainbow trout (<i>Oncorhynchus mykiss</i>)	96-h LC ₅₀	>1,000 mg/L
Water flea (<i>Daphnia magna</i>)	48-h LC ₅₀	>1,000 mg/L
Rat	LD ₅₀ (oral)	>5,000 mg/L
	LD ₅₀ (dermal)	>5,000 mg/kg
	4-h LC ₅₀ (inhalation)	4.6 mg/L

Source: Reference (31).

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

> - Minimum concentration.

9.4.5 Sodium Acetate

Sodium acetate is typically applied in its solid form and is “relatively harmless,” according to the U.S. Fish and Wildlife standards (31). Sodium acetate is not considered hazardous, but may irritate the skin on contact or irritate the respiratory tract following inhalation of dust. Acute aquatic and mammalian toxicity data are summarized below.

Species	Duration	Concentration/Dose
Water flea (<i>Daphnia magna</i>)	48-h LC ₅₀	2,400 mg/L
Fathead minnow (<i>Pimephales promelas</i>)	24-h LC ₅₀	2,750 mg/L
Rat	LD ₅₀ (oral)	3,530 mg/kg
Mouse	LD ₅₀ (subcutaneous)	8,000 mg/kg
Mouse	LD ₅₀ (intravenous)	335 mg/kg

Source: Reference (31).

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

9.4.6 Sodium Formate

Sodium formate is typically applied in a pellet form and is mixed with corrosion inhibitors to meet the required specifications. Mammalian toxicity data for pure sodium formate (based on mice) are as follows (31):

- LD_{50} (oral) = 11,200 mg/kg; and
- LD_{50} (intraperitoneal) = 807 mg/kg.

Toxicity data obtained from a sodium formate deicer manufacturer are summarized below.

Species	Duration	Concentration/Dose
Water flea (<i>Daphnia magna</i>)	24-h EC_{50}	4,800 mg/L
	48-h EC_{50}	4,400 mg/L
	24-h EC_0	3,300 mg/L
	48-h EC_0	3,200 mg/L
Zebra fish	96-h LC_{50}	100 mg/L
Rat	LD_{50} (oral)	>2,000 mg/L
	4-h LC_{50} (inhalation)	>670 mg/L

Source: Reference (31).

LC_{50} - Median lethal concentration that kills 50% of the test organisms.

EC_{50} - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

LD_{50} - Median lethal dose that kills 50% of the test organisms.

> - Minimum concentration.

Significant exposure to sodium formate deicer may adversely affect people suffering from chronic disease of the respiratory system, skin, and/or eyes. In addition, less sodium formate needs to be applied as compared to several other pavement deicers (e.g., urea) (17).

9.4.7 Alternative Pavement Deicers

Although they are available for use, isopropanol and propylene glycol are not typically used as runway or pavement deicers at commercial airports. EPA is aware of only one airport that mixes propylene glycol with hot sand; the average volume of propylene glycol used is less than 100 gallons per year at this airport. As discussed in Section 9.3.2, isopropanol is a highly flammable liquid that is also highly volatile. It requires special handling requirements and provides minimal anti-icing protection because of its high rate of evaporation. See Section 9.3.2 for a more detailed discussion on the toxicity of isopropanol. However, it is significantly less expensive than other runway deicers on a per gallon basis (27). Propylene glycol's high cost may deter airports from using it as a runway deicer alternative. The toxicological effects of propylene glycol are discussed in Section 9.1.

9.4.8 Chlorides

Magnesium chloride, sodium chloride, and potassium chloride are all used landside (i.e., roadway) but not as runway deicers due to their corrosive effects on aircraft and aircraft components. Salts are commonly used as nutrients and/or dietary supplement food additives in small doses. Large doses may cause adverse human health effects (e.g., gastrointestinal irritation or weakness) (14).

9.4.9 Sand

Sand is nontoxic to the environment and is effective for increasing friction between aircraft and pavement, but may interfere with the mechanical working of aircraft (e.g., engine stalls due to ingestion of sand). Sand is often mixed with other deicing agents (e.g., urea) prior to application.

9.5 **References**

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Table 9-1**Acute and Chronic Toxicity Data for Pure Glycols for Aquatic Species**

Species	Duration and Endpoint	Life Stage	Temp. (° C)	Concentration of Pure Ethylene Glycol (mg/L)	Concentration of Pure Propylene Glycol (mg/L)	Reference
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	24-h LC ₅₀	0.64 g	12	65,100 (12)	79,700 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	0.64 g	12	54,500 (12)	79,700 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	0.64 g	12	54,500 (12)	51,600 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	0.3 - 5 g	12 - 15	50,800 (12) 45,600 (34) 17,800 (34) 22,810 (35) 24,591 (35) 41,000 (36)	51,600 (12) 45,600 (34) 42,380 (35) 37,067 (35)	Ward et al. 1992 (12) Mayer and Ellersieck 1986 (34) Beak Consultants 1995 (35) Johnson and Finley 1980 (36)
Fathead Minnow (<i>Pimephales promelas</i>)	24-h LC ₅₀	0.3 g	22	83,400 (12)	77,800 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	0.3 g	22	52,300 (12)	54,000 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	≤7 d old	25	81,950 (37)	> 62,000 (37)	Pillard 1995 (37)
	72-h LC ₅₀	0.3 g	22	52,300 (12)	51,400 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	0.3 - 0.4 g	21 -23	50,400 (12) 57,000 (38)	51,400 (12)	Ward et al. 1992 (12) Mayes et al. 1983 (38)
	96-h LC ₅₀	≤7 d old	25	72,860 (37)	55,770 (37)	Pillard 1995 (37)
	96-h NOEC (mortality)	≤7 d old	25	39,140 (37)	52,930 (37)	Pillard 1995 (37)
	7-d NOEC (mortality)	≤7 d old	25	32,000 (37)	< 11,530 (37)	Pillard 1995 (37)
	7-d NOEC (growth)	≤7 d old	25	15,380 (37)	< 11,530 (37)	Pillard 1995 (37)
Goldfish (<i>Carassius auratus</i>)	24-h LC ₅₀	6.2 cm 3.3 g	20	>5,000 (39)	>5,000 (39)	Bridie et al 1979 (39)
Clawed Frog (<i>Xenopus laevis</i>)	48-h LC ₅₀	3-4 weeks old	20.0-20.5	19,350 (35) 15,667 (35)	18,700 (35) 24,285 (35)	Beak Consultants 1995 (35)
Water Flea (<i>Daphnia magna</i>)	24-h LC ₅₀	<24 h old (0.19 mg)	20	80,600 (12)	70,700 (12)	Ward et al. 1992 (12)
	24-h EC ₅₀ (immobilization)	<24 h old	20	48,582 (40)	>10,000 (41)	Lilius et al 1995 (40) Kuhn et al 1989 (41)
	48-h LC ₅₀	<24 h old (0.19 mg)	20	54,700 (12) 46,300 (13) 51,100 (13)	43,500 (12)	Ward et al. 1992 (12) Cowgill et al 1985 (13)

Table 9-1 (Continued)

Species	Duration and Endpoint	Life Stage	Temp. (° C)	Concentration of Pure Ethylene Glycol (mg/L)	Concentration of Pure Propylene Glycol (mg/L)	Reference
<i>Ceriodaphnia dubia</i>	48-h LC ₅₀	<24 h old	25	34,440 (37)	18,340 (37)	Pillard 1995 (37)
	48-h NOEC	<24 h old	25	24,000 (37)	13,020 (37)	Pillard 1995 (37)
	7-d NOEC (mortality)	<24 h old	25	24,000 (37)	29,000 (37)	Pillard 1995 (37)
	7-d NOEC (reproduction)	<24 h old	25	8,590 (37) 3,469 (35)	13,020 (37)	Pillard 1995 (37) Beak Consultants 1995 (35)
Green Algae (<i>Selenastrum capricornutum</i>)	24-h EC ₅₀	1,000 cells/mL	24	<6,400 (12)	5,200 (12)	Ward et al. 1992 (12)
	48-h EC ₅₀	1,000 cells/mL	24	13,100 (12)	34,100 (12)	Ward et al. 1992 (12)
	72-h EC ₅₀	1,000 cells/mL	24	<6,400 (12)	24,200 (12)	Ward et al. 1992 (12)
	96-h EC ₅₀	1,000 cells/mL	24	7,900 (12)	19,000 (12)	Ward et al. 1992 (12)
	14-d EC ₅₀	1,000 cells/mL	24	18,200 (12)	18,100 (12)	Ward et al. 1992 (12)
	96-h IC ₅₀	NR	25	13,067 (35)	20,690 (35)	Beak Consultants 1995 (35)
	96-h IC ₂₅	NR	25	8,828 (35)	1,516 (35)	Beak Consultants 1995 (35)
	96-h LOEC	NR	25	13,925 (35)	126 (35)	Beak Consultants 1995 (35)
	96-h NOEC	NR	25	6,963 (35)	37 (35)	Beak Consultants 1995 (35)
	96-h IC ₂₅	NR	25	5,336 (42)	20,800 (42)	DuFresne and Pillard 1995 (42)
Duckweed (<i>Lemna minor</i>)	96-h IC ₂₅ (frond growth)	5 plants/beaker	25	17,115 (42)	12,000 (42)	DuFresne and Pillard 1995 (42)
	96-h LOEC (frond growth)	5 plants/beaker	25	10,000 (42)	5,000 (42)	DuFresne and Pillard 1995 (42)
	96-h IC ₂₅ (chlorophyll)	5 plants/beaker	25	19,848 (42)	21,882 (42)	DuFresne and Pillard 1995 (42)
	96-h LOEC (chlorophyll)	5 plants/beaker	25	20,000 (42)	20,000 (42)	DuFresne and Pillard 1995 (42)
	96-h IC ₂₅ (pheophytin)	5 plants/beaker	25	16,470 (42)	12,000 (42)	DuFresne and Pillard 1995 (42)

Table 9-1 (Continued)

Species	Duration and Endpoint	Life Stage	Temp. (° C)	Concentration of Pure Ethylene Glycol (mg/L)	Concentration of Pure Propylene Glycol (mg/L)	Reference
Duckweed (cont.)	96-h LOEC (pheophytin)	5 plants/beaker	25	40,000 (42)	20,000 (42)	DuFresne and Pillard 1995 (42)
Sheepshead minnow (<i>Cyprinodon variegatus</i>)	24-h LC ₅₀	0.74 g	22	81,700 (12)	63,500 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	0.74 g	22	74,800 (12)	52,500 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	0.74 g	22	39,100 (12)	35,900 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	0.74 g	22	27,600 (12)	23,800 (12)	Ward et al. 1992 (12)
Mysid (<i>Mysidopsis bahia</i>)	24-h LC ₅₀	2.4 mg	22	73,900 (12)	31,000 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	2.4 mg	22	52,600 (12)	27,300 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	2.4 mg	22	43,600 (12)	23,400 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	2.4 mg	22	34,200 (12)	18,800 (12)	Ward et al. 1992 (12)
Marine algae (<i>Skeletonema costatum</i>)	24-h EC ₅₀	1,000 cells/mL	20	<6,900 (12)	31,500 (12)	Ward et al. 1992 (12)
	48-h EC ₅₀	1,000 cells/mL	20	23,900 (12)	19,000 (12)	Ward et al. 1992 (12)
	72-h EC ₅₀	1,000 cells/mL	20	29,900 (12)	19,300 (12)	Ward et al. 1992 (12)
	96-h EC ₅₀	1,000 cells/mL	20	44,200 (12)	19,100 (12)	Ward et al. 1992 (12)
	14-d EC ₅₀	1,000 cells/mL	20	<5,300 (12)	<5,300 (12)	Ward et al. 1992 (12)

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

NOEC - No-observed-effect concentration.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

IC₂₅ - Concentration that inhibits growth and reproduction in 25% of the test organisms.

LOEC - Lowest concentration at which effects were observed.

() - Reference for the data provided.

Table 9-2**Additional Acute and Chronic Toxicity Data Sources for Pure Glycols**

Pure Glycol Type	Species	Reference
Ethylene Glycol	Rainbow trout (<i>Oncorhynchus mykiss</i>)	Beak Consultants 1995 (35)
	Fathead minnow (<i>Pimephales promelas</i>)	Mayes et al. 1983 (38)
		Beak Consultants 1995 (35)
	Bluegill sunfish (<i>Lepomis macrochirus</i>)	Mayer and Ellersieck 1986 (34)
		Abdelghani et al. 1990 (12)
	Guppy (<i>Poecillia reticulata</i>)	Konemann 1981 (43)
	Clawed frog (<i>Xenopus laevis</i>)	deZwart and Slooff 1987 (44)
	Water flea (<i>Daphnia magna</i>)	Gersich et al. 1986 (45)
		Hermens et al. 1984 (46)
		Calleja et al. 1994 (47)
		Bringmann and Kuhn 1977 (48)
	Water flea (<i>Daphnia pulex</i>)	Lilius et al. 1995 (40)
	<i>Ceriodaphnia dubia</i>	Cowgill et al. 1985 (13)
		Pillard 1995 (37)
		Beak Consultants 1995 (35)
	<i>Streptocephalus proboscideus</i>	Calleja et al. 1994 (47)
	<i>Chironomus tentans</i>	Aeroports de Montreal 1995 (49)
	Crayfish (<i>Procambarus sp.</i>)	Abdelghani et al. 1990 (12)
	Rotifer (<i>Brachionus calyciflorus</i>)	Beak Consultants 1995 (35)
		Calleja et al. 1994 (47)
	Ciliated protozoan (<i>Colpidium campylum</i>)	Beak Consultants 1995 (35)

Table 9-2 (Continued)

Pure Glycol Type	Species	Reference
Ethylene Glycol (con't.)	Green algae (<i>Selenastrum capricornutum</i>)	Aéroports de Montréal and Analex Inc. 1994 (50)
	Cryptomonad (<i>Chilomonas paramecium</i>)	Ward and Boeri 1993 (51)
	Brine shrimp (<i>Artemia salina</i>)	Price et al. 1974 (52)
	Shrimp (<i>Crangon crangon</i>)	Blackman 1974 (53)
	Polychaeta (<i>Ophryotrocha labronica</i>)	Akesson 1970 (54)
Propylene Glycol	Rainbow trout (<i>Oncorhynchus mykiss</i>)	Majewski et al. 1978 (55)
	Fathead minnow (<i>Pimephales promelas</i>)	Pillard 1995 (37)
	Water flea (<i>Daphnia magna</i>)	Kuhn et al. 1989 (41)
	<i>Ceriodaphnia dubia</i>	Pillard 1995 (37)
	Green algae (<i>Selenastrum capricornutum</i>)	Dufresne and Pillard 1995 (42)
	Duckweed (<i>Lemna minor</i>)	Dufresne and Pillard 1995 (42)
	Harpacticoid copepod (<i>Nitocra spinipes</i>)	Tarkpea et al. 1986 (56)

() - Reference for the data provided.

Table 9-3**Human Toxicity Data for Pure Ethylene Glycol and Propylene Glycol**

Exposure Type	Health Effect	Exposure/ Duration/ Frequency	NOAEL	LOAEL and Seriousness	Reference
Inhalation	Ethylene Glycol				
	Systemic - Respiratory	15 min.		55 mg/L (less serious)	Wills et al. 1974 (57)
	Systemic - Hematological	30 days (20-22 hrs/day)	19 mg/L		Wills et al. 1974 (57)
	Systemic - Renal	30 days (20-22 hrs/day)	19 mg/L		Wills et al. 1974 (57)
	Neurological	30 days (20-22 hrs/day)		19 mg/L (less serious)	Wills et al. 1974 (57)
Oral (ingestion)	Ethylene Glycol				
	Death	Once		7,070 mg/kg/d (serious)	Gordon and Hunter 1982 (58)
		Once		4,071 mg/kg/d (serious)	Siew et al. 1975 (59)
		Once		2,379 mg/kg/d (serious)	Walton 1978 (60)
		Once		1,559 mg/kg/d (serious)	Verschueren 1983 (23)
	Systemic - Metabolism	Once		4,332 mg/kg/d (serious)	Cheng et al. 1987 (61)
		Once		7,070 mg/kg/d (serious)	Gordon and Hunter 1982 (58)
		Once		11,238 mg/kg/d (serious)	Heckerling 1987 (62)
		Once		3,171 mg/kg/d (serious)	Parry and Wallach 1974 (63)
		Once		7,600 mg/kg/d (serious)	Peterson et al. 1981 (64)
		Once		4,071 mg/kg/d (serious)	Siew et al. 1975 (59)
		Once		12,839 mg/kg/d (serious)	Spillane et al. 1991 (65)
	Systemic - Respiratory	Once		7,070 mg/kg/d (less serious)	Gordon and Hunter 1982 (58)

Table 9-3 (Continued)

Exposure Type	Health Effect	Exposure/ Duration/ Frequency	NOAEL	LOAEL and Seriousness	Reference
Oral (cont.)	Systemic - Cardiovascular	Once		7,070 mg/kg/d (serious)	Gordon and Hunter 1982 (58)
		Once		3,171 mg/kg/d (serious)	Parry and Wallach 1974 (58)
		Once		4,071 mg/kg/d (serious)	Slew et al. 1975 (59)
	Systemic - Renal	Once		7,070 mg/kg/d (serious)	Gordon and Hunter 1982 (58)
		Once		11,238 mg/kg/d (serious)	Heckerling 1987 (62)
		Once		2,714 mg/kg/d (serious)	Mallya et al. 1986 (66)
		Once		3,171 mg/kg/d (serious)	Parry and Wallach 1974 (63)
		Once		7,600 mg/kg/d (serious)	Peterson et al. 1981 (64)
		Once		4,071 mg/kg/d (serious)	Slew et al. 1975 (59)
		Once		12,839 mg/kg/d (serious)	Spillane et al. 1991 (65)
	Systemic - Gastrointestinal	Once		12,839 mg/kg/d (serious)	Spillane et al. 1991 (65)
	Neurological	Once		9,771 mg/kg/d (serious)	Blakeley et al. 1993 (67)
		Once		4,332 mg/kg/d (serious)	Cheng et al. 1987 (61)
		Once		7,070 mg/kg/d (less serious)	Gordon and Hunter 1982 (58)
		Once		11,238 mg/kg/d (serious)	Heckerling 1987 (62)
		Once		2,714 mg/kg/d (serious)	Mallya et al. 1986 (66)
		Once		3,171 mg/kg/d (serious)	Parry and Wallach 1974 (63)
		Once		4,071 mg/kg/d (serious)	Slew et al. 1975 (59)
		Once		12,839 mg/kg/d (serious)	Spillane et al. 1991 (65)

Table 9-3 (Continued)

Exposure Type	Health Effect	Exposure/ Duration/ Frequency	NOAEL	LOAEL and Seriousness	Reference
Dermal	Propylene Glycol				
	Systemic - Hematological	5 days (1x/day)	6,100 mg/kg		Commens 1990 (68)
	Systemic - Respiratory	70 hr (>1x/d)		9,000 mg/kg (serious)	Fligner et al. 1985 (69)
	Systemic - Cardiovascular	70 hr (>1x/d)		9,000 mg/kg (serious)	Fligner et al. 1985 (69)
	Systemic - Metabolism	70 hr (>1x/d)		9,000 mg/kg (serious)	Fligner et al. 1985 (69)
	Systemic - Dermal	20-24 hours		3.2% (less serious)	Hannuksela et al. 1975 (70)
		48 hours once		10 mg (less serious)	Kinnunen and Hannuksela 1989 (71)
		48 hours once		0.2 mg (less serious)	Kinnunen and Hannuksela 1989 (71)
		7 days (2x/day)	104 mg		Trancik and Malbach 1982 (72)
		48 hours once		2.5% (less serious)	Warshaw and Herrmann 1952 (73)
		48 hours once	15 mg	31 mg (less serious)	Willis et al. 1988 (74)
		48 hours once		16 mg (less serious)	Willis et al. 1989 (75)
	Systemic - Dermal	21-22 days		207 mg (less serious)	Trancik and Maibach 1982 (72)
	Immunological/ Lymphoreticular	20-24 hours		3.2% (less serious)	Hannuksela et al. 1975 (70)
	Neurological	70 hours (>1x/day)		9,000 mg/kg (serious)	Fligner et al. 1985 (69)

Note: No human toxicological data are available for inhalation and oral exposure to propylene glycol and dermal exposure to ethylene glycol.

NOAEL - No-observable-adverse-effect-level.

LOAEL - Lowest-observable-adverse-effect-level.

Serious - Effects that evoke failure in a biological system and can lead to morbidity or mortality.

Less Serious - Effects not expected to cause significant dysfunction or death.

() - Reference for the data provided.

Table 9-4**Acute Toxicity Data for Type I and II Formulated Fluids**

Species	Duration and Endpoint	Fluid Type	Life Stage	Temp. (° C)	Concentration of Ethylene Glycol Formulated Fluid (mg/L)	Concentration of Propylene Glycol Formulated Fluid (mg/L)	Reference
Fathead Minnow (<i>Pimephales promelas</i>)	96-h LC ₅₀	I	≤14 d	20-25	12,000 (76) 10,635 (35)	4,900(76) 1,588(35)	Ward 1994 (76) Beak Consultants 1995 (35)
	7-d NOEC (mortality)	I	≤7 d	25	6,090 (37)	270 (37)	Pillard 1995 (37)
	7-d NOEC (growth)	I	≤7 d	25	<3,330 (37)	98 (37)	Pillard 1995 (37)
	7-d IC ₂₅ (growth)	I	≤7 d	25	3,660 (37)	110 (37)	Pillard 1995 (37)
	48-h LC ₅₀	I	≤7 d	25	8,540 (37)	790 (37)	Pillard 1995 (37)
	48-h LC ₅₀	I	≤60 d	21	10,940 (77)		Hartwell et al. 1993,1995 (77)
	96-h LC ₅₀	I	≤60 d	21	10,940 (77)		Hartwell et al. 1993,1995 (77)
	7-d LC ₅₀	I	≤60 d	21	10,940 (77)		Hartwell et al. 1993,1995 (77)
	96-h LC ₅₀	I	≤7 d	25	8,050 (37)	710 (37)	Pillard 1995 (37)
	96-h LC ₅₀	II	≤7 d	21-25	210 (76)	100 (76) 18 (77)	Ward 1994 (76) Hartwell et al. 1993, 1994 (77)
	48-h LC ₅₀	II	≤7 d	22 - 25		42 (77)	Hartwell et al. 1993,1995 (77)
	7-d LC ₅₀	II	≤7 d	22		18 (77)	Hartwell et al. 1993,1995 (77)
Rainbow Trout (<i>Oncorhynchus mykiss</i>)	96-h LC ₅₀	I	0.3-5.0 g	15	10,635 (35)	2,096 (35)	Beak Consultants 1995 (35)
	96-h LC ₅₀	I	juvenile	12	3,700 (76)	3,200 (76)	Ward 1994 (76)
	96-h LC ₅₀	II	juvenile	11-12	200 (76)	38 (76)	Ward 1994 (76)

Table 9-4 (Continued)

Species	Duration and Endpoint	Fluid Type	Life Stage	Temp. (° C)	Concentration of Ethylene Glycol Formulated Fluid (mg/L)	Concentration of Propylene Glycol Formulated Fluid (mg/L)	Reference
<i>Ceriodaphnia dubia</i>	7-d NOEC (mortality)	I	<24 h	25	8,400 (37)	660 (37)	Pillard 1995 (37)
	7-d NOEC (reprod.)	I	<24 h	25	<3,330 (37)	600 (37)	Pillard 1995 (37)
	7-d IC ₂₅	I	<24 h	25	3,960 (37)	640 (37)	Pillard 1995 (37)
	48-h LC ₅₀	I	<24 h	25	13,140 (37)	1,020 (37)	Pillard 1995 (37)
	48-h EC ₅₀	I	<24 h	21	7,730 (77)		Hartwell et al. 1993,1995 (77)
	96-h EC ₅₀	I	<24 h	21	5,384 (77)		Hartwell et al. 1993,1995 (77)
	7-d EC ₅₀ (reprod.)	I	<24 h	21	1,817 (77)		Hartwell et al. 1993,1995 (77)
Water Flea (<i>Daphnia magna</i>)	48-h LC ₅₀	I	<24h	20	26,185 (35)	4,192 (35)	Beak Consultants 1995 (35)
	48-h EC ₅₀	I	<24h	20-21	7,100 (76)	6,000 (76)	Ward 1994 (76)
	48-h EC ₅₀	II	<24h	19-21	120 (76)	280 (76)	Ward 1994 (76)
Sheepshead Minnow (<i>Cyprinodon variegatus</i>)	96-h LC ₅₀	I	juvenile	22	19,000 (76)	7,000 (76)	Ward 1994 (76)
	96-h LC ₅₀	II	juvenile	21-23	270 (76)	290 (76)	Ward 1994 (76)
Mysid (<i>Mysidopsis bahia</i>)	96-h LC ₅₀	I	<24h	23-26	1,100 (76)	1,800 (76)	Ward 1994 (76)
	96-h LC ₅₀	II	<24h	24-25	29 (76)	390 (76)	Ward 1994 (76)
Marine algae (<i>Skeletonema costatum</i>)	96-h LC ₅₀	I	10,000 cells/mL	20-24	1,200 (76)	510 (76)	Ward 1994 (76)
	96-h LC ₅₀	II	10,000 cells/mL	19-21	7 (76)	29 (76)	Ward 1994 (76)

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

() - Reference for the data provided.

Table 9-5

**Additional Aquatic Toxicity Data Sources for
Formulated Fluids**

Glycol and Fluid Type	Species	Reference
Ethylene Glycol Type I	<i>Daphnia pulex</i>	Hartwell et al. 1993; 1995 (77)
	Water flea (<i>Daphnia magna</i>)	HydroQual Laboratories 1994 (78)
		Hartwell et al. 1993; 1995 (77)
	<i>Chironamus tentans</i>	Aéroports de Montreal & Analex 1995 (49)
	Green algae (<i>Selenastrum capricornutum</i>)	Ward 1994 (76)
Ethylene Glycol Type II		Aéroports de Montreal & Analex 1995 (49)
	Green algae (<i>Selenastrum capricornutum</i>)	Aéroports de Montreal & Analex 1994 (50)
		Ward 1994 (76)
Propylene Glycol Type I	Green algae (<i>Selenastrum capricornutum</i>)	Ward 1994 (76)
Propylene Glycol Type II	<i>Daphnia magna</i>	Hartwell et al. 1993; 1995 (77)
	<i>Daphnia pulex</i>	Hartwell et al. 1993; 1995 (77)
	Green algae (<i>Selenastrum capricornutum</i>)	Ward 1994 (76)

() - Reference for the data provided.

Table 9-6**Aquatic Toxicity Results for Formulated Fluids and Their Components**

Species	Solution	Concentrations of Solution Tested PG/TTZ/Adpack (mg/L)	Duration	Concentration measured as PG (mg/L)	Concentration measured as TTZ (mg/L)
<i>Ceriodaphnia dubia</i>	PG + TTZ	10,000/600/0	48-h LC ₅₀	1,647	98
		10,000/120/0	48-h LC ₅₀	8,770	109
		20,000/110/0	48-h LC ₅₀	11,842	68
	TTZ only	0/150/0	48-h LC ₅₀	NA	108
		0/180/0	48-h LC ₅₀	NA	102
	PG only	31,000/0/0	48-h LC ₅₀	15,052	NA
	Fully formulated fluid	5,000/31/P ^a	48-h LC ₅₀	3,829	24
		9,400/52/P ^b	48-h LC ₅₀	3,224	18
	PG + additive pack	10,000/0/P ^c	48-h LC ₅₀	5,122	NA
		11,000/0/P ^d	48-h LC ₅₀	4,919	NA
Fathead minnow (<i>Pimephales promelas</i>)	PG + TTZ	10,000/120/0	96-h LC ₅₀	3,566	43
		20,000/110/0	96-h LC ₅₀	6,742	39
	TTZ only	0/150/0	96-h LC ₅₀	NA	38
		0/190/0	96-h LC ₅₀	NA	65
	PG only	99,000/0/0	96-h LC ₅₀	34,060	NA
	Fully formulated fluid	5,000/28/P ^a	96-h LC ₅₀	1,716	10
		9,000/52/P ^b	96-h LC ₅₀	1,525	8
	PG + additive pack	10,000/0/P ^c	96-h LC ₅₀	1,434	NA
		11,000/0/P ^d	96-h LC ₅₀	1,866	NA
Microtox®	PG + TTZ	10,000/58/0	15-min EC ₅₀	1,127	6
		10,000/600/0	15-min EC ₅₀	153	9
	TTZ only	0/48/0	15-min EC ₅₀	NA	7
	PG only	10,000/0/0	15-min EC ₅₀	5,650	NA

Table 9-6 (Continued)

Species	Solution	Concentrations of Solution Tested PG/TTZ/Adpack (mg/L)	Duration	Concentration measured as PG (mg/L)	Concentration measured as TTZ (mg/L)
Microtox® (cont.)	Fully formulated fluid	10,000/61/P ^a	15-min EC ₅₀	950	6
		9,400/52/P ^b	15-min EC ₅₀	1,497	8
	PG + additive pack	10,000/0/P ^c	15-min EC ₅₀	5,247	NA

Source: Reference (15).

PG - propylene glycol.

TTZ - 4-methyl-benzotriazole and 5-methyl-benzotriazole (common name: tolyltriazole).

NA - Not applicable.

LC₅₀ - Lethal concentration that kills 50% of the test organisms.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally

P^a - Present at an unknown concentration (proprietary information) from Manufacturer 1 (TTZ present).

P^b - Present at an unknown concentration (proprietary information) from Manufacturer 2 (TTZ present).

P^c - Present at an unknown concentration (proprietary information) from Manufacturer 1 (without TTZ).

P^d - Present at an unknown concentration (proprietary information) from Manufacturer 2 (without TTZ).

Table 9-7

Aquatic Toxicity Data for Diethylene Glycol

Species	Duration & Endpoint	Life Stage	Temp. (° C)	Concentration of Diethylene Glycol (mg/L)	Reference
Rainbow trout (<i>Oncorhynchus mykiss</i>)	24-h LC ₅₀	4.1 cm & 0.64 g	12	87,100 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	4.1 cm & 0.64 g	12	79,800 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	4.1 cm & 0.64 g	12	55,400 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	3.5 - 4.1 cm & 0.42 - 0.64 g	12 - 15	52,800 (12) 62,934 (35)	Ward et al. 1992 (12) Beak Consultants 1995 (35)
Fathead minnow (<i>Pimephales promelas</i>)	24-h LC ₅₀	3.1 cm & 0.3 g	22	86,800 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	3.1 cm & 0.3 g	22	86,800 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	3.1 cm & 0.3 g	22	86,800 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	3.1 cm & 0.3 g	22	84,100 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	19.1 mm & 0.102 g	24.9	75,200 (79)	Geiger et al. 1990 (79)
Guppy (<i>Poecillia reticulata</i>)	168-h LC ₅₀	2-3 cm	22	61,000 (43)	Konemann 1981 (43)
Goldfish (<i>Carassius auratus</i>)	24-h LC ₅₀	6.2 cm & 3.3 g	20	>5,000 (39)	Bridie et al. 1979 (39)
Clawed toad (<i>Xenopus laevis</i>)	48-h LC ₅₀	3-4 weeks old	20	20,358 (35) 20,496 (35) 3,065 (44)	Beak Consultants 1995 (35) deZwart and Zloof 1987 (44)
Water flea (<i>Daphnia magna</i>)	24-h LC ₅₀	< 24 h old	20 - 22	>10,000 (48) 78,500 (12)	Bringmann and Kuhn 1977 (48) Ward et al. 1992 (12)
	48-h LC ₅₀	< 24 h old	20	47,200 (12)	Ward et al. 1992 (12)
Green algae (<i>Selenastrum capricornutum</i>)	24-h EC ₅₀	1,000 cells/mL	24	6,400 (12)	Ward et al. 1992 (12)
	48-h EC ₅₀	1,000 cells/mL	24	24,000 (12)	Ward et al. 1992 (12)
	72-h EC ₅₀	1,000 cells/mL	24	6,400 (12)	Ward et al. 1992 (12)
	96-h EC ₅₀	1,000 cells/mL	24	19,900 (12)	Ward et al. 1992 (12)
	14-d EC ₅₀	1,000 cells/mL	24	37,000 (12)	Ward et al. 1992 (12)
Sheepshead minnow (<i>Cyprinodon variegatus</i>)	24-h LC ₅₀	0.74 g	20	90,700 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	0.74 g	20	87,900 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	0.74 g	20	79,600 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	0.74 g	20	62,100 (12)	Ward et al. 1992 (12)

Table 9-7 (Continued)

Species	Duration & Endpoint	Life Stage	Temp. (° C)	Concentration of Diethylene Glycol (mg/L)	Reference
Mysid (<i>Mysidopsis bahia</i>)	24-h LC ₅₀	2.4 mg	22	54,900 (12)	Ward et al. 1992 (12)
	48-h LC ₅₀	2.4 mg	22	43,800 (12)	Ward et al. 1992 (12)
	72-h LC ₅₀	2.4 mg	22	42,900 (12)	Ward et al. 1992 (12)
	96-h LC ₅₀	2.4 mg	22	36,900 (12)	Ward et al. 1992 (12)
Brine shrimp (<i>Artemia salina</i>)	24-h LC ₅₀	nauplii	24.5	>10,000 (52)	Price et al. 1974 (52)
Marine algae (<i>Skeletonema costatum</i>)	24-h EC ₅₀	1,000 cells/mL	20	8,900 (12)	Ward et al. 1992 (12)
	48-h EC ₅₀	1,000 cells/mL	20	26,900 (12)	Ward et al. 1992 (12)
	72-h EC ₅₀	1,000 cells/mL	20	27,300 (12)	Ward et al. 1992 (12)
	96-h EC ₅₀	1,000 cells/mL	20	40,800 (12)	Ward et al. 1992 (12)
	14-d EC ₅₀	1,000 cells/mL	20	22,600 (12)	Ward et al. 1992 (12)

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

() - Reference for the data provided.

Table 9-8**Mammalian Toxicity Data for Diethylene Glycol**

Exposure Type	Species	Typical Dose	Amount	Units
Inhalation	Mouse	Lowest published lethal concentration	130	mg/m ³ /2 hours
Oral	Human	Lowest published lethal dose	1,000	mg/kg
	Dog	LD ₅₀	9,000	mg/kg
	Guinea pig	LD ₅₀	7,800	mg/kg
	Cat	LD ₅₀	3,300	mg/kg
	Mouse	LD ₅₀	23,700	mg/kg
	Rabbit	LD ₅₀	4,400	mg/kg
	Rat	LD ₅₀	12,565	mg/kg
Dermal	Rabbit (intravenous)	Lowest published lethal dose	2,236	mg/kg
	Mouse (subcutaneous)	Lowest published lethal dose	5,000	mg/kg
	Rabbit (skin)	LD ₅₀	11,890	mg/kg
	Mouse (intraperitoneal)	LD ₅₀	9,719	mg/kg
	Rat (intravenous)	LD ₅₀	6,565	mg/kg
	Rat (subcutaneous)	LD ₅₀	18,800	mg/kg
	Rat (intraperitoneal)	LD ₅₀	7,700	mg/kg

Source: Reference (23).

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

Table 9-9**Aquatic Toxicity Data for Isopropanol**

Species	Duration & Endpoint	Life Stage	Temperature (° C)	Concentration of Isopropanol (mg/L)
Fathead minnow (<i>Pimephales promelas</i>)	1-h LC ₅₀	NA	NA	11,830
	24-h LC ₅₀	NA	NA	11,160
	48-h LC ₅₀	NA	NA	11,130
	72-h LC ₅₀	NA	NA	11,130
	96-h LC ₅₀	NA	NA	11,130
Water flea (<i>Daphnia magna</i>)	EC ₅₀ (reproduction)	NA	NA	3,010
	NOEC (reproduction)	NA	NA	2,100
	NOEC (growth)	NA	NA	757
	24-h LC ₅₀	NA	NA	9,500
Goldfish (<i>Carassius auratus</i>)	24-h LC ₅₀	NA	NA	>500
Brown shrimp (<i>Crangon crangon</i>)	48-h LC ₅₀	NA	NA	1,400
	98-h LC ₅₀	NA	NA	1,150
Guppy (<i>Poecilia reticulata</i>)	7-d LC ₅₀	NA	NA	7,060
Green algae (<i>Scenedesmus quadricauda</i>)	7-d EC ₀	NA	NA	1,800
Microtox™ (<i>Photobacterium</i>) test	5-min EC ₅₀	NA	NA	22,800

Source: Reference (20).

LC₅₀ - Median lethal concentration that kills 50% of the test organisms.

NOEC - No-observed-effect concentration.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

NA - Not available.

Table 9-10**Mammalian Toxicity Data for Isopropanol**

Exposure Type	Species	Typical Concentration/Dose	Amount	Units
Inhalation	Rat	Lowest published lethal concentration	16,000	mg/m ³ /4 hours
	Mouse	Lowest published lethal concentration	12,800	mg/m ³ /3 hours
Oral	Human	Lowest published toxic dose	223 - 14,432	mg/kg
		Lowest published lethal dose	3,570 - 5,272	mg/kg
	Rat	LD ₅₀	5,045	mg/kg
	Dog	LD ₅₀	4,797	mg/kg
	Rabbit	LD ₅₀	6,410	mg/kg
	Mouse	LD ₅₀	3,600	mg/kg
Dermal	Rat	LD ₅₀ (intraperitoneal)	2,735	mg/kg
		LD ₅₀ (intravenous)	1,088	mg/kg
	Dog	Lowest published lethal dose (intravenous)	5,120	mg/kg
	Cat	Lowest published lethal dose (intravenous)	1,963	mg/kg
	Rabbit	LD ₅₀ (skin)	12,800	mg/kg
		LD ₅₀ (intravenous)	1,184	mg/kg
		LD ₅₀ (intraperitoneal)	667	mg/kg
	Mouse	LD ₅₀ (intraperitoneal)	4,477	mg/kg
		Lowest published lethal dose (subcutaneous)	6,000	mg/kg
		LD ₅₀ (intravenous)	1,509	mg/kg
	Guinea pig	LD ₅₀ (intraperitoneal)	2,560	mg/kg
	Hamster	LD ₅₀ (intraperitoneal)	3,444	mg/kg
	Frog	Lowest published lethal dose (par)	20,000	mg/kg

Source: Reference (28).

LD₅₀ - Median lethal dose that kills 50% of the test organisms.

10.0 ENVIRONMENTAL IMPACTS FROM THE DISCHARGE OF DEICING/ANTI-ICING AGENT-CONTAMINATED STORM WATER

Deicing/anti-icing agents enter the environment after they are applied to aircraft and paved areas, including runways, taxiways, roadways, and gate areas. It is estimated that approximately 80% of the Type I deicing fluids that are applied to aircraft fall to the pavement (1). Unless they are captured for recycling, recovery, or treatment (either on site or at a publicly owned treatment works (POTW)), deicing agents will flow away to be diluted with other runoff sources or evaporate. If runoff containing deicing agents is not contained or treated, substantial amounts of deicing/anti-icing chemicals may be released to the ground or discharged, where some constituents may degrade but others may ultimately contaminate ground or surface waters. Of the remaining 20% that does not fall to the pavement, an estimated 15% is dispersed to the air while only 5% remains on the aircraft until it shears off during takeoff.

Anti-icing agents make up a smaller percentage of the contaminated storm water runoff than deicing agents. This is because the polymers and thickeners that comprise anti-icing agents make anti-icers more likely to adhere to surfaces and because less volume of fluid is used as compared to deicing agents. Because of these two factors, anti-icing solutions may also result in less air emissions (2). However, anti-icing fluids are more likely to be “carried out” on the plane to runways, which are generally not connected to the airport’s glycol-contaminated wastewater collection system. Some anti-icing fluid drips off the wings during taxiing, while the majority shears off the wing during take-off.

In addition to aquatic and health impacts (discussed in Section 9.0), the biodegradation of glycols released into the aquatic environment can greatly impact water quality in receiving streams, including significant reduced oxygen levels. Section 10.1 discusses, where known, degradability and environmental fate of ethylene glycol and propylene glycol, formulated aircraft deicing/anti-icing fluids (ADFs), alternate freezing-point depressants, and pavement deicing agents. This section also describes the potential effects of direct and indirect releases of aircraft deicing fluids and pavement deicing agents to surface waters and to air. Section 10.2

discusses reports of environmental impacts from the discharge of deicing/anti-icing agent-contaminated storm water. Section 10.3 discusses the effects that the indirect discharge of deicing/anti-icing agent-contaminated wastewater has on POTWs. All tables are located at the end of this section.

10.1 Degradability and Environmental Fate of Deicing/Anti-icing Agents

When released to the environment, ADFs and pavement deicers are generally biodegradable; however, some components require significantly more oxygen to biodegrade than others. Significant oxygen requirements can reduce oxygen levels in receiving streams to the point where the streams do not have enough oxygen to support aquatic life. Sections 10.1.1 through 10.1.4 discuss degradability and oxygen demand as well as environmental fate and bioaccumulation of deicing/anti-icing agents.

10.1.1 Ethylene Glycol and Propylene Glycol

Several environmental effects studies have been performed using pure ethylene glycol and propylene glycol. Both exert a large oxygen demand when biodegrading, which can affect aquatic life by depleting available oxygen in a receiving stream. Propylene glycol requires more oxygen than ethylene glycol to biodegrade (3, 4, 5).

Propylene glycol is more likely to volatilize to the air following aircraft deicing. Both chemicals easily break down in the environment and are not expected to be retained in the tissue of organisms or increase with continued exposure (i.e., bioaccumulate) (4, 5).

Biodegradation

When released into the environment, both ethylene glycol and propylene glycol are expected to partition to surface or groundwater. They are expected to rapidly biodegrade and not to persist in the environment. Biodegradation rates depend on temperature and oxygen conditions

and glycols biodegrade more slowly under anaerobic conditions. The half-life of ethylene glycol and propylene glycol in water under aerobic and anaerobic conditions, and in soil are shown below. Note that these data were not conducted under the same laboratory conditions and may not be directly comparable (5).

Glycol Type	Half-Life		
	Aquatic		Soil
	Aerobic Conditions	Anaerobic Conditions	
Ethylene Glycol	2 to 12 days	4 to 48 days	0.2 to 0.9 days (5 - 22 hours)
Propylene Glycol	1 to 4 days	3 to 5 days	Equal to or slightly less than in water

Based on data presented in Sections 9.1.1 and 9.1.2, both ethylene glycol and propylene glycol have a low toxic potential for aquatic and other animal life; however, aquatic life may be indirectly impacted by the glycol's rapid biodegradation. The biodegradation of glycols consumes oxygen and can lead to low oxygen levels in aquatic systems. Anaerobic biodegradation may also release relatively toxic byproducts such as acetaldehyde, ethanol, acetate, and methane (6).

While ethylene glycol and propylene glycol are both highly biodegradable, ethylene glycol requires less oxygen to degrade than propylene glycol, as shown in the following table.

Oxygen Measure	Ethylene Glycol	Propylene Glycol
Literature values for BOD ₅ (at 20°C), mg O ₂ /L glycol	400,000 - 800,000	1,000,000
Literature values for BOD ₅ (at 20°C), g O ₂ /g glycol	0.4 - 0.7	1
Ethylene glycol manufacturer values for theoretical oxygen demand (i.e., ultimate BOD), g O ₂ /g glycol	1.3	1.7
Propylene glycol manufacturer values for average COD:BOD ratio	2.08	2.23

BOD₅ - 5-day biochemical oxygen demand.

COD - Chemical oxygen demand.

Source: References: (3, 4, 7).

In comparison, the BOD₅ of raw domestic sewage is approximately 200 mg of oxygen per liter of sewage while the BOD₅ of treated effluent (discharged to receiving streams) is about 20 mg of oxygen per liter of effluent (8).

Several variables can greatly affect biodegradation rates, such as the quantity of glycols released, the water temperature, and the chemical and biological quality of the receiving stream. Glycol biodegradation reduces the normal dissolved oxygen content in the receiving stream and may cause the oxygen level to fall below the acceptable level for aquatic survival. When all of the dissolved oxygen in a stream is used, the stream becomes anaerobic and aquatic life is threatened. The amount of dissolved oxygen in water decreases with increasing temperature, and streams are more likely to be threatened by naturally occurring low oxygen levels in the summer.

In tests performed by a propylene glycol manufacturer, the ultimate BOD was determined for varying glycol concentrations, temperature, and time using activated sludge samples that were acclimated to glycols (9). Table 10-1 presents the results of these studies. The results show that, in general, propylene glycol exerts a higher BOD value (in mg of oxygen per liter of glycol) than ethylene glycol, except at the lowest concentrations and lowest temperature tested (1.3 or 3.3 mg/L and 4°C). The results also show that for either glycol, in general, a lower BOD value is expected at lower temperatures.

Since most deicing operations occur when temperatures are low, the BOD₅ at 20°C test (the typical laboratory test temperature) is an overly conservative estimate of the actual oxygen demand that would be measured in the receiving stream. However, in early spring when temperatures may rise and when glycols may be released from melting snow dump piles, the BOD₅ at 20°C may be a more accurate indicator of what is occurring in the environment.

The Streeter-Phelps Model estimates dissolved oxygen (DO) concentrations in a given stream as a function of time. It may be used to determine a DO deficit following a large discharge of pollutants that exert a high oxygen demand when biodegrading, such as ethylene

glycol or propylene glycol. The model accounts for temperature, pollutant loading, and rate of stream flow, but not for other oxygen consumption factors such as additional pollutant loadings that use oxygen to biodegrade. In one experiment that used the Streeter-Phelps Model, assuming a 10:1 dilution factor in receiving streams, several iterations and different downstream DO levels and time periods were used to estimate a maximum ethylene glycol loading upstream to ensure safe DO levels. The downstream oxygen levels, or “oxygen targets,” are based on guidelines for protection of cold-water and warm-water species. The results showed that to achieve a final DO concentration of at least 6.0 mg/L (assumed minimum concentration for warm-water fish), over a 4-hour retention time, less than 800 mg/L of pure ethylene glycol must be in the discharged effluent. To achieve a final DO concentration of at least 9.5 mg/L (assumed concentration for cold-water fish), over a 4-hour retention time, less than 300 mg/L of pure ethylene glycol must be in the discharged effluent. The longer the discharge retention time, the smaller the amount of glycol that can be discharged without resulting in a DO concentration below the target level. For example, to achieve a final DO concentration of 9.5 mg/L over a 24-hour retention time, less than 48 mg/L of pure ethylene glycol would be encountered downstream. Therefore, according to the Streeter-Phelps model, assuming a 10:1 dilution factor in receiving streams, a wastestream containing 480 mg/L of ethylene glycol could be discharged to a receiving stream with a 24-hour retention time without resulting in a DO concentration of less than 9.5 mg/L (10).

Environmental Fate and Bioaccumulation

Ethylene glycol and propylene glycol are highly soluble in water; therefore, volatilization is not likely to be a significant pathway for removal of ethylene and propylene glycol from water under typical natural conditions. The Henry’s Law Constants (at 25°C) for ethylene glycol and propylene glycol are 2.3×10^{-10} atm-m³/mol and $1.2\text{--}1.7 \times 10^{-8}$ atm-m³/mol, respectively (5). Propylene glycol will more readily volatilize than ethylene glycol due to its higher Henry’s Law Constant; both are considered volatile organic compounds (VOCs) by EPA. If released to the air, both glycols are likely to remain in the vapor phase and are expected to undergo rapid photochemical oxidation via reaction with hydroxyl radicals (5). Several studies confirm that neither ethylene glycol nor propylene glycol significantly volatilize to the air. In a study

performed by a propylene glycol manufacturer, a negligible amount of propylene glycol volatilized from a biological treatment reactor, even under favorable conditions (3).

Because both glycols are very soluble in water, biodegradation is the most important process that breaks down ethylene glycol and propylene glycol. Both glycols have a low octanol/water partition coefficient (K_{OW}), which suggests that bioaccumulation is not likely to occur (5). Ethylene glycol and propylene glycol break down very quickly in humans and animals. Studies have found that ethylene glycol was no longer present in body tissues just 48 hours after exposure (5). Crayfish exposed to high concentrations of ethylene glycol (50 to 1,000 mg/L) over a 2-month period did not bioaccumulate significant amounts of ethylene glycol (11). (See Section 9.1 for information on the toxicity of ethylene glycol and propylene glycol.)

10.1.2 Formulated Aircraft Deicing/Anti-icing Fluids

As discussed in Section 10.1.1, both pure ethylene glycol and propylene glycol exert a high oxygen demand on receiving streams, which may significantly affect dissolved oxygen concentrations in these streams. ADFs will exert a lower oxygen demand than pure glycol, primarily because ADFs are diluted with water. Because the additive package is only a small portion of ADFs (typically less than 2%), the chemical additives should not cause a significant increase in the oxygen demand of ADFs. However, some additives may be toxic to the microorganisms that biodegrade them, inhibiting the biodegradation of ADFs, and therefore reducing the BOD measured during laboratory analyses.

Like pure ethylene glycol and propylene glycol, the glycol portion of ADFs is not expected to bioaccumulate and will rapidly biodegrade. Propylene glycol-based ADFs would be expected to biodegrade slightly faster than ethylene glycol-based ADFs, because pure propylene glycol degrades faster than pure ethylene glycol.

A summary of BOD₅ and COD results for Type I, II, and IV ADFs is shown below. The results indicate that ADFs are readily and rapidly biodegraded. Note that the Type I

data presented are for concentrated fluid and not as applied fluid. EPA recognizes that the propylene glycol-based Type I fluid has a lower BOD₅ than the ethylene glycol-based Type I fluid which conflicts with BOD data presented in Section 10.1.1. This occurrence may be due to the different volume of glycol used in each formulation or varying testing conditions. In general, Type II and Type IV solutions should have a higher BOD concentration than Type I solutions (as applied) because they contain a higher concentration of glycol. Note that the source for the propylene glycol and ethylene glycol fluid tests are different; data are provided by their corresponding fluid manufacturers. Because the sources are different, test conditions (e.g., temperature, fluid concentration) may have varied, which could yield incomparable results. Although the ultimate BOD values for ADFs are less than that of their corresponding pure glycol, formulated fluids may still pose an oxygen depletion threat on receiving streams.

Fluid Type	COD (mg/L)	BOD, Day 5 (mg/L)	BOD, Day 10 (mg/L)	BOD, Day 15 (mg/L)	BOD, Day 20 (mg/L)
Type I - EG based (concentrate)	1,260,000	873,000	1,070,000	NA	1,210,000
Type I - PG based (concentrate)	1,400,000	840,000	NA	NA	NA
Type II - PG based	NA	730,000	NA	NA	NA
Type IV - EG based	945,000	463,000	576,000	775,000	935,000
Type IV - PG based	794,000	520,000	NA	NA	785,000

Source: References (12, 13, 14, 15, 16).

NA - Not available.

EG - Ethylene glycol.

PG - Propylene glycol.

COD - Chemical oxygen demand.

Although present in small amounts, fluid additives may impact the biodegradability of ADFs. Limited data are available to assess the impact of ADF additives on the fate of ADFs; however, tolyltriazole (TTZ) can significantly impact the degradability of ADFs. Cornell et al. performed tests on the degradation rate of formulated fluids to assess the effects of the additive pack without TTZ (e.g., surfactants, buffers) and where TTZ was the only additive. It was found that TTZ has a significant impact on the degradation rate. With TTZ present at concentrations

that might be found in airport soils, the pseudo-first order biodegradation rate constant for a propylene glycol-based ADF (containing TTZ) was approximately three times smaller than that of pure propylene glycol. The degradation rate also decreased as the TTZ concentration increased. While the additives package (without TTZ) reduced the degradation constant, the presence of TTZ (with and without the additives package) caused a much greater decrease in the degradation rate (17, 18).

TTZ is composed of two isomers, 4-methyl-benzotriazole (4-MEBT) and 5-methyl-benzotriazole (5-MEBT). U.S. Patent 5,503,775 claims that under aerobic conditions, 5-MEBT is biodegradable while 4-MEBT is recalcitrant (17). While current work is being performed to study the effects of TTZ on the biodegradation of ADFs and glycol, EPA believes that no current research is being performed to study the effects of each isomer on biodegradation rates.

Another main concern of ADF additives is their decomposition products. The degradation of several potential fluid additives may result in more toxic compounds than the primary compounds. For example, TTZ is an azo compound. Azo compounds are known to biotransform under anaerobic conditions into more toxic compounds such as aromatic amines and nitro compounds (12). As mentioned above, TTZ may not be very degradable and may bioaccumulate (17). Anaerobic conditions, caused by the high oxygen demand during glycol degradation, may catalyze the formation of more toxic byproducts when additives decompose (12). Environmental fate and bioaccumulation data are currently not available for other ADF additives.

Inhibition testing may be used to measure a compound's toxic potential on biological systems (e.g., biological wastewater treatment systems). An ethylene glycol ADF manufacturer performed bacteria inhibition testing using Type IV fluid and found the following results.

Fluid Type	IC ₅₀ (mg/L)	NOEC (mg/L)
Type I - EG based	64,000 (or 6.4% concentration)	NA
Type IV - EG based	9,100 (or 0.91% concentration)	2,500 (or 0.25% concentration)

Source: Reference (13).

NOEC - No-observed-effect concentration.

IC₅₀ - Concentration that inhibits growth in 50% of the test organisms.

NA - Not available.

These results show that ethylene glycol-based Type IV ADFs are significantly more toxic to bacteria than Type I fluids. However, Type IV ADFs are not likely to reach POTWs in large concentrations because these fluids are typically carried out beyond collection areas.

The same ADF manufacturer developed air emission rates in 1998. The rates are based on fundamental chemical engineering calculations of mass transport across a boundary layer (i.e., the glycol concentration in a given sample). These rates, shown below, indicate that the use of propylene glycol-based ADFs results in higher air emissions than that of ethylene glycol-based ADFs (2). However, it is important to note that wind and turbulence during storms would disperse the vapor emissions to very low ambient concentrations. These results agree with results predicted based solely on Henry's Law Constant for pure ethylene glycol and propylene glycol (see Section 10.1.1).

Glycol	Product Name	Fluid Type	Glycol Content (% wt.)	Glycol Content (lb/gal)	Glycol Air Emissions (lb glycol per 10,000 gal applied)
Ethylene Glycol	Deicing Fluid Concentrate	I	92	8.52	9.37
	Deicing Fluid XL 54	I	54	4.84	5.32
	Deicing Fluid "50/50"	I	48.4	4.3	4.73
	Deicing/Anti-icing Fluid ULTRA+	IV	64	5.79	6.37
Propylene Glycol	Typical Deicing Fluid "45/55"	I	55	4.78	8.87

Source: Reference (2).

As discussed in Section 4.2.1, up to 4,000 gallons of Type I fluid may be used to deice one aircraft during a severe storm event. Although air emissions factors are relatively low, extensive use of deicing fluids during storm events may result in significant air emissions. Based on the above information, propylene glycol-based ADFs are estimated to result in more than twice the air emissions than ethylene glycol-based ADFs. In addition, the results show that the higher the glycol concentration, the more air emissions are expected to occur. Therefore, it would be expected that Type II and IV fluids would result in greater air emissions than Type I fluids. However, it is important to note that, while Type II and IV fluids would cause higher air emission rates, these fluids are typically applied in much smaller volumes than Type I fluids and are designed to stick to aircraft, which may ultimately reduce net air emissions.

10.1.3 Alternative Freezing-Point Depressants

As discussed in Section 9.3, diethylene glycol and isopropanol are both other freezing-point depressants, although neither is currently used in for deicing/anti-icing aircraft in the U.S. However, diethylene glycol is believed to be used currently in Europe.

Diethylene Glycol

Diethylene glycol, though not used as the main freezing-point depressant in U.S. ADFs, may be found in ethylene glycol-based formulations as a byproduct of the ethylene glycol manufacturing process. Diethylene glycol is biodegradable, though not as easily as ethylene glycol or propylene glycol, is not likely to volatilize to the air, and is not likely to bioaccumulate (based on its low octanol water coefficient) (3, 18, 19). It has an aerobic half life of 3.5 to greater than 20 days, depending on temperature (6). In addition to temperature, degradation rates may also be affected by acclimation. For example, in one study, acclimated bacteria completely degraded a sample of diethylene glycol in 5 days, while unacclimated bacteria degraded only 21% of a diethylene glycol sample (18). Unlike ethylene glycol and propylene glycol, hydrolysis may be an important fate process for diethylene glycol in water because it is easily hydrolyzed.

However, like ethylene glycol, there is potential for more toxic compounds to be formed from anaerobic diethylene glycol degradation (e.g., acetaldehyde, ethanol, and acetate) (6).

Diethylene glycol has a theoretical oxygen demand of 1.51 grams of oxygen per gram of diethylene glycol (18). This theoretical oxygen demand is greater than that for ethylene glycol but less than that for propylene glycol. Several sources have studied the BOD₅ of diethylene glycol, with results ranging from 1.3% to 10% of the theoretical oxygen demand (18). These results are significantly lower than those for ethylene glycol and propylene glycol, indicating that it takes a greater amount of time to completely degrade diethylene glycol.

One propylene glycol manufacturer has conducted studies comparing the biodegradability of diethylene glycol, ethylene glycol, and propylene glycol. BOD₅ data collected during the study were inconsistent and erratic for diethylene glycol, indicating that diethylene glycol is not as readily biodegradable as ethylene glycol and propylene glycol (3). The COD:BOD ratio for diethylene glycol is an order of magnitude higher than that of the other glycols, also indicating that it is not as degradable. The lower biodegradability of diethylene glycol is most likely due to the ether structure of the compound. The data also show that diethylene glycol takes a longer amount of time to biodegrade than ethylene glycol and propylene glycol. A main concern of diethylene glycol degradation is the potential for significant oxygen depletion in receiving streams. Although diethylene glycol requires a similar amount of oxygen to degrade as other glycols, the fact that it takes longer to degrade means that it places a strain, although lesser, on oxygen levels in receiving streams for a longer period of time.

Table 10-2 summarizes diethylene glycol degradation data for four different test conditions. These data show that diethylene glycol is more easily degraded at lower concentrations, in buffered solutions, and at higher temperatures. The removal rates and percent removals for ethylene glycol and propylene glycol are significantly higher than those for diethylene glycol given the same input parameters (3).

In summary, diethylene glycol may be a viable substitute for ethylene glycol and propylene glycol; however, it does not offer any environmental benefits over the glycols currently in use in the U.S. Aquatic and mammalian toxicity values are similar to those of ethylene glycol. Diethylene glycol requires approximately the same amount of oxygen to degrade as ethylene glycol and propylene glycol, but it degrades more slowly. This results in a smaller daily oxygen demand over a longer period of time. This characteristic does not strain oxygen levels as much as the other glycols because the oxygen demand is more gradual; however, diethylene glycol is present in a receiving stream for a longer period of time, which may potentially result in other toxicological effects if present in high concentrations.

Isopropanol

Isopropanol is biodegradable in water, with a half-life of between 2 and 20 days (20). Based on its Henry's Law Constant, it is slightly volatile (21). Upon discharge to water, approximately 77.5% of isopropanol will stay in the water while the remainder volatilizes to the air (20). It is highly soluble in water and is not likely to bioaccumulate; the isopropanol concentration found in fish tissues is expected to be the same as the average isopropanol concentration in the water from which the fish was sampled (20). When released into soil, it is expected to biodegrade, evaporate, or seep into groundwater (22).

Isopropanol has a theoretical oxygen demand of 2.40 grams of oxygen per gram of isopropanol (18). This theoretical oxygen demand is significantly higher than that of glycols. Several sources have studied the BOD₅ (at 20°C) of isopropanol, with results ranging from 60 - 70% of the theoretical oxygen demand for acclimated sludge, indicating that isopropanol is highly biodegradable (18). In addition, based on Monod-type kinetics, the maximum rate of substrate utilization per unit mass of biomass ($k_{\max}$) is very high ($4.89\text{E-}06$) for isopropanol (23). A high $k_{\max}$ value also indicates that the pollutant is highly biodegradable. These results show rapid biodegradation of isopropanol which, combined with a high theoretical oxygen demand, can greatly reduce oxygen levels in receiving streams and would result in greater oxygen depletion than either ethylene glycol or propylene glycol.

10.1.4 Pavement Deicers

There are several pavement deicers that are available and in use by airports. As described in Section 9.4, these deicers have varying toxicity. Like toxicity, these agents have vastly different degradability and environmental fate characteristics.

Urea

Excessive urea in receiving streams often accelerates algal blooms in warmer months, due to the additional nitrogen available. Algal blooms consume large amounts of oxygen, resulting in even greater reduced dissolved oxygen concentrations in streams, and may cause eutrophication in lakes. Due to urea's low octanol/water partition coefficient (-1.52 at 20 to 25°C), urea is not likely to bioaccumulate. It is also not likely to volatilize to the air because of its low Henry's Law Constant. It readily leaches from soil into surface and groundwater (24).

Another factor to consider is the effect of temperature on the degradation of urea to ammonia. Studies have shown that urea completely degrades to ammonia in 4 to 6 days in water at 20°C and negligible degradation occurs at temperatures of less than 8°C (likely temperatures of water bodies during deicing events) (25). Therefore, while the use of urea may cause potential toxic effects to the aquatic environment because of ammonia formation, it may not be as large a concern during winter months as it would during spring or summer months.

Urea/Ethylene Glycol Mix

In a biodegradability test performed using a formulated urea and ethylene glycol fluid, the COD was reported as 1.45 pounds of oxygen per pound of fluid and the BOD as 0.94 pounds of oxygen per pound of fluid. The percent of fluid biodegraded after 21 days (at 20°C) was reported as 94% (26).

Potassium Acetate

All forms of potassium acetate are readily biodegradable. It exerts a BOD that is much lower than other runway deicers (e.g., urea). Reported BOD₅ values are in the range of 0.14 to 0.30 grams of oxygen per gram of potassium acetate (12).

Calcium Magnesium Acetate (CMA)

CMA is also readily biodegradable, which makes it a favorable alternative runway anti-icer (26). EPA was not able to locate any information regarding BOD₅ values for CMA.

Sodium Acetate

Sodium acetate is readily biodegradable even at low temperatures. One manufacturer's sodium acetate-based deicer has a BOD₅ of 0.58 grams of oxygen per gram of anhydrous sodium acetate at 20°C. The chemical oxygen demand is 0.78 grams of oxygen per gram of anhydrous sodium acetate (26).

Sodium Formate

Sodium formate is also highly biodegradable; one specific sodium formate-based deicer has a BOD₅ of 0.23 grams of oxygen per gram of sodium formate, but this rate is highly dependent on temperature (26).

Alternative Pavement Deicers

Transport Canada and ADI Nolan Davis, Inc. conducted a three-year evaluation to compare the performance and impacts of urea and glycols in storm water runoff to that of the newer pavement deicing agents (e.g., sodium formate, potassium acetate, CMA) (12). The results

show that the newer chemicals are “relatively benign” compared to urea and glycols, and are summarized as follows:

- Sodium formate - had little or no impact on water chemistry. It also was difficult to detect, which indicates rapid degradation. Sodium was more frequently detected than formate, although it was difficult to solely attribute detected sodium concentrations to the application of sodium formate. The fact that formate was difficult to detect indicates that it is not persistent in the environment.
- CMA - had little or no impact on water chemistry, and calcium, magnesium, and acetate were all readily detected.
- Potassium acetate - had little impact on surface water, except that BOD₅ levels significantly increased, which was attributed to increased acetate levels. Potassium acetate was more easily detected than sodium formate and had no discernable impact on groundwater, vegetation, and other soil and stream life.

Sand

Sand, while not degradable, can clog storm drains and contaminate water bodies through increased erosion and sediment buildup.

Salts

Salts are not applied to airside pavements, but runoff from roadside pavements can cause water quality in receiving streams to deteriorate.

10.2 Reports of Environmental Impacts from Airport Deicing Operations

The deicing or anti-icing of aircraft and runways is a necessary operation at many airports during the winter months. The release of deicing/anti-icing agents can negatively impact the environment or local POTWs that receive discharges from airports. As part of this study,

EPA reviewed published literature for evidence of environmental impacts on aquatic life, human health, POTW operations, and the quality of receiving waters due to the discharge of deicing anti-icing chemicals.

Literature abstracts were obtained through the computerized information system, DIALOG (Knight-Ridder Information, February 1999), which provides access to scientific journal abstracts such as Pollution Abstracts, Aquatic Science and Fish Abstracts, and Water Resource Abstracts. Newspaper articles were also obtained through DIALOG from 25 randomly selected newspapers serving major northern metropolitan areas. EPA acknowledges that the information in these newspaper articles may not be scientifically accurate or technically representative of actual environmental impacts; however, EPA believed it was important to recognize additional sources of information regarding potential environmental impacts.

In the review of literature abstracts and newspaper articles, environmental impacts were noted from 17 airports and in six general studies. Impacts included: (1) aquatic life effects such as fish kills, growth of biological slimes, elimination of aquatic life, stressed invertebrate communities, and impaired fisheries; (2) effects on wildlife, birds and cattle; (3) human health problems (worker and population exposure - headaches, nausea); (4) aesthetic effects (odor, color, foaming); and (5) effects on the quality of receiving waters (low DO, high BOD, organic enrichment), groundwater, water supplies, and soils. Impacts were mainly due to presence of ethylene and propylene glycol in the receiving streams from storm water runoff. New concerns with the aquatic toxicity of ADF additives were also noted, as well as concerns with the release of other toxic organic chemicals, oil and grease, and metals from airport operations. Table 10-3 summarizes the information collected from the literature.

Specifically, past and current environmental impacts due to the direct discharge of ADF included: (1) aquatic life effects, such as fish kills (four airports), elimination of all aquatic life (two airports), bacterial growth (one airport), concerns with shrimp farming (one airport); (2) aesthetic effects, such as odors and foaming (four airports); (3) effects on the quality of receiving

waters, such as exceeding water quality standards (three airports); and (4) effects on water supplies (1 airport).

It is important to note that many of the airports discussed have made improvements in the collection and treatment of deicing fluids over the past 5 years. Contained deicing areas, increased recycling, and newly built storm water retention basins are all examples of recent improvements. Consequently, the information presented in Table 10-3 may not represent current airport deicing operations.

10.3 Effect on POTWs

Pretreatment standards are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. Section 307(b) of the Clean Water Act authorizes EPA to establish pretreatment standards for pollutants that pass through POTWs or interfere with treatment processes or sludge disposal methods at POTWs. To assess pass-through, EPA generally compares the POTW secondary treatment performance for each pollutant under consideration for regulation to the treatment performance achieved by direct dischargers using best available technologies economically achievable (BAT). This ensures that 1) the wastewater treatment performance for indirect dischargers is equivalent to that for direct dischargers, and 2) the treatment capability and performance of the POTW are considered when regulating the discharge of pollutants from indirect dischargers. Because, at this time, EPA is conducting a study rather than developing effluent limitations for airport deicing operations, a formal POTW pass-through analysis was not performed. However, EPA collected information from POTWs to better understand the impacts wastewater containing deicing/anti-icing chemicals have on POTWs. Appendix A contains information regarding the location of airports referenced in this section.

10.3.1 EPA POTW Questionnaires

As discussed in Section 3.2.3, EPA mailed questionnaires to nine POTWs that accept or have accepted wastewater discharges containing deicing/anti-icing chemicals. EPA received responses to eight of the nine POTW questionnaires. The information collected from these questionnaires, in addition to information collected during site visits, from literature and newspaper searches, and from discussions with airport, airline, and POTW trade association members, was used to assess whether wastewater discharges from airport deicing operations pass through or interfere with POTW operations. Responses to the POTW questionnaires are discussed in the following subsections.

10.3.1.1 Chemicals Typically Found in Discharges

All POTWs surveyed indicated accepting wastewater containing ethylene glycol, propylene glycol, or both. Other chemicals reported in wastewater discharges accepted by the POTWs include potassium acetate, sodium formate, potassium formate, and urea, which are all used as pavement deicers. The Patapsco Wastewater Treatment Plant, which receives discharges from the Baltimore/Washington International Airport, indicated that they accept discharges containing diethylene glycol in addition to ethylene glycol and propylene glycol. See Sections 9.3 and 10.1.3 for more information regarding diethylene glycol.

10.3.1.2 Contribution of Wastewater Containing Deicing/Anti-Icing Chemicals to POTWs

Based on information from the questionnaires, discharges of wastewater containing deicing/anti-icing chemicals do not significantly contribute flow and organic loading to POTW operations. The daily average hydraulic loading for the questionnaire recipients ranges from 1 to 250 million gallons. The percentage of flow from accepted airports relative to total POTW flow ranges from less than 0.01% to 3%, with a mean contribution of approximately one percent. The percentage of BOD accepted from airports relative to total POTW BOD loading

ranges from 0% to 41%, with a mean contribution of approximately four percent. Therefore, airports discharging wastewater containing deicing/anti-icing chemicals to POTWs contribute relatively more BOD loading than hydraulic loading.

10.3.1.3 Documented Negative Impacts at POTWs

Several POTWs reported increased secondary sludge generation and operating costs after accepting wastewater containing aircraft and airfield pavement deicing/anti-icing chemicals. Additional sludge is generated as a result of accepting high loads of glycol and other organic materials that are easily digested by biological treatment microorganisms. Based on biological treatment operating principles, if a plant were to receive a sudden load of highly concentrated organic matter, then more waste sludge would be generated. The extra sludge would need to be wasted (i.e., disposed of) in order for the POTW to meet its discharge limitations. Most POTWs have sludge dewatering on site to handle current sludge generation and any excess sludge. However, additional sludge dewatering incurs energy, chemical, and labor costs, in addition to disposal costs. The addition of glycols and other organic matter in POTW influents may also require additional aeration and microorganisms to degrade these pollutants. The Wyandotte Wastewater Treatment Plant, to which the Detroit Metropolitan Airport discharges its wastewater, has experienced significant oxygen depletion in its secondary biological treatment system as a result of accepting wastewater containing glycols from deicing/anti-icing operations. When this occurs, the POTW either increases the oxygen supplied to the treatment system or asks the airport to reduce its discharge flow. Additional aeration also incurs increased operation and maintenance costs due to associated additional energy and labor.

Although all POTW questionnaire recipients currently accept wastewater from airport deicing/anti-icing operations, two POTWs indicated that they have previously rejected wastewater containing airport deicing/anti-icing chemicals. The Moon Township Municipal Authority, which accepts wastewater from the Pittsburgh International Airport, was forced to reject discharges in 1993. Problems began shortly after the airport first began discharging wastewater containing deicing/anti-icing chemicals. The POTW experienced a drop in dissolved

oxygen concentrations and a problem with maintaining residual chlorine. The POTW solved these initial problems after working with the airport's contractor to adjust discharge pollutant loads and flow rates. However, even after an agreement was reached, the POTW received several large accidental discharges of wastewater containing deicing/anti-icing chemicals; the most recent accidental discharge caused the plant to completely lose all dissolved oxygen and killed all of the biomass in the treatment system. After this incident, the POTW refused to accept further discharges from the airport. The airport responded by hiring a different contractor to manage discharges of wastewater from deicing/anti-icing operations, and the POTW now accepts the airport's discharges.

The Trinity River Authority Central Regional Wastewater System, which accepts wastewater containing deicing/anti-icing chemicals from the Dallas/Ft. Worth International Airport, experienced a similar situation to that described in Pittsburgh. The POTW received a discharge containing an excessively high glycol concentration, which upset the treatment plant. The POTW then refused to accept discharges until the airport installed holding ponds to control discharges to the POTW. Even with controlled discharge, the POTW must maintain a higher concentration of microorganisms in its treatment system during the winter to better accommodate wastewater discharges containing deicing/anti-icing chemicals.

The Salt Lake City Water Reclamation POTW also experienced a treatment plant upset resulting from the acceptance of airport deicing/anti-icing wastewater from the Salt Lake City International Airport. In this case, the POTW did not require that the airport stop discharging. The problem was solved when the POTW required the airport to control its rate of discharge.

The Columbia Boulevard Wastewater Treatment Plant, which accepts wastewater from the Portland International Airport, requests that the airport avoid discharging during periods of high hydraulic loading. The POTW is forced to bypass its secondary treatment when the hydraulic capacity of the system is exceeded. The POTW's secondary treatment is where treatment of deicing/anti-icing chemicals typically occurs.

Although no documentation was provided, POTWs are also concerned with potential byproducts from the degradation of deicing/anti-icing chemicals (e.g., acetaldehyde). POTWs expressed concern over the fact that byproducts may potentially interfere with or pass through a POTW.

10.3.1.4 Documented Positive Impacts

One POTW has benefitted from accepting wastewater containing deicing/anti-icing chemicals. After implementing a batch discharge system, the Kansas City Todd Creek Wastewater Treatment Plant has experienced a reduction in its final effluent BOD by an average of 3 to 4 mg/L.

10.3.2 Evidence of POTW Pass-Through

Although EPA did not perform a thorough POTW pass-through analysis for this study, EPA compared the ethylene glycol and propylene glycol percent removal achieved by a POTW with that achieved by direct dischargers that have implemented collection and on-site treatment technologies. EPA was not able to find a published source that provides a POTW percent removal (based on activated sludge or an equivalent technology) for ethylene glycol or propylene glycol. However, the Moon Township POTW performed sampling in 1993 to study the effectiveness of ethylene glycol treatment and submitted these data to EPA. The sampling data are summarized below.

Date	Influent Ethylene Glycol Concentration (mg/L)	Effluent Ethylene Glycol Concentration (mg/L)	Percent Removal
4/12/93	36	13	64
4/13/93	20	11	45
4/14/93	2.7	3.5	NR
4/15/93	14	7.9	44
4/20/93	16	4.1	74

NR - Not removed.

Data based on a discharge of 1,500 lbs/day of ethylene glycol from the airport.

The data show that the POTW generally experienced low influent concentrations of ethylene glycol and that the average effluent concentration was approximately 10 mg/L. The POTW was generally able to treat the influent ethylene glycol when the influent concentration was already very low. The average POTW percent removal in the data provided was 57%, as compared to >99% at an EPA sampled airport with on-site biological treatment.

As shown in Section 13.2, most airports with indirect discharge permits have limits or monitoring requirements for glycols and/or BOD. Based on responses to the POTW questionnaire, several POTWs reported that they are able to accommodate wastewater containing deicing/anti-icing chemicals, but these discharges must be monitored with controlled discharge into the sewer system, including a period of acclimation at the beginning of each deicing season. As more airports begin discharging their wastewater containing deicing/anti-icing chemicals, more POTWs will need to control the amount of glycols or BOD that are discharged on a daily basis. These limits will be based on the design requirements and effluent limits achievable at the POTW. Although few adverse effects have resulted from controlled wastewater discharges, POTWs remained concerned about accidental discharges and the potential for deicing/anti-icing chemical byproducts to upset the treatment plant. Additional monitoring is needed to better understand the overall impacts that wastewater from deicing/anti-icing operations have on POTW operations.

10.4 References

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Table 10-1

**Ultimate BOD Values for Pure Ethylene Glycol and
Propylene Glycol Acclimated Sludge Seeds**

Day	Ethylene Glycol BOD Value (in mg O₂/L)	Propylene Glycol BOD Value (in mg O₂/L)
4° C - 1.3 or 3.3 mg/L test substance		
0	0	0
5	150,000	75,000
10	150,000	150,000
17	300,000	225,000
27	525,000	375,000
35	825,000	675,000
4° C - 6.7 or 10.0 mg/L test substance		
0	0	0
5	30,000	0
10	45,000	60,000
17	90,000	120,000
27	165,000	510,000
35	495,000	900,000
4° C - 20.0 mg/L test substance		
0	0	0
5	10,000	0
10	20,000	15,000
17	30,000	40,000
27	65,000	Discarded
10° C - 1.3 or 3.3 mg/L test substance		
0	0	0
5	-75,000	-75,000
10	300,000	675,000
16	600,000	1,050,000
20	825,000	1,200,000
27	1,350,000	1,575,000
35	1,800,000	2,100,000

Table 10-1 (Continued)

Day	Ethylene Glycol BOD Value (in mg O₂/L)	Propylene Glycol BOD Value (in mg O₂/L)
10°C - 6.7 or 10.0 mg/L test substance		
0	0	0
5	0	30,000
10	105,000	615,000
16	360,000	960,000
20	870,000	1,005,000
27	1,005,000	1,140,000
35	1,155,000	1,290,000
10°C - 20.0 mg/L test substance		
0	0	0
5	0	35,000
10	40,000	Discarded
16	350,000	Not Tested

Source: Reference (11).

Table 10-2**Biological Degradation Results for Diethylene Glycol**

Parameter	Run			
	1	2	3	4
Diethylene glycol concentration (mg/L)	2,100	1,700	1,000	160
Biomass	acclimated	acclimated	acclimated	acclimated
Temp. °C	19.3	9.8	19.2	19.4
pH	unbuffered	unbuffered	buffered	unbuffered
Detention time (hours)	27	60	48	33
Initial COD concentration (mg/L)	3,100	5,600	3,200	250
Effluent COD concentration (mg/L)	2,300	3,900	1,040	30
Removal rate (1/day)	0.31	0.17	1.1	5.3
Percent removal	25.8	30.4	67.5	88

Source: Reference (3).

Table 10-3**Reported Environmental Impacts from Airport Deicing Operations**

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
Seattle-Tacoma International Seattle, WA (SEA)	Miller Creek, Des Moines Creek, Puget Sound	Ethylene glycol in receiving streams due to runoff	Toxic effects on fish	1993 - Tacoma News Tribune reports “death” of Miller Creek due to runoff from airport. Salmon no longer present in creek. Airport to conduct water-quality study. 1995 - Seattle Post-Intelligencer reports environmental group filed lawsuit against airport charging regularly fouling nearby salmon-bearing streams in violation of water pollution laws and permit. Excessive amounts of oil, grease, metals, toxic petrochemicals and ethylene glycol entering Des Moines Creek, Miller Creek and eventually Puget Sound.
Westchester County White Plains, NY (HPN)	Kensico Reservoir	Propylene glycol in reservoir	Population exposure	1999 - New York Times reports propylene glycol found in Kensico Reservoir at levels high enough to set off warning system. Reservoir serves New York City and most of southern Westchester.
	Rye Lake, Blind Brook; Blind Brook WWTP	Deicers in receiving streams due to runoff and in discharges to WWTP	---	1997 - Journal article summarizes program to improve storm water management at airport including construction of detention ponds to lessen impact on receiving waters, separation of deicing runoff, and discharging limited amount of deicing runoff to local WWTP. Concern with protecting NYC water supply and impact of BOD loading on WWTP.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
General	Environmental Impact of Deicers in Airport Stormwater Runoff	Deicers in receiving streams and groundwater due to runoff	Toxic effects on aquatic life - fish kills	1990 - Michigan DNR conducted investigation into aircraft and runway deicing. Concerns with aquatic toxicity of ammonia, oxygen depletion, organic enrichment of receiving streams and obnoxious odors during biodegradation process. Article notes fish kills from Lambert Field discharge and impairment to aquatic communities at Pittsburgh, Nashville, and Anchorage. Groundwater contamination at Michigan airports may be occurring. Regulatory action necessary to control indiscriminate releases.
Lambert-St. Louis International St. Louis, MO (STL)	Coldwater Creek	Ethylene glycol in receiving stream due to runoff	Population exposure	1995 - St. Louis Post Dispatch reports thousands of gallons of ethylene glycol entering Coldwater Creek. Residents along creek report foul odors. Airport ordered by EPA and State Department of Natural Resources to make improvements. Airport says cannot meet ordered deadline and faces fines of up to \$10,000/day.
Cleveland International Airport Cleveland, OH (CLE)	Rocky River	Toxic chemicals in receiving stream	---	1991 - Columbus Dispatch reports state is in litigation with airport over flow of chemicals into Rocky River. Chemicals detected more than decade ago, but no fish kills attributed.
Detroit Metropolitan Romulus, MI (DTW)	Detroit River	Ethylene glycol in receiving stream	---	1990 - Detroit Free Press reports state officials investigating allegations of airport runoff polluting Detroit River. Ethylene glycol flowing untreated from ponds into storm drains.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
Dayton Municipal Airport Dayton, OH (DAY)	Mill Creek	Ethylene glycol in receiving stream and groundwater	Fish kills; population exposure	1991 - Columbus Dispatch reports fish kill in Mill Creek in 1987. Associated Press reports 1998 - Ohio EPA cites at least seven times since 1978 spills have affected the quality of receiving streams. In 1996, airport paid \$2.6 million to settle lawsuit by homeowners for contaminated well water.
Chicago O'Hare International Chicago, IL (ORD)	NRDC Lawsuit	Ethylene glycol releases	---	1998 - Chicago Tribune reports NRDC contends O'Hare has violated federal reporting requirements (time, place, quantity) approximately 180 times since Nov. 1996 in its use of ethylene glycol. Airport reports average use of 241,689 lbs/day. NRDC estimates 84,591 lbs/day being released to environment. EPA investigating allegations.
Cincinnati/ Northern Kentucky International Erlanger, KY (CVG)	Elijah Creek	Deicing chemicals in receiving stream	Effects on aquatic life population exposure; aesthetic effects	1992 - Associated Press reports state has cited airport for discharge of deicing chemicals. Major impact on Elijah Creek. Discharges harmed aquatic life, caused unpleasant odors and discoloration of creek.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
Airborne Express (ABX Air, Inc.) Wilmington, OH (ILN)	Lytle Creek	Deicers in receiving stream	Effects on aquatic life - fish kills; population exposure; effects on wildlife	1998 - Associated Press reports disappearance of aquatic life in Lytle Creek and subsequent disappearance of birds. Foul odors reported. Residents complaining of illness. Thousands of fish killed (bass, blue gill). State EPA issued airport a notice of violation for exceeding limit for deicing runoff. Airport has established a manmade wetland to breakdown deicers before discharge.
Portland International Portland, OR (PDX)	Columbia Slough	Glycols in receiving water due to runoff; urea in land area	Effects on aquatic life (glycols); severe oxygen shortages but no fish kills. Urea increased grass growth, which attracted wildlife and posed a hazard to jets.	1999 - Oregonian reports a Portland Legislator (Randy Leonard) is drafting legislation (the Columbia Slough bill) that would order the airport to stop discharging glycol into any body of water. (Note that the legislation did not pass.) Columbia Slough already badly polluted and very sluggish and cannot handle load of glycol. Airport trying to minimize discharges, but says ban difficult to achieve. In 1998, Oregon DEQ began preparing permit to limit discharge of glycol - some to Columbia Slough, Portland sewers, Columbia River and off-site disposal. Discharges to be corrected by year 2005. Airport stopped using the runway deicer urea and started using potassium formate. Note that Oregon DEQ issued an NPDES permit to the airport to implement BMPs to reduce deicing storm water runoff to the Columbia Slough.

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Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
Minneapolis-St. Paul International Woodland, MN (MSP)	Minnesota River	Glycols in receiving stream due to runoff	Effects on aquatic life - low oxygen levels but no documented fish kills	1993 - Star Tribune reports state issued new permit for airport requiring reduced discharges and extensive monitoring. Glycol is adding stress to Minnesota River and ability to recover from other pollutants, particularly agricultural chemicals.
Greater Buffalo International Cheektowaga, NY (BUF)	Ellicott Creek	Ethylene glycol and propylene glycol in receiving stream	---	1994 - Buffalo News reports on concerns for Ellicott Creek. Residents report seeing foaming material in stream.
Pittsburgh International, Pittsburgh, PA (PIT)	McClarens Run, Enlow Run, and Montour Run	Propylene glycol and urea in receiving water	Fish kills; population exposure	1998 - Pittsburgh Post-Gazette reports Pennsylvania DEP ordered airport to correct long-standing water pollution problems caused by glycol deicers, as well as other groundwater and discharge problems. Strong antifreeze odor also noted. In 1994, airport had agreed to stop harmful deicing practices and paid \$60,268 to state's Clean Water Fund. In 1996, skiers, and fishermen complained of headaches and nausea and strong odors. PA DEP filed lawsuit because of permit violations. Violations include urea, glycols, phenol, xylene, ethyl benzene, and oil/grease. Fines up to \$25,000/day for past violations. Fish kills occurred in winter of 1992-93 and 1993-94.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
PIT (cont.)	Montour Run and Tributaries	Deicing fluids in receiving streams due to runoff	Effects on aquatic life	1998 - Journal article presents results of 1996 study on impacts of airport runoff on water quality and aquatic life. Principal effects related to runway deicing operations. High BOD due to glycols and urea. High concentrations of ammonia. Organic load stimulated growth of dense biological slimes on streambeds. Invertebrate communities severely stressed and dominated by pollution tolerant species. Fishery of watershed impaired.
Anchorage International Airport Anchorage, AK (ANC)	Lake Hood	Ethylene glycol in receiving stream due to runoff	Toxic effects on wildlife	1991 - Anchorage Daily News reports concerns for wildlife that use Lake Hood. Also concerned with oil/grease and aviation fuel.
Baltimore/Washington International Baltimore, MD (BWI)	Sawmill Creek, Stony Run, Cabin Branch, Kitten Branch, Muddy Bridge Branch	Ethylene glycol in receiving streams due to runoff	Toxic effects on aquatic life; population exposure; aesthetic effects	1998 - Washington Post/Baltimore Sun report lawsuit filed by NRDC against airport for violating CWA over past 3 years. Residents complain of odor and foaming. Concern for Chesapeake Bay. Problems with \$16 million dollar deicing collection system. Concentration of glycol in Sawmill Creek more than 6X level to kill aquatic life.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
BWI (cont.)	Toxicity of Stormwater	Deicing chemicals in receiving streams due to runoff	Potential acute toxicity to aquatic life	1995 - Journal article on study designed to investigate the acute toxicity of storm water from BWI. Samples from winter storm events caused acute toxicity to both fathead minnow and daphnid with LC ₅₀ values as low as 1.0-2.0% effluent due to glycol-based deicers. High oxygen demand and elevated nitrogen levels also potential problems. Samples from rain events during nonwinter months did not cause acute-toxicity unless associated with fuel spills.
Denver International Airport Denver, CO (DIA)	Third Creek, Barr Lake	Propylene glycol in receiving stream	Effects on aquatic life - all life killed due to low oxygen levels; population exposure; aesthetic effects	1997/1998 - Denver Post/Rocky Mountain News report spills of propylene glycol into Third Creek. All aquatic life for 2 miles in Third Creek killed due to depletion of oxygen. Concern for bird sanctuary at Lake Barr. Farmers concerned for cattle. Complaints about odor and color. In 1998 dam built to protect Third Creek from runoff broke.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
General	Management of Aircraft Deicing Fluids	Deicing chemicals in receiving streams due to runoff and in discharges to WWTPs	Toxic effects on aquatic life; POTW operations effects	1994 - Journal article states principal environmental impact of deicing activities is oxygen demand. CBOD ₅ of ethylene glycol ranges from 400,000-800,000 mg/L and propylene glycol > 1 x 10 ⁶ mg/L (untreated domestic wastewaters is 200-300 mg/L). One-half of deicing fluids ends up in storm water. Ammonia released from urea potentially toxic to aquatic life and contributes to nitrogenous oxygen demand. Various alternative technologies and strategies exist depending upon airport and are discussed in article. Disposal at municipal wastewater treatment plants dependent on plant location, capacity, and charges for treating high-BOD wastes.
General	Management of Deicing Constituents	Deicers in receiving streams and groundwater due to storm water discharges	Toxic effects on aquatic life; aesthetic effects	1992 - Master thesis research identifies use and management practices of deicing constituents (glycol, urea, CMA, and sodium formate). Concerns of discharges include high BOD, nitrate and nitrite enrichment of surface and groundwaters, impaired aesthetic water quality, ammonia formation, and overall toxicity to aquatic life.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
Major International North America	Detection of Aircraft Deicing/Anti-icing Fluid Additives (ADFs) in Water Monitoring Well	Tolytriazoles present in subsurface water samples from airport deicing activities	Toxic effects on microorganisms	1998 - Journal article presents results of research that describes first evidence that constituents within ADFs, other than glycols, are present in subsurface water samples from a major North American airport at environmentally significant concentrations. Tolytriazoles concentrations approximately 25 times higher than reported EC50 values in Microtox assays. Previous glycol levels from well were 24,410 mg/L.
General	Environmental Impacts of America's Airports	Deicing fluids in receiving streams due to runoff	---	1995 - NRDC study of most important environmental issues and best management techniques to mitigate them. Surveyed 125 busiest airports (46 responded) and in-depth research at government agencies on 50 busiest. Significant environmental impacts common at most airports and regulatory framework currently in place inadequate. Deicing and water quality one of the significant impacts. Study recommends: (1) developing effluent guidelines; (2) addressing worker health and safety from ethylene glycol exposure; (3) lowering threshold of national storm water program to include smaller airports; (4) conducting research on deicing alternatives; (5) requiring airports to report releases in TRI; (6) making storm water pollution prevention plans public.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

Table 10-3 (Continued)

Airport	Site/Study	Exposure		Impacts (a)
		Environment	Biota/Effect	
General	Petition to Require SIC 45, Transportation by Air, To Report Releases of Toxic Chemicals	---	---	1997 - NRDC, Defenders of Wildlife, National Audubon Society, and Humane Society petition EPA to initiate rulemaking requiring airports, airline terminals, and aircraft maintenance facilities to report releases of toxic chemicals listed on TRI. Basis of petition is ranking (3rd) as industry for inclusion in TRI. 58 million pounds of ethylene glycol released/year. Use increasing and cheaper than alternatives. Other toxics include trichloroethylene, methylene chloride, acetone, chloroform, methyl ethyl ketone, isopropyl alcohol, glycol ethers, toluene, xylene and other petroleum distillates. Petition cites examples of ethylene glycol toxicity to humans and wildlife, health effects of other toxics, and significant human and wildlife exposures from deicing operations. Petition published in the <u>Federal Register</u> and awaiting further action.

Sources: DIALOG database (Journals and Newspaper Articles) - February, 1999 Retrieval, Internet and States.

(a) EPA recognizes that not all impacts presented in this table are scientifically based and the Agency takes no position on the accuracy of any conclusion derived from the cited materials. Due to recent improvements in the collection and treatment of deicing fluids at airports, the information presented in this table may not represent current airport deicing conditions.

11.0 POLLUTANT LOADINGS AND COSTS TO MANAGE WASTEWATER FROM AIRPORT DEICING OPERATIONS

EPA evaluated the effectiveness of implementing an effluent guideline to control discharges of wastewater from aircraft deicing/anti-icing operations. EPA developed estimates of pollutant loadings in wastewater discharges from aircraft deicing/anti-icing operations and loadings in storm water discharges from these operations using the current storm water permit regulations as a basis of comparison.

EPA did not consider pollutant loadings in storm water discharges from pavement deicing/anti-icing because EPA believes that, as a result of the implementation of the storm water permit regulations, increased use of alternate agents that contain no glycol and minimal biochemical oxygen demand (BOD) load will continue. Consequently, EPA did not account for loadings from pavement deicers in this analysis.

Estimates of pollutant loadings were developed for the following four cases:

1. Estimated pollutant loadings prior to implementation of the EPA Phase I Storm Water Permit Application Regulations;
2. Estimated current pollutant loadings;
3. Estimated pollutant loadings when storm water permits have been fully implemented; and
4. Estimated pollutant loadings assuming implementation of an effluent guideline.

Section 11.1 describes the methodology used to develop pollutant loadings and presents the results. Section 11.2 provides costing information for managing wastewater from airport deicing operations.

11.1 Pollutant Loading Estimates

Aircraft deicing and anti-icing operations are conducted at passenger terminal gates and aircraft parking ramps where aircraft deicing/anti-icing fluid (ADF) applied to aircraft falls on the pavement, commingles with storm water, and discharges to U.S. surface waters via storm water drainage systems. Some airports collect wastewater from aircraft deicing/anti-icing areas for discharge to publicly owned treatment works (POTWs). Other sources of ADF discharges include leaks from worn or defective fittings on deicer trucks and other application equipment; spills such as overfilling deicer truck tanks, leaks from fluid storage tanks; drips from aircraft during taxiing and takeoff; leaks from containment and collection structures; and leaks from wastewater storage facilities. While these other sources undoubtedly contribute to pollutant loadings, EPA believes their combined contribution is minor compared to that from the spray application of the fluids. EPA, therefore, developed pollutant loading estimates for the industry based solely on estimates of the average volume of fluid sprayed and considered all other sources of ADF discharges to be negligible.

EPA developed pollutant loading estimates using the following six-step method.

1. Compiled a list of U.S. airports that potentially perform a significant number of deicing/anti-icing operations and grouped these airports based on their size and climate.
2. Estimated the total annual volume of fluid used at each airport identified in Step 1 using fluid use data collected from the industry.
3. Estimated the percentage of the fluid sprayed that has the potential to impact U.S. surface waters and calculated the volume of ADF discharged annually to U.S. surface waters for each airport identified in Step 1.
4. Used the estimated volumes calculated in Step 3 combined with information collected from the industry to estimate the pollutant loadings discharged to U.S. surface waters prior to the implementation of EPA's Phase I Storm Water Permit Application Regulations.

5. Used the estimated volumes calculated in Step 3 combined with information collected from the industry to estimate the current pollutant loadings and the loadings remaining after full implementation of the Phase I Storm Water Permit Application Regulations.
6. Estimated the pollutant loadings assuming implementation of an effluent guideline.

The following subsections describe Steps 1 through 6. The report entitled Development of Estimated Loadings in Wastewater Discharges From Aircraft Deicing/Anti-icing Operations describes EPA's methodology in greater detail and presents airport-specific estimates (1).

11.1.1 Airport Groups (Step 1)

As described in Section 4.3.1.1, EPA identified 212 airports that potentially perform significant airport deicing/anti-icing operations and arranged them into 20 Airport Groups based on operations and snowfall characteristics. EPA used the 20 Airport Groups to estimate fluid use for airports for which fluid use data were not available (as described in Section 11.1.2).

11.1.2 Fluid Use Estimates (Step 2)

Although EPA would have preferred to use actual ADF use data for all airports identified as potentially performing significant deicing/anti-icing operations, EPA was unable to do so because it would have required a large number of airports to submit detailed ADF use data. Under the Paper Work Reduction Act, this type of request would require U.S. Office of Management and Budget approval, a process that could not have been completed within the study schedule. Also, EPA realized that many U.S. airports have not collected ADF use data from their tenants for previous seasons.

EPA was able to collect a limited amount of ADF use data directly from airports. To supplement these data, EPA requested national estimates of fluid use data from industry

airport and airline trade associations. Unfortunately, EPA did not receive any fluid use data from these organizations; thus, the national estimated fluid use for airports was estimated based on the airport data collected by EPA under this study.

These data were provided by respondents to EPA's 1999 Airport Mini-Questionnaire and by airport authorities during site visits, and consisted of data from 23 U.S. airports. The airports submitted fluid use data in a variety of formats. Several airports provided fluid use data by glycol base (i.e., ethylene glycol and propylene glycol) and fluid type (i.e., Type I, Type II (if applicable) and Type IV). For Type I fluids, some airports reported the volume as a Type I concentrate, while others reported the volume as diluted (i.e., ready-to-use) Type I fluid. A few airports provided fluid use data by glycol base, but not by fluid type. To simplify this analysis, EPA converted available ADF use data for each airport to a single common basis, expressed as Type I fluid at 50% dilution (i.e., as applied). EPA's data conversion methodology is illustrated below using data from the following airports as examples.

Des Moines International Airport, Des Moines, IA (DSM)

This airport provided fluid use data for three consecutive deicing seasons for Type I propylene glycol-based fluid, Type I ethylene glycol-based fluid, Type IV propylene glycol-based fluid, and Type IV ethylene glycol-based fluid. The volumes reported for Type I fluids were for 50% ADF solutions. For each year, EPA calculated the total volume used by adding the volumes of each fluid type and glycol base. EPA then averaged the annual totals to determine the average total annual ADF use.

EPA recognizes that Type II/IV fluids are greater than 50% ADF solutions. Therefore, EPA's simplification to sum Type II/IV fluid volumes into the total as though it were a 50% ADF solution results in a low ADF use bias. EPA believes this bias is not significant because typically less than 10% of ADF use is Type II/IV fluids.

Anchorage International Airport, Anchorage, AK (ANC)

Anchorage International Airport submitted fluid use data for two deicing seasons by glycol base, but not by fluid type. The fluid volumes were reported as concentrated ADF solutions. For each deicing season, EPA calculated the total volume of concentrated fluid used by adding the volumes reported for ethylene glycol-based fluid and propylene glycol-based fluid. EPA then averaged the annual totals to determine the average total annual ADF use. Finally, EPA multiplied the average ADF use by two to convert to a 50% ADF solution basis.

To estimate fluid use for airports for which no data were available, EPA developed fluid use factors. EPA divided the total ADF volume calculated for each airport for which data were available by the total number of aircraft operations performed at the airport and used the result to calculate fluid use factors. For some Airport Groups, fluid use data were available for two or more of the airports in the group. For airports in these groups, EPA calculated an average fluid use factor to represent the group. Fluid use factors could not be calculated for some Airport Groups because no fluid use data were available for airports in these groups. In these cases, EPA estimated fluid use factors based on an engineering assessment of the fluid use factors calculated for other Airport Groups.

Note that the fluid use factors described in this section do not represent fluid use per aircraft deicing/anti-icing operation. For example, the number of annual operations used to calculate the fluid use factors include operations outside of the deicing season, and not all operations during the deicing season correspond to deicing/anti-icing operations. Instead, the fluid use factors are solely for the purpose of normalizing fluid use data among airports of similar size and climate.

Fluid use factors for each Airport Group were then used to estimate fluid use at airports for which fluid use data were not available. For example, the volume of fluid used at

airports assigned to a given Airport Group was estimated by multiplying the total annual aircraft operations for each airport by the fluid use factor (in gallons of ADF per operation) for the group.

11.1.3 Estimated Annual Volume of Fluid That Has the Potential to Impact U.S. Surface Waters and POTWs (Step 3)

Not all the fluid sprayed has the potential to impact U.S. surface waters and POTWs since some of the fluid will be lost to the air during spray application, some will remain on the aircraft, and some will be retained in adjacent grassy areas. EPA assumes that only the volume of fluid falling on paved deicing/anti-icing areas has the potential to impact U.S. surface waters and POTWs. Estimates developed by Environment Canada in the early 1980s suggested that the percentage of fluid falling on paved deicing/anti-icing areas could be as low as 50 percent (2). More recent research conducted by Limno-Tech, Inc., an environmental consulting company assisting airports with ADF-contaminated storm water management, indicates that for Type I fluids, approximately 80% of the fluid sprayed falls on paved deicing/anti-icing areas (3). Based on fluid use and fluid collection data provided by several U.S. airports, EPA believes that the more recent estimate made by Limno-Tech is more accurate than the estimate developed by Environment Canada.

For each airport, EPA calculated the estimated annual volume of fluid that has the potential to impact U.S. surface waters and POTWs by multiplying the estimated annual ADF volume used at the airport by 0.8.

11.1.4 Estimated Annual Volume of Aircraft Deicing/Anti-icing Fluid Discharged Prior to the Implementation of EPA's Phase I Storm Water Permit Application Regulations (Step 4)

EPA does not have sufficient fluid use data to directly calculate pollutant loadings discharged prior to implementing the Phase I storm water permit application regulations. As a result, EPA instead estimated these loadings using current ADF use data and other available information.

EPA knows of no airport or airport tenant that implemented wastewater containment and collection practices specifically for wastewater generated from aircraft deicing/anti-icing operations prior to EPA's publication of the storm water permit application regulations on November 16, 1990. Consequently, EPA assumed that no U.S. airports managed wastewater specifically from aircraft deicing/anti-icing operations prior to 1990 (i.e., all U.S. airports were direct dischargers) and that all U.S. airports would have continued to be direct dischargers if EPA's storm water program had not been promulgated.

EPA estimated the pollutant loadings for the 212 airports that potentially perform significant deicing operations by summing the estimated volume of fluid that has the potential to impact U.S. surface waters and POTWs (discussed in Section 11.1.3) and converting the result to pounds of ADF as applied. The results indicate that an estimated 28 million gallons of ADF (50% concentration) were discharged annually to surface waters (with zero gallons discharged to POTWs) prior to the implementation of EPA's Phase I Storm Water Permit Application Regulations. EPA believes that this estimate has a high bias because it reflects increased ADF use since 1990 caused by FAA's 1992 amendments to the aircraft deicing regulations and by industry growth. EPA believes it is appropriate to include this bias to enable comparison to the pollutant loadings estimates developed in Section 11.1.5 (for current loadings) and 11.1.6 (for loadings after implementation of an effluent guideline), which also reflect increased ADF use since 1990.

11.1.5 Estimated Annual Volume of Aircraft Deicing/Anti-icing Fluid Currently Discharged (Step 5)

EPA reviewed all currently available information, including that collected from site visits, industry conferences, questionnaires, and literature sources, to identify airports currently collecting or otherwise managing wastewater from aircraft deicing/anti-icing operations. EPA evaluated the efficiency of ADF wastewater management systems currently used at U.S. airports and used this information to develop four categories of wastewater management performance as shown below:

- Category 1 - Airports with exemplary collection systems capable of collecting an average of 87.5% of the ADF that would potentially impact U.S. surface waters (i.e., 70% of fluid applied).
- Category 2 - Airports with collection systems capable of collecting an average of 51.25% of the ADF that would potentially impact U.S. surface waters.
- Category 3 - Airports that have implemented some type of wastewater collection system, but the system is either incomplete or limited in area. These airports are capable of collecting an average of 25% of the ADF that would potentially impact U.S. surface waters.
- Category 4 - Airports that have no provisions for collecting and treating wastewater from ADF operations (i.e., 0% collection).

All of the airports identified as potentially performing significant aircraft deicing/anti-icing operations were assigned to one of the four wastewater management performance categories based on a review of their ADF wastewater management systems. In this context, management includes wastewater collection systems with either on-site treatment (including glycol recycling) or controlled discharge to a POTW.

EPA estimated the total volume of ADF discharged to U.S. surface waters and POTWs for the 212 airports that potentially perform significant deicing operations by summing the estimated volume of fluid that is not collected for each airport. The results indicate that an estimated 21 million gallons of ADF (50% concentration) are currently discharged directly to surface waters. This represents a 25% reduction from pre-storm-water program estimates. EPA estimates an additional 2.1 million gallons of ADF (50% concentration) are currently discharged to POTWs.

EPA estimates that ADF discharges will be further reduced to an estimated 17 million gallons of ADF (50% concentration) discharged directly to surface waters when the requirements of all storm water permits are fully implemented. EPA also expects the volume of ADF discharges to POTWs to steadily increase. EPA's estimate of the discharges associated with

full implementation of storm water permit regulations are based on the assumptions that Category 3 airports will implement Category 2 levels of control and that Category 4 airports will implement Category 3 levels of control.

11.1.6 Estimated Annual Volume of Aircraft Deicing/Anti-icing Fluid Discharged to U.S. Surface Waters After Implementation of an Effluent Guideline (Step 6)

To estimate the impact of an effluent guideline, EPA assumed that all U.S. airports identified as potentially performing significant aircraft deicing/anti-icing operations would implement wastewater management programs that have collection efficiencies comparable to the Category 1 airports. EPA calculated the total volume of ADF that would be discharged by the 212 airports that potentially perform significant deicing operations (assuming 100% implementation) by summing the estimated volume of fluid that would not be collected at each airport. The results indicate that an estimated 3.6 million gallons of ADF (50% concentration) would be discharged directly to surface waters following the implementation of an effluent guideline. This represents an 87% reduction from the pre-storm-water permit regulation estimates and a 62% reduction from current estimates.

An unknown portion of the additional 62% reduction in direct discharges to U.S. surface waters from current estimates would be discharged to POTWs. This portion would be dependent on the specific ADF collection and mitigation systems implemented by individual airports.

EPA's estimates of the annual ADF volume discharged by airports that potentially perform significant deicing/anti-icing operations for each of the three regulatory scenarios are summarized below.

Case	Estimated Volume of ADF Discharged to U.S. Surface Waters (million gallons/yr)	Estimated Volume of ADF Discharged to POTWs (million gallons/yr)
Discharges prior to implementation of EPA's Storm Water Program	28	0
Current discharges	21	2.1
Discharges following full implementation of storm water permit regulations	17	>2.1
Discharges following implementation of an effluent guideline	3.6	>2.1

11.1.7 Pollutant Loading Estimates

EPA calculated pollutant loadings using the estimated total ADF volumes discharged and converting to pounds of ADF and to pounds of BOD₅. Since the biochemical oxygen demand for Type I fluids differs depending on the glycol-base, EPA calculated a range the for the pounds of BOD₅ using BOD₅ data for propylene glycol-based and ethylene glycol-based Type I fluids. The following table summarizes the pollutant loadings to U.S. surface waters and POTWs.

Case	Estimated Loadings Discharged to U.S. Surface Waters		Estimated Loadings Discharged to POTWs	
	ADF Concentrate (million lbs/yr)	BOD₅ Range (million lbs/yr)	ADF Concentrate (million lbs/yr)	BOD₅ Range (million lbs/yr)
Discharges prior to implementation of EPA's Storm Water Program	126	98 - 102	0	0
Current discharges	95	74 - 77	9.6	7.4 - 7.8
Discharges following full implementation of storm water permit regulations	75	58 - 61	>9.6	>7.4
Discharges following implementation of an effluent guideline	16	12 - 13	>9.6	>7.4

11.2 Costs to Manage Wastewater from Airport Deicing Operations

This section provides costing information for airports that have upgraded their management systems to control wastewater from airport deicing operations. The available cost data from airports is summarized below. The Airport Group for each airport is listed as a means for comparison among airports that would be expected to have similar ADF use, and the Wastewater Management Category is listed to compare airport costs by current estimated ADF-capture efficiency.

Airport Group	Management Category	Airport	Capital Cost (Year Installed)	Annual Operating Cost
A1	1	Denver International (DIA)	\$36 million (1995)	\$550,000
A2	2	Minneapolis-St. Paul International (MSP)	\$1.75 million (1993)	\$1.4 million
	2	Chicago O'Hare International (ORD)	\$98 million (1996)	\$1 million
A4	2	Dallas/Ft. Worth International (DFW)	\$1.7 million (1997)	Not available
B2	2	Salt Lake City International (SLC)	\$27.8 million (1998)	\$760,000
	1	Baltimore/Washington International (BWI)	\$22 million (1997)	Not available
C2	2	Bradley International (BDL)	\$17.7 million (1999)	Not available
	2	General Mitchell International (MKE)	Not available	\$1 million
C3	3	Kansas City International	\$8.5 million (1999)	Not available
D1	1	Albany International	\$30.25 million (1989-1998)	\$325,000
	1	Greater Buffalo International	\$5.6 million (1996)	\$100,000
E2	1	Greater Rockford	\$1.8 million (1994)	\$176,000

Tables 11-1 and 11-2 at the end of this section list specific capital and annual operating costs, respectively, provided by airports, vendors, and other contacts. EPA obtained these costs through EPA-sponsored meetings, industry conferences, EPA mini-questionnaires, EPA site visits, and other data submittals provided at EPA's request. These tables provide capital costs for specific components of storm water management systems and annual costs for specific types of operating costs (e.g., labor and electricity). These tables may not represent the full range

of costs that airports may incur when designing, installing, and operating a comprehensive management system for wastewater from airport deicing operations.

Section 14.2.3 describes airline deicing costs by major component, including costs of delay, labor and operating costs, materials, and capital costs.

11.3 References

1. Eastern Research Group, Inc. Development of Estimated Loadings in Wastewater Discharges From Aircraft Deicing/Anti-icing Operations. December 1999 (DCN T11074).
2. Transport Canada. State of the Art Report on Aircraft Deicing/Anti-icing. November 1985 (DCN T10669).
3. University of Massachusetts. Workshop: Best Management Practices for Airport Deicing. July 1999 (DCN 10661).

Table 11-1**Capital Costs Incurred by Airports for Management of Wastewater from Airport Deicing Operations**

Airport/Source	Description of Management Project	Year Construction Completed or Equipment Acquired	Capital Costs
Dallas/Ft. Worth International Airport (DFW)	Two 3-million-gallon detention ponds with liners and covers; pumping station; diversion box; and grit chamber with oil skimmer	1997	\$1.7 million
Minneapolis-St. Paul International Airport (MSP)	Three 1-million-gallon storage ponds with liner, leak detection system, and monitoring wells; an operations center with boiler and recirculation pump for preventing wastewater freezing	1993	\$1 million
	Elgin vacuum trucks	Unknown	\$275,000 each
Kansas City International Airport (MCI)	Trench drains around passenger terminals; a diversion box; two 1-million-gallon concrete wastewater storage basins; modifications to the Todd Creek Wastewater Treatment Plant	Under construction	\$8.5 million (estimated)
Denver International Airport (DIA)	Wastewater collection system for nine aircraft deicing pads and United Airlines gates; three 420,000-gallon wastewater storage tanks; two detention ponds (total capacity 12 million gallons; ADSI glycol recycling plant; glycol storage tanks	1995	\$36 million
Albany International Airport (ALB)	Elgin vacuum truck	Unknown	\$248,000
	Retrofitting 16 deicer trucks with dripless fittings and automatic filling shut-off valves	Unknown	\$4,000
	Construction of a wastewater collection system at passenger terminals and two lined lagoons (one 6-million-gallon lagoon and one 2.3-million-gallon lagoon)	1989	\$10 million
	Improvements to the wastewater collection system and construction of a wastewater treatment facility (designed and operated by EFX; see EFX entry later in this table) Improvements to the collection system included: blowers and a recirculation pump for the lagoons; a 2.5-million-gallon tank for wastewater storage; two wet wells (60,000 gallon and 80,000 gallon) with float activated pumps; and four 4,000-gallon portable tanks for storage of wastewater with high glycol content	1989 to Present	\$20 million

Table 11-1 (Continued)

Airport/Source	Description of Management Project	Year Construction Completed or Equipment Acquired	Capital Costs
Greater Rockford Airport (RFD)	Wastewater treatment facility (includes a 16-million-gallon lined detention pond aerated with four mechanical and 12 aspirating aerators, a recirculation pump, a 5-million-gallon lined settling pond, two 50,000-gallon static inclined plate, oil/water separators, and storage building)	1994	\$1.8 million
Bradley International Airport (BDL)	Two Tennant™ vacuum trucks	1990	\$140,000
	One truck-mounted Ramp Ranger™	Unknown	\$211,000
	One trailer-mounted Ramp Ranger™	Unknown	\$180,000
	One AR Plus Interceptor™	Unknown	\$200,000
	Construction of deicing pad including three aircraft deicing stations, a deicing pad control tower, ADF storage area with five 20,000-gallon ADF storage tanks, a siamese drainage collection system with automated drain valves, and two 1-million-gallon underground storage tanks	Summer 1999	\$17 million (estimated)
Buffalo-Niagara International Airport (BUF)	Installation of storm drain valves and coating pavement surface with a sealant (cargo and GA facilities only)	1995	\$1.2 million
	Construction of an underground storm water pipe for conveying wastewater from the cargo area to a contaminated wastewater storage basin. Also includes the enlargement of the underground wastewater storage basin from its current capacity of 200,000 gallons to a capacity of approximately 1 million gallons	November 1999	\$4.2 million (estimated)
Chicago O'Hare International Airport (ORD)	Snow dump improvements including concrete pad, drainage collection system, and piping to existing detention ponds	Planned	\$435,000 (estimated)
	Construction of hold pad with drainage collection system and a lined detention pond	1996	\$10 million
	Expansion of wastewater storage facility at North Detention Pond including two additional detention ponds and junction control chambers; installation of a drainage collection system for north airfield and aircraft maintenance hangars	Planned	\$80 million (estimated)
	Four aboveground storage tanks for ADF with containment structures and deicer truck filling stations	1996	\$3.3 million

Table 11-1 (Continued)

Airport/Source	Description of Management Project	Year Construction Completed or Equipment Acquired	Capital Costs
Salt Lake City International Airport (SLC)	Six primary aircraft deicing pads; five secondary deicing pads; three 3-million-gallon detention ponds with membrane liner and cover; drainage collection system for deicing pads and passenger terminals (including piping, diversion boxes, and pumps)	1998	\$23 million
	Wastewater storage tank and deicing pad (GA facility)	Unknown	\$362,000
	Glycol recycling plant	1998	\$4.5 million
G. Frigon/Dames & Moore	Pinch valves	Unknown	\$8,000 - \$16,000/each
	Butterfly valves	Unknown	\$1,200/each
EFX	EFX anaerobic biological treatment system (not including storm water collection and equalization) at Albany International Airport (ALB)	1998	\$1.6 million
ATA member	Ice detection system	Unknown	\$60,000
	Large blankets (for wings)	Unknown	\$10,000/aircraft
AR Plus/VQuip	Storm drain inserts	Unknown	\$1,200 - \$1,800
	High-capacity vacuum unit	Unknown	\$240,000 - \$250,000
Air Canada	Wetland for storm water management at Edmonton airport, Alberta, Canada	Under construction	\$1 million
AR Plus	6" valve Interceptor™	Unknown	\$600 - \$800
	3300G Ramp Ranger™	Unknown	\$250,000

Table 11-2**Annual Costs Incurred by Airports for Management of Wastewater from Airport Deicing Operations**

Airport/Source	Description of Management Project	Year	Operating Costs
General Mitchell International Airport (MKE)	Annual operating costs for vacuum truck and drain valves	1998-1999	\$1 million (estimated)
Minneapolis-St. Paul International Airport (MSP)	Detention pond cleaning and sludge removal (cost per pond)	Unknown	\$2,600
	Annual operating and maintenance costs for holding ponds, boiler, and associated equipment. Also includes monitoring costs, including biannual sampling from monitoring wells	Unknown	\$270,000
	Annual costs for storm water monitoring and analytical analysis	Unknown	\$650,000
	Annual POTW charges for wastewater treatment	Unknown	\$150,000 - \$200,000
	Annual wastewater transportation costs (including trucks and labor), installation/removal of sewer plugs, and maintenance of sewer plugs	Unknown	\$350,000
Denver International Airport (DIA)	Annual POTW surcharges for BOD, TKN, and hydraulic load	Unknown	\$550,000 (estimated)
Buffalo-Niagara International Airport (BUF)	Per hour energy costs for operation of InfraTek®	Unknown	\$100
	Annual BOD surcharge from POTW	Unknown	\$1,800 - \$2,400
Albany International Airport (ALB)	Annual costs of storm water monitoring at three sites including: (1) quarterly monitoring for volatile organics (benzene, toluene, and xylene) and semivolatile organics; and (2) daily monitoring for glycol from October to May	Unknown	\$50,000 (estimate)

Table 11-2 (Continued)

Airport/Source	Description of Management Project	Year	Operating Costs
Albany International Airport (ALB) (cont.)	Annual electricity for aeration of lagoons	1996	\$80,633
		1995	\$76,187
		1994	\$79,823
		1993	\$100,959
		1992	\$122,557
		1991	\$61,561
	Albany County Sewer District glycol/BOD annual disposal charges	1997	\$15,756
		1996	\$289,545
		1995	\$220,381
		1994	\$299,341
		1993	\$277,369
		1992	\$132,815
		1991	\$121,044
	Village of Colonie annual conveyance fees	1996	\$180,620
		1995	\$143,665
		1994	\$166,946
		1993	\$173,318
		1992	\$109,791
		1991	\$93,217
Greater Rockford Airport (RFD)	Annual operating costs (e.g. electricity, chemicals) for operation of the airport's wastewater treatment facility	1998	\$108,000
	Annual labor costs for operation of the airport's wastewater treatment facility	1998	\$60,000 - \$75,000
Chicago O'Hare International Airport (ORD)	Per hour cost of leasing and operating Aero Snow™ portable snow melters (per unit)	1998-1999	\$6,000
	Annual POTW disposal costs	Unknown	\$800,000 - \$1 million

Table 11-2 (Continued)

Airport/Source	Description of Management Project	Year	Operating Costs
Salt Lake City International Airport (SLC)	Operating expenses for recycling plant	1998-1999	\$760,000
Dallas/Ft. Worth International Airport (DFW)	POTW surcharge for discharges that exceed BOD limit	Unknown	\$0.08/lb BOD
	POTW charges	Unknown	\$1.07/1,000 gallons
FAA	Operating the InfraTek® system at Rochester International Airport	Unknown	\$200 - \$500/aircraft
AR Plus	3300G Ramp Ranger™ hourly operation	Unknown	\$100 - \$110/hr of operation
	2800 Interceptor™ rental	Unknown	\$3,500/mo (1-year rental agreement)
		Unknown	\$1,850/mo (3-year rental agreement)
		Unknown	\$1,200/mo (5-year rental agreement)
	3300 Ramp Ranger™ rental	Unknown	\$19,500/mo (1-year rental agreement)
		Unknown	\$10,320/mo (3-year rental agreement)
		Unknown	\$6,770/mo (5-year rental agreement)
	T4000 Ramp Ranger™ rental	Unknown	\$5,215/mo (1-year rental agreement)
		Unknown	\$2,765/mo (3-year rental agreement)
		Unknown	\$1,815/mo (5-year rental agreement)
	Catch basin inserts	Unknown	\$27.30/mo (3-year rental agreement)
		Unknown	\$18.75/mo (5-year rental agreement)

Table 11-2 (Continued)

Airport/Source	Description of Management Project	Year	Operating Costs
AR Plus (cont.)	Wastewater treatment costs based on concentration of glycol in collected wastewater	Unknown	No charge (>20% glycol)
		Unknown	\$0.07/gal (16 - 20%)
		Unknown	\$0.09/gal (11 - 15%)
		Unknown	\$0.12/gal (6 - 10%)
		Unknown	\$0.15/gal (3 - 5%)
		Unknown	\$0.18/gal (<3%)
	Personnel costs	Unknown	\$45/hour (project supervisor)
		Unknown	\$35/hour (equipment operator)
		Unknown	\$30/hour (field technician)
Air Canada	Wastewater treatment costs for Vancouver Int'l at Seattle POTW	1999	\$0.15/L of wastewater
EFX	EFX anaerobic biological treatment system @ 200 GPM and influent of 2,000 mg/L of COD (includes amortized capital and annual operating costs)	Unknown	<\$3.00/1,000 gallons (annualized)

12.0 TRENDS IN THE INDUSTRY

This section describes trends in the aircraft and pavement deicing industry, including types and amounts of aircraft deicing/anti-icing fluids (ADFs) used (Section 12.1), types and amounts of pavement deicing/anti-icing agents used (Section 12.2), deicing/anti-icing equipment and operations (Section 12.3), and mitigation of wastewater containing spent deicing/anti-icing agents (Section 12.4). (Economic trends within the air transportation industry, including airports and airlines, are described throughout Section 14.0 and specifically within Section 14.2.4.) These trends demonstrate a greatly increased awareness within the past decade of deicing issues and their potential impacts on the environment by airlines, airports, the EPA and other regulatory agencies, and the public.

All of the apparent trends discussed in this section are based on information obtained during EPA's data-collection activities and subsequent analyses, which are described throughout this report. Note, however, that the vast majority of these sources are not statistically reliable. Accordingly, the trends described in this section should be considered qualitative or anecdotal because available data are insufficient to validate trends statistically. Appendix A contains information regarding the location of airports referenced in this section.

12.1 Trends in the Use of Aircraft Deicing/Anti-icing Fluids

Based on the limited quantitative data available to EPA, propylene glycol-based rather than ethylene glycol-based ADFs are now predominantly used in the U.S. This is a large shift from the status of the industry 10 years prior. This is demonstrated by a letter from the Air Transport Association (ATA) dated March 1989, "Ethylene glycol is the dominant deicer in use by airlines in the U.S. today.... Propylene glycol is an anti-icer that is receiving increasing use because it protects aircraft surfaces for a longer period after application, and because a market shortage of ethylene has introduced supply and cost problems for ethylene glycol" (1).

The shift toward using anti-icing fluids in combination with Type I fluids is demonstrated by an EPA report dated September 28, 1990, “Presently there are two types of fluids available to commercial airlines and airport authorities. Type I fluids are used for deicing only and Type II fluids are used for deicing and anti-icing” (1). Since 1990, fluid manufacturers have developed two anti-icing fluid types, Types III and IV, and have developed ethylene glycol-based anti-icing chemicals (fluid types are described in Section 4.2.1.1). In fact, Union Carbide, an ethylene glycol-based ADF manufacturer, first developed Type IV fluids. (Note that Type II and Type III fluids have since become largely obsolete.)

Three primary factors have influenced changes in the types and quantities of ADFs used by the industry. First, ethylene glycol is listed as a hazardous air pollutant under the Clean Air Act and is therefore subject to Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) reporting requirements when released in a quantity of more than 5,000 pounds in a 24-hour period. Propylene glycol is not listed as a hazardous air pollutant and is not reportable under CERCLA. Although airports may qualify for eliminated or reduced reporting requirements via the federally permitted release exemption (2), many airports have moved from dominant use of ethylene glycol-based fluids to increased use of propylene glycol-based fluids in part to avoid the burden associated with recordkeeping and reporting. Note that available toxicity data presented in Section 9.0 indicate that the base glycols exhibit acute aquatic toxicological effects at concentrations within the same order of magnitude; however, the formulated fluids vary by manufacturer. Due to propylene glycol’s lower mammalian toxicity, some airports have switched to propylene glycol in part to meet demands of consent decrees or local citizen’s groups.

Second, the use of deicing agents increased dramatically in 1992 and 1993 because of new Federal Aviation Administration (FAA)-mandated deicing rules developed following a crash caused by improper deicing at LaGuardia Airport. These regulations prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, control surfaces, engine inlets, and other critical surfaces of an aircraft and are referred to as the “clean aircraft concept” (see Section 13.4.1). Typical tests show that 1/32nd of an inch of ice accumulation along the leading edge of the wing of a large jet or 1/64th of an inch on a smaller aircraft can decrease lift on takeoff from

12% to 24%, depending on the size of the aircraft (3). Several airport operators reported at the American Association of Airport Executives Conference on Aircraft Deicing, August 23, 1993, that the annual volume of aircraft deicing fluids used by U.S. airlines increased threefold since the crash (4). Airlines also increased use of aircraft anti-icing chemicals to extend holding times and reduce secondary aircraft deicing requirements. Total use of ADFs in the future is likely to increase due to continued growth of the air transportation industry.

Third, on November 16, 1990, EPA published the National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges (see Section 13.1). These regulations require airports with deicing and other industrial activities to obtain a storm water discharge permit. Although there are several permitting alternatives, all permits require the development and implementation of a Storm Water Pollution Prevention Plan specifying pollution prevention and best management practices to control pollutant discharges. Consequently, many airlines have further increased use of anti-icing fluids (Type II/IV fluids) to reduce the overall amount of aircraft deicing chemicals used (see Section 6.2.1). In addition, glycol recycling to mitigate glycol-contaminated wastewater has proliferated (see Section 6.4). As a result, some airports have completely substituted propylene glycol-based fluids for ethylene glycol-based fluids because most recycling systems cannot separate the two glycols and because of current strength of the secondary markets for propylene glycol.

EPA obtained recent glycol usage data (of varying quality) from 26 airports. An analysis of these data substantiates trends since 1990 for increased used of propylene glycol-based ADFs and of Type II/IV ADFs, as shown in the table below.

Trend	Percentage of Airport ADF Applied		
	1990	1996 to Present (a)	
		Average Percentage	Range of Percentages
Use of Propylene Glycol-Based ADFs (data from 21 airports)	<50%	78	11 to 100
Use of Type II/IV ADFs (data from 18 airports)	Assumed <1%	6.1	0 to 15

(a) Most data are for the 1996-1997 through the 1998-1999 deicing seasons, although some data include earlier years.

Recent trends in ADF usage are more difficult to characterize. EPA obtained ADF usage data for multiple years (generally for the 1996-1997, 1997-1998, and 1998-1999 deicing seasons) for 15 of the 26 airports. The following summarize EPA's findings regarding trends in propylene glycol-based fluid use during this period: eight airports reported either no change (generally because the airports use only propylene glycol-based fluids) or varying usage (i.e., both increases and decreases) on a percentage basis; three airports reported increasing usage on a percentage basis; one airport reported decreasing usage on a percentage basis; and three airports did not provide sufficient data for this analysis. These data suggest that the industry may be reaching equilibrium in glycol usage in this regard. EPA is aware that airlines are very concerned that increased substitution of propylene glycol-based ADFs for ethylene glycol-based ADFs could result in the loss of a diverse, competitive market of formulated fluids.

The following summarize EPA's findings regarding recent trends in Type II/IV fluid use: three airports reported either no change (i.e., no use of Type II/IV fluids) or varying usage (i.e., both increases and decreases) on a percentage basis; eight airports reported increasing usage on a percentage basis; two airports reported decreasing usage on a percentage basis; and two airports did not provide sufficient data for this analysis. These data suggest that the industry is increasing its usage of Type II/IV fluids.

While use of Type II/IV fluids may reduce the total volume of ADF applied at an airport, spent Type II/IV fluids are more difficult to collect because the fluids are widely dispersed through dripping and sloughing during the taxi and takeoff of aircraft. "Glycol dripping off aircraft once it leaves the deicing pads is our biggest challenge," according to Dan Smith, environmental scientist at Dayton International Airport (5). Because of this, it may be more environmentally beneficial for airports with highly efficient spent ADF collection and mitigation practices to use Type I fluids instead of Type II/IV fluids because Type I fluids are easier to collect than Type II/IV fluids. However, the increased safety that comes with the extended protection of the anti-icers may outweigh benefits related to ease of collection.

In an effort to lessen the environmental impacts of spent ADFs, airlines are pressuring manufacturers to develop more environmentally benign ADFs. ATA is working with the Society of Automotive Engineers (SAE) to require standardized reporting of environmental information for all fluid types. (SAE standards for ADFs are described in detail in Section 13.5.) The proposed revised reporting requirements include data for biochemical oxygen demand (specifically 5 days and 28 days at 5° C and 20° C), chemical oxygen demand (rather than total oxygen demand), additional aquatic toxicity testing (specifically *Ceriodaphnia dubia* as test organism), and 10 trace metals (rather than four) for which water quality criteria exist. The ATA/SAE Environmental Workgroup is also considering imposing an aquatic toxicity protocol or goal that would apply to new fluid formulations. Fluid manufacturers have agreed to continue working on reducing the aquatic toxicity of their products and to work with SAE to consider developing an SAE aquatic toxicity protocol (6).

At the Airport Deicing Summit for New York State on March 25, 1999, two representatives of ADF formulators/manufacturers, one from Octagon Process and one from Lyondell (formerly ARCO), discussed the status of work toward and impediments to developing less toxic aircraft deicing/anti-icing fluids. The Octagon representative stated that deicing/anti-icing additives now comprise only 0.5% of formulated fluids and that manufacturers and formulators continue efforts to make their products more environmentally friendly. However, the representative anticipates only minor incremental improvements in products because of the following factors:

- The variety of replacement chemical additives is small.
- Some possible chemical additives interact and therefore cannot be combined.
- Performance standards are complex. For example, a variety of metals and alloys must be protected from corrosion under a variety of conditions. In addition, the armed forces wish to use commercial rather than military deicing fluids, resulting in an even greater variety of exotic alloys and coatings requiring protection.

- Carcinogenic chemical additives are unacceptable.
- Fluid costs are paramount. Potentially promising alternative freezing point depressants, such as fish fatty acids, would be prohibitively expensive at an estimated \$100 per gallon.
- Many individual fluid additives perform multiple functions but may be relatively toxic. These additives could be replaced by multiple, less toxic additives; however, the combined toxicity of the replacement additives can be greater than the toxicity of the original additive (7).

12.2 Trends in the Use of Airport Pavement Deicing/Anti-icing Agents

Based on the limited quantitative data available to EPA, potassium acetate is now predominantly used for pavement deicing/anti-icing in the U.S. This is a change that has occurred over the past two to three years. The change is demonstrated in an EPA report dated September 28, 1990, "Runway deicing materials are normally ethylene glycol, UCAR (by Union Carbide), and pelletized urea.... Alternative materials including calcium magnesium acetate (CMA) are under investigation and used at several airports." Also in this report, "A solution of potassium acetate with corrosion inhibitors is under investigation as an alternative to glycol-based compounds for airside use, especially for runway deicing and anti-icing" (1).

EPA obtained pavement deicer usage data (of varying quality) from 26 airports. An analysis of these data substantiate trends since 1990 of decreased use of glycols and urea as airport deicing/anti-icing agents and increased use of alternative airfield deicers/anti-icers. Only three airports reported using runway deicing material composed of a mixture of ethylene glycol (50% to 60%), urea (25% to 40%), water (0% to 25%), and dipotassium phosphate (0% to 3%) (e.g., UCAR). One airport reported using small amounts of propylene glycol (75 gallons per year) as a wetting agent for sand.

Fourteen airports reported using urea for pavement deicing within the last three deicing seasons. Of these, six airports have now either discontinued or are phasing out use of urea in favor of sodium acetate, sodium formate, or potassium acetate. The remaining eight

airports have not reported plans to discontinue or reduce use of urea. Factors preventing or inhibiting use of alternative pavement deicing/anti-icing agents at these eight airports include: (1) concerns about the possible impact of potassium acetate on electrical systems, (2) increased cost of alternate agents, and (3) greater efficiency of urea.

EPA anticipates that trends toward decreased use of ethylene glycol and urea for pavement deicing/anti-icing will continue because of concerns of the resulting high pollutant loadings in runoff, high potential for aquatic toxicity from the degradation of urea, and the high cost of collecting and mitigating contaminated runoff from paved areas.

12.3 Trends in Deicing/Anti-icing Equipment and Operations

Section 6.2 describes a variety of ADF minimization methods that airports and airlines may implement. Of these methods, only the use of Type IV anti-icing fluids has gained apparent wide-spread use throughout the industry, as described in Section 12.1. However, information available to EPA suggests a trend toward increased use of infrared and forced-air aircraft deicing systems. Both technologies appear to be moving from the experimental or testing phase to permanent, commercial use. EPA also anticipates increased use of ice detection systems for both aircraft and pavement.

Trends among the remaining ADF pollution prevention practices are difficult to evaluate. Airports and airlines have not yet identified an optimum combination of pollution prevention and spent fluid mitigation methods. Changes in fluid price, recycled/recovered fluid secondary markets, and fluid toxicity are also expected to influence the selection of pollutant control practices and technologies. EPA anticipates that future trends within the industry will stratify by small versus large airports and by the specific preferences (based on economic considerations and experience) of major carriers operating at each airport. For example, many airlines, particularly at their hubs and large stations, blend ADFs to temperature and use a fleet of enclosed-basket deicing trucks (8, 9).

EPA has limited information on trends in pavement deicing/anti-icing equipment and operations, other than the increased use of alternative agents described in Section 12.2. EPA believes that the majority of minimization methods described in Section 6.5.3 are standard operating procedures at U.S. airports because they save airport resources. EPA is not aware of any trends in the use of alternative pavement deicing/anti-icing methods described in Section 6.5.2 (e.g., heated pavements).

12.4 Trends in Spent Deicing/Anti-icing Chemical Mitigation

Available data demonstrate an increasing trend toward collecting wastewater contaminated with ADFs using a combination of the practices described in Section 6.3. EPA is aware of several airports that are studying options for collecting contaminated wastewater (e.g., General Mitchell International Airport, Washington Dulles International Airport, Ronald Reagan Washington National Airport, and Portland International Airport). With few exceptions, large airports that perform significant deicing operations have implemented one or more collection systems for wastewater contaminated with ADFs (10). Specific collection controls are determined based largely on cost-effectiveness, which is greatly influenced by airport-specific considerations such as climate, airport layout, airport operations, existing infrastructure, feasibility of glycol recovery/recycling (on site or off site), availability and accessibility of land, and the feasibility of discharging contaminated wastewater to a publicly owned treatment works (POTW).

Collection of ADF-contaminated wastewater has resulted in increased use of the following wastewater management techniques, including:

- Direct discharge at a controlled rate;
- Indirect discharge at a controlled rate;
- On-site wastewater treatment followed by direct or indirect discharge; and
- On-site or off-site glycol recycling/recovery followed by indirect discharge of residual wastewater.

Recent trends appear to favor use of glycol recycling/recovery. Prior to 1995, only Denver's Stapleton Airport performed glycol recycling/recovery. Today, at least 15 airports use on-site or off-site glycol recycling/recovery (see Section 6.4). EPA anticipates a growing use of glycol recycling/recovery as part of a total mitigation strategy as more airports implement wastewater collection systems and while secondary glycol markets remain strong. Several vendors offer wastewater collection and recycling/recovery services via leasing agreements that can be implemented relatively quickly with minimal capital expenditure. However, because recycling/recovery is generally prohibitively expensive for relatively dilute wastewaters, most airports must also use alternative discharge or disposal practices for these dilute wastewaters.

Available information also demonstrates a significant increase in indirect discharge of ADF-contaminated wastewater to a POTW. These include discharges with and without pretreatment. For example, systems used to recycle/recover glycol from spent ADF currently operating in the U.S. discharge residual wastewater to a POTW. EPA is also aware of several more airports that are considering or negotiating discharge of ADF-contaminated wastewater to a POTW.

EPA is not aware of any airports that operated on-site treatment designed to control glycol discharges prior to 1994. Today, EPA is aware of at least four airports that operate or are constructing on-site treatment systems for ADF-contaminated wastewater (see Section 7.0); however, EPA is not aware of any additional airports considering on-site wastewater treatment. In general, airports prefer indirect discharge of wastewater to on-site treatment. Unique instances of high conveyance and discharge fees, the inability of the POTW to accept ADF-contaminated wastewater, or other site-specific considerations cause airports to consider on-site treatment. EPA also recognizes that uncertain future regulatory requirements discourage airports from implementing such capital improvements as on-site wastewater treatment that may be difficult and expensive to retrofit to new requirements.

In contrast to trends in mitigating ADF-contaminated wastewater, EPA is aware of only one airport, Chicago O'Hare International Airport, that collects wastewater contaminated

with pavement deicing/anti-icing chemicals from runways and taxiways. EPA is not aware of any additional airports considering collection of these wastewaters, presumably because of prohibitively high collection costs. Substitution of glycol-based and urea-based deicing/anti-icing agents with more environmentally benign agents have greatly reduced environmental incentives to collect and mitigate these wastewaters.

12.5 **References**

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3. Barry Valentine. What's the Problem We're Trying to Solve. The Airport Deicing Advisor. November 1999 (DCN T11071).
4. U.S. Environmental Protection Agency. Emerging Technology Report: Preliminary Status of Airplane Deicing Fluid Recovery Systems. September 1995 (DCN T04674).
5. Bremer, K. "The Three Rs - Reduce, Recover, and Recycle," Airport Magazine. March/April 1998 (DCN T10361).
6. Stormwater Subcommittee Presentation to SAE G-12 Fluids Subcommittee. October 20, 1999 (DCN T11046).
7. Meeting Summary for Albany Aircraft Deicing Summit. March 1999 (DCN T10542).
8. Meeting Summary between U.S. EPA and Air Transport Association, November 1998 (DCN T10464).
9. Letter from Scott F. Belcher, Air Transport Association to Shari Zuskin Barash, U.S. EPA. November 4, 1999 (DCN T11063).
10. Eastern Research Group, Inc. Development of Estimated Loadings to the Environment from Aircraft Deicing/Anti-icing Study. December 1999 (DCN T11074).

13.0 RELATIONSHIP TO OTHER REGULATIONS

This section discusses other regulations pertaining to deicing/anti-icing operations at airports. Section 13.1 presents an overview of the EPA Storm Water Program; Section 13.2 discusses other national, state, and local permitting issues; Section 13.3 discusses the Canadian guidelines for the discharge of aircraft deicing/anti-icing fluids (ADF)-contaminated wastewater; Section 13.4 discusses Federal Aviation Administration (FAA) regulations for airport and aircraft deicing/anti-icing operations; and Section 13.5 discusses the SAE standards and the role of Society of Automotive Engineers (SAE) in establishing safe and effective ADFs. Appendix A contains information regarding the location of airports referenced in this section.

13.1 EPA Storm Water Program

The 1972 amendments to the Federal Water Pollution Control Act (referred to as the Clean Water Act or CWA), prohibit the discharge of any pollutant to navigable waters from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Efforts to improve water quality under the NPDES program have traditionally and primarily focused on reducing pollutants in industrial process wastewater and municipal sewage discharges because these sources have represented pressing environmental problems. However, as pollution control measures were initially developed for these discharges, it became evident that more diffuse sources (occurring over a wide area) of water pollution, such as agricultural and urban runoff, were also major causes of water quality problems.

EPA performed several assessments to estimate the impact of diffuse and other sources on water quality. These included the National Water Quality Inventory Report to Congress (prepared biennially), America's Clean Water - The States' Nonpoint Source Assessment (performed biennially), and the Nationwide Urban Runoff Program. These studies determined background levels of pollutants from urban runoff, as well as other sources including illicit connections, construction site runoff, industrial site runoff, and illegal dumping. The studies

noted that elimination of these other sources could dramatically improve the quality of urban storm water discharges.

In part, in response to these studies, Congress passed the Water Quality Act of 1987 (WQA), which contains three provisions specifically addressing storm water discharges. The central WQA provision governing storm water discharges is WQA Section 405, which alters the regulatory approach to control pollutants in storm water discharges by adopting a phased and tiered approach. The new provisions phase in permit application requirements, permit issuance deadlines, and compliance with permit conditions for different categories of storm water discharges. WQA Section 405 adds Section 402(p) to the CWA, which imposed a time limited “moratorium” on permitting of storm water discharges. The legislation also identified five types of storm water discharges that were subject to the moratorium and required a NPDES permit. One type is “discharge associated with industrial activity.”

13.1.1 Storm Water Permit Application Regulations

On November 16, 1990, EPA published the National Pollutant Discharge Elimination System Permit Application Regulations for Storm Water Discharges (55 FR 47989; codified in 40 CFR 122). The rule presents a preliminary permitting strategy and permit application requirements for 11 major industrial classifications, and specifically identified “airport deicing operations” as industrial activities, the discharge from which require a permit. The rule also defines storm water to mean storm water runoff, snow-melt runoff, and surface runoff and drainage (§122.26(b)(13)).

The NPDES rule provided three major options for obtaining permits for storm water discharges associated with industrial activity: (1) a notice of intent to be covered by a general permit that provides baseline storm water management practices, (2) group permit applications, and (3) individual permit applications. EPA envisioned implementing these three permitting options over time to reflect priorities within given states. EPA intended that issuance of baseline permits (i.e., issuing one permit to authorize a group of discharges) would be the initial

starting point. As priorities and risks within a state are evaluated, classes of storm water discharges would be identified for watershed permitting (typically accomplished via general area-specific permits), industry-specific (group) permitting, or facility-specific (individual) permitting.

On August 16, 1991, September 9, 1992, and September 25, 1992, EPA published “General Permits for Storm Water Discharges Associated With Industrial Activity” (56 FR 40948 and 57 FR 44438). This general permit included the baseline permit requirements intended to initially cover most storm water discharges associated with industrial activities in states without authorized NPDES programs. This permit also served as a model for states with authorized NPDES programs. Section 13.1.2 describes the general permit requirements in detail. Note that EPA did not reissue general permits for storm water discharges at facilities located in areas where EPA is the NPDES permitting authority. Therefore, airports located in these areas that were covered by general permits are now covered by either group or individual permits. General permits for airports located in areas with approved state NPDES programs remain in effect.

On November 19, 1993 and September 29, 1995, EPA published requirements for the “Multi-Sector General Permit” for storm water discharges associated with industry activity based on group permit applications submitted by storm water dischargers in similarly situated industries (58 FR 61146 and 60 FR 50804). This permit includes requirements that are specific to individual industrial sectors. Section 13.1.3 describes in detail the requirements specific to airport deicing/anti-icing operations.

Group permit applications were filed by entities representing groups of applicants that were part of the same subcategory or are otherwise sufficiently similar. The applications identified the participants, and described the industrial activities of participants and why they were sufficiently similar to be covered by a general permit. The American Association of Airport Executives (AAAE) prepared and submitted a group permit application including over 700 airports.

EPA received group permit applications from over 1,200 groups representing over 60,000 facilities from most of the major industrial classifications, except construction activities. The large number of facilities addressed by the regulatory definition of “storm water discharge associated with industrial activity” would have placed a tremendous administrative burden on EPA and states with authorized NPDES programs to issue and administer separate permits for each of these industrial group applicants. To facilitate the process of developing permits for each of the 1,200 group applications submitted, EPA classified the groups into 29 industrial sectors, in which the nature of industrial activity, type of materials handled, and material management practices used were sufficiently similar for the purposes of developing permits. Each industrial sector was represented by one or more groups that participated in the group application process. Airport deicing operations are included in Industrial Sector S (Vehicle Maintenance Areas, Equipment Cleaning Areas, or Deicing Area located at Air Transportation Facilities).

NPDES authorities issue individual permits (or modify existing individual permits to incorporate storm water discharge-related conditions) when warranted by the need for individual control mechanisms, their potential for pollution prevention, and where reduced administrative burdens exist. Section 13.1.4 describes in detail the requirements for individual permit applications.

13.1.2 General Permit (Baseline Industrial General Permit)

Facilities submit a notice of intent (NOI) to be covered by a general permit to authorize storm water discharges (the deadline for submitting a NOI for existing facilities was October 1, 1992). The NOI contains basic information such as the name and address of the facility, the Standard Industrial Classification codes that best represent the principal products or activities provided by the facility, the facility latitude and longitude, a brief description of the discharge and receiving water, and an indication of whether they have sampling data available for storm water discharges. Permits may require additional information where appropriate. Unless otherwise specified, dischargers are automatically authorized to discharge under the general permit by submitting an NOI in accordance with the terms of the permit.

General permit conditions and requirements are summarized below:

- Prohibition of non-storm-water discharges (with some specific exceptions) and discharges that contain a hazardous substance in excess of reporting quantities at 40 CFR 117.3 or 40 CFR 302.4.
- Annual monitoring of storm water discharges from aircraft or airport deicing areas for oil and grease, 5-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids (TSS), pH, and the primary ingredient used in the deicing materials (e.g., ethylene glycol, propylene glycol, ammonia) for airports with over 50,000 flight operations per year. Other airports are not required to conduct discharge monitoring unless required by the permitting authority.
- Facilities are subject to record-keeping requirements, but generally do not have reporting requirements. (NOI provisions for reissued permits require dischargers to summarize the quantitative data collected during the previous permit term.) Facilities may collect a minimum of one grab sample from holding ponds or impoundments with a retention period greater than 24 hours. For all other discharges, both a grab and a composite sample are required.
- Estimation of the size of the drainage area and runoff coefficient of the drainage area.
- Preparation, retention, and implementation of a site-specific storm water pollution prevention plan to minimize and control pollutants. Plan requirements are based on traditional storm water management, pollution prevention, and best management practice concepts tailored to storm water discharges associated with industrial activities, and are imposed in lieu of numeric effluent limitations. Specific plan requirements are discussed below.
 - Identification of a team responsible for developing the plan and assisting the plant manager with implementing, maintaining, and revising the plan.
 - Description of activities, materials, and physical features of the facility that may contribute significant amounts of pollutants to storm water runoff. The plan must contain a site map showing storm water drainage, control structures, and areas of potential pollution sources (e.g., material storage and processing and waste disposal). It must also include an inventory of exposed materials, a

list of significant spills and leaks that occurred three years prior to the effective date of the permit, an evaluation of the presence of non-storm-water discharges, a description of existing data on the quality or quantity of storm water discharges, and a risk identification and summary of potential pollutant sources.

- Evaluation, selection, and description of the pollution prevention measures, best management practices, and other controls that the facility will implement. At a minimum, the plan must address good housekeeping practices, preventive maintenance, spill prevention and response, inspections, employee training, record-keeping and internal reporting procedures, sediment and erosion control, and management of runoff.
- Description of annual comprehensive site compliance evaluations to confirm the accuracy of the evaluations and descriptions in the plan, determine the effectiveness of the plan, and assess compliance with the terms and conditions of the permit.

13.1.3 Multi-Sector General Permit

Group permit applications could have been filed by an entity representing a group of applicants that were part of the same subcategory or, if such a grouping was not applicable, were sufficiently similar as to be appropriate for general permit coverage under §122.28. The permit application consisted of two parts, Part 1, which was due on September 30, 1991, and Part 2, which was due on October 1, 1992. Part 1 included the following:

- Identification of the participants in the group application by precipitation zone (Appendix E to §122);
- Description of the industrial activities of participants and why they are significantly similar to be covered by a general permit;
- List of significant stored materials exposed to precipitation and materials management practices used to diminish contact; and
- Identification of group members who will submit quantitative data and description of why these selected facilities are representative of the group.

Part 2 of the permit application included submission of information for each representative facility equivalent to information that facilities applying for individual permits are required to submit.

AAAE's group permit application included Part 1 and Part 2 information for 59 airports considered to be representative of the 700 airports comprising the group permit application. Part 2 of the group application did not specify that facilities must sample storm water discharges from areas where deicing/anti-icing activities occurred and/or during times when such operations were conducted. As a result, only one facility indicated that the sampling data submitted were collected from areas where deicing activities were conducted.

EPA reviewed the group permit application to develop permit requirements contained in the Multi-Sector General Permit - Section S. Requirements specific to deicing/anti-icing operations are described in 60 FR 50998 (September 25, 1995) and include the following:

- Dry weather discharges of deicing/anti-icing chemicals are not authorized by this permit. There is no limit, however, on the time between a snowfall and snow-melt for the purpose of including a snow-melt discharge in the definition of storm water.
- Airports that use more than 100,000 gallons of glycol-based deicing/anti-icing chemicals and/or 100 tons of urea on an average annual basis will:
 - Prepare estimates for annual pollutant loadings discharged to storm sewer systems or surface waters, prior to and after implementation of the facility's storm water pollution prevention plan.
 - Monitor outfalls from the airport that collect runoff from areas where deicing/anti-icing activities occur for BOD₅, COD, ammonia, and pH. The airport should monitor these outfalls four times per year, from December through February when deicing/anti-icing activities occur, within the second and fourth years after permit issuance. A minimum of one grab sample and one flow-weighted composite sample should be collected from each outfall. Sampling within the fourth year may be waived if sampling data collected within the second year are less than monitoring cut-off concentrations of 30 mg/L for BOD₅, 120 mg/L for COD, 19 mg/L for ammonia, and between of 6 and 9 standard units for pH.

- Record precipitation event data.
- The airport will prepare a comprehensive storm water pollution prevention plan that integrates areas of the facility occupied by airport tenants (i.e., co-located industrial activities), regardless of whether or not tenants are co-permittees. The operator(s)/owner(s) (the airport authority) of the airport storm water outfalls is (are) ultimately responsible for compliance with all terms and conditions of this or other NPDES permits applicable to storm water outfalls. Plan requirements specific to deicing/anti-icing operations are described below.
 - Identification of a team responsible for developing the plan and assisting facility management in its implementation, maintenance, and revision.
 - Description of potential pollutant sources and a site map indicating the locations of aircraft and runway deicing/anti-icing operations.
 - Description of the potential pollutant sources from aircraft and runway deicing/anti-icing operations (including apron and centralized aircraft deicing/anti-icing stations, runways, taxiways, and ramps) and identification of any pollutant or pollutant parameter of concern.
 - Requirements for facilities that conduct deicing/anti-icing operations to maintain a record of the types (including the Material Safety Data Sheets) and monthly quantities of deicing/anti-icing chemicals used. Tenants and fixed-base operators who conduct deicing/anti-icing operations will provide records to the airport authority to include in the comprehensive plan.
 - Description of storm water discharge management controls appropriate for each area of operation and a schedule for implementing such controls. Specifically, operators who conduct aircraft and/or runway (including taxiways and ramps) deicing/anti-icing operations will consider alternative practices to reduce the overall amount of deicing/anti-icing chemicals used and/or lessen environmental impacts.

For runway deicing operations, operators will evaluate: present application rates to ensure against excessive overapplication; metered application of deicing chemical; prewetting dry chemical constituents prior to application; installation of runway ice detection systems; implementation of anti-icing operations as a

preventive measure against ice buildup; the use of substitute deicing compounds, such as potassium acetate, in lieu of ethylene glycol, propylene glycol, and/or urea.

For aircraft deicing operations, operators will evaluate current application rates and practices to ensure against excessive overapplication, and consider pretreating aircraft with hot water before applying a deicing chemical, thus reducing the overall amount of chemical used per application. Operators will implement measures determined to be reasonable and appropriate.

- Description of management practices to control or manage contaminated runoff from areas where deicing/anti-icing operations occur to reduce the amount of pollutants being discharged from the site. The airport should consider structural controls such as establishing a centralized aircraft deicing facility, and/or collection of contaminated runoff for treatment or recycling. The plan should consider recovering deicing/anti-icing materials when these materials are applied during nonprecipitation events to prevent these materials from later becoming a source of storm water contamination. The airport will implement and maintain controls determined to be reasonable and appropriate.
- Inspections of areas where deicing/anti-icing operations are conducted at least once per week during deicing/anti-icing application periods.
- Pollution prevention training to inform management and personnel responsible for implementing activities identified in the storm water pollution prevention plan of the components and goals of the plan.
- Comprehensive site compliance evaluations at least annually during periods of deicing/anti-icing operations to ensure that measures to reduce pollutant loadings are adequately and properly implemented in accordance with the terms of the permit, and to determine whether additional control measures are needed.

13.1.4 Individual Permit

Application requirements for individual permits include submitting the appropriate permit application forms and the following supplemental information:

- A site map of the facility including details of drainage and discharge structures, drainage areas, and pertinent features of drainage areas of all storm water outfalls, including paved areas and buildings, significant material storage and disposal areas, structural control measures, materials loading and access areas, chemical application areas, and areas associated with hazardous waste.
- An estimate of the area of impervious surfaces and the total area drained by each outfall and a description of the pertinent features listed above.
- A certification that all outfalls that should contain storm water discharges associated with industrial activity have been evaluated for the presence of non-storm-water discharges.
- Existing information regarding significant leaks or spills of toxic or hazardous pollutants at the facility that have taken place within three years of application submittal.
- Quantitative data based on samples collected during storm events from all outfalls containing storm water discharges associated with industrial activity. Required sampled parameters include oil and grease, pH, BOD₅, COD, TSS, total phosphorus, total Kjeldahl nitrogen, nitrate plus nitrite nitrogen, any pollutant limited in an effluent guideline to which the facility is subject, any pollutant listed in the facility's NPDES permit for its process wastewater (if applicable), and other pollutants as required under §122.21(g)(7)(iii) and (iv). Samples must be collected in accordance with §122.21.
- Flow measurements or estimates, and the total amount of discharge for the storm event(s) sampled.
- The date and duration of the storm event(s) sampled and other related information.

Based on a review of the permit application, the regulatory authority issues a facility-specific permit (or modifies an existing permit) to incorporate unique permit requirements. Requirements typically include discharge monitoring, implementation of best management practices, and an assessment of the impacts of these practices.

13.2 National, State, and Local Limitations

This section discusses current national, state, and local regulations pertaining to the discharge of storm water contaminated with deicing/anti-icing agents.

13.2.1 National Regulations

One of the purposes of this study is to evaluate whether national effluent limitations guidelines and standards are warranted for deicing/anti-icing operations. The only national regulations currently applicable to discharges of airport deicing operations wastewater are EPA's storm water program (see Section 13.1). Ethylene glycol and propylene glycol, however, are regulated by EPA and the Food and Drug Administration (FDA) under several regulations. Ethylene glycol is listed as a Hazardous Air Pollutant (HAP) under the Clean Air Act Amendments of 1990 (propylene glycol is not). Because ethylene glycol is a HAP, it is automatically subject to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and thus reporting requirements. The reportable quantity is 5,000 pounds of ethylene glycol in a 24-hour period, which converts to approximately 1,200 gallons of Type I deicing fluid applied as a 50/50 mixture in a 24-hour period.

Wastewater associated with manufacturing ethylene glycol and propylene glycol is regulated under different subparts of the effluent limitations guideline for organic chemicals, plastics, and synthetic fibers (OCPSF). Although the OCPSF guidelines do not apply to ADF discharges from an airport, effluent limitations have been promulgated for BOD₅, TSS, and pH for both subparts. The monthly average BOD₅ limitations for the manufacture of ethylene glycol and propylene glycol are 30 mg/L and 34 mg/L, respectively. Manufacturers of ethylene glycol and propylene glycol are also both regulated under the Clean Air Act under New Source Performance Standards for the Synthetic Organic Chemical Manufacturing Industry (SOCMI).

The FDA has established regulations for both glycols. The FDA established that propylene glycol is "generally recognized as safe" (GRAS) for human consumption; however, it

recently withdrew the GRAS status for the use of propylene glycol in cat food (1). According to FDA guidelines, ethylene glycol can only be used as an indirect food additive for use in adhesives. On an international level, the World Health Organization has set an acceptable daily intake level of propylene glycol at 0 to 25 mg/kg.

13.2.2 State and Local Regulations

The CWA includes a number of programs implemented at the state and local levels aimed at restoring and maintaining water quality. These include state, territorial and authorized tribal water quality standards; state, territorial and authorized tribal nonpoint source management programs; state, territorial and authorized tribal water quality monitoring programs; and the NPDES permit program for point sources. These programs combined with national regulations have produced significant and widespread improvements in water quality over the last quarter-century, but many water bodies remain impaired by one or more pollutants. For example, the National Water Quality Inventory Report to Congress for 1996 indicates that of the nation's water bodies that have been assessed, approximately 40% of these do not fully support water quality standards or uses. The major causes of impairments in water bodies include sediments, nutrients, and pathogens. Other causes include dissolved oxygen, habitat and flow alterations, pH, metals, mercury, and pesticides. Recent EPA regulatory revisions provide increasing emphasis on restoring impaired and threatened waters.

Discharge of deicing agent-contaminated storm water from airports is increasingly controlled by state and local regulations. For example, several states have implemented water-quality guidelines for ethylene glycol; the guidelines vary greatly between states (2). Due to local limitations and considerations given to receiving streams, airport-specific discharge limits can vary widely within a given state. For example, two airports, both in New York, comply with vastly different propylene glycol levels because one airport discharges to a water body that serves as a drinking water intake and, therefore, has more stringent limits than the other airport, which does not. Total maximum daily loads (TMDLs), which are water quality-based maximum loadings for individual streams, can also dictate discharge limits for airports. (TMDLs are described in greater

detail below.) Table 13-1 at the end of this section summarizes airport permit data collected by EPA for wastewater from airport deicing operations. EPA collected permit data from site visits and mini questionnaires. EPA also requested permit data from certain airports.

At least nine states have implemented drinking water guidelines and standards for ethylene glycol. The acceptable ethylene glycol concentration in effluent discharges from these states ranges from 100 ppb to 14,000 ppb (or 14 mg/L) (2). At least five states have implemented water quality standards to protect human health or aquatic life, and the acceptable ethylene glycol concentration from these states ranges from 7 ppb to 19,000 ppb (2). EPA was able to identify only one state, New York, that has implemented a drinking water standard for propylene glycol. The state Health Department establishes maximum concentration levels (MCLs) that are protective of public water supplies in New York State. The MCL for propylene glycol was recently revised from 50 ppb to 10,000 ppb (or 10 mg/L) (3).

Although not specifically developed to control the discharges from airport deicing operations, water quality standards for BOD or dissolved oxygen have been widely implemented throughout many states. As a result, permit writers may be indirectly controlling the discharge of ADF-contaminated wastewater by considering the acceptable oxygen levels in the receiving stream.

Airports that discharge to impaired water bodies may be required to meet NPDES permit limits designed to achieve total maximum daily loads (TMDLs). A TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards (including a margin of safety and consideration of seasonal variations), and allocates pollutant loadings among point and nonpoint pollutant sources. Section 303(d) of the CWA requires states, territories, and authorized tribes to identify and establish a priority ranking for waters for which existing pollution controls are not stringent enough to attain and maintain water quality standards. EPA intends that TMDLs be established over a 15-year timeframe with TMDLs for the most impaired water bodies established earlier in this timeframe. Priorities must take into consideration the severity of the pollution and uses of the water bodies (e.g., drinking

water sources). Although the future impact of TMDLs on airport deicing operations is unknown, airports discharging to receiving streams with dissolved oxygen or nutrient criteria are most likely to be affected.

EPA is aware of only one airport, Portland International Airport in Portland, Oregon, whose NPDES storm water discharge permit incorporates limits based on a TMDL to attain water quality standards in the Columbia Slough. The permit contains limits reflecting BOD₅ waste load allocations to achieve the receiving stream dissolved oxygen criterion. The waste load allocation increases with increased flow in the Columbia Slough. Discharge monitoring is required throughout the deicing season (November 1 through April 30) with more frequent monitoring requirements during and following deicing/anti-icing events. Monitoring is not required from May 1 through October 31 (4).

Based on EPA's data-gathering activities, pollutants that airports typically monitor for in discharges from airport deicing operations to surface waters and/or to POTWs include:

- BOD₅;
- COD;
- TSS;
- Ethylene and/or propylene glycol;
- Copper, lead, and zinc;
- Ammonia as nitrogen; and
- pH.

Many airports are required to monitor only for these pollutants and are not subject to specific concentration limits or action levels. Many of those airports may only be required to monitor for some of these pollutants (i.e., not the entire list). However, at airports that have specific numerical requirements in their permits, limitations are typically placed on BOD₅, TSS, ammonia as nitrogen, glycols, and metals (e.g., copper, lead, zinc). EPA did not identify any airport currently monitoring specifically for pollutants that may be a component of the ADF additive pack (e.g., tolyltriazoles). As discussed in Section 9.2, EPA and current ADF researchers believe the additive pack may be the greatest contributor to the aquatic toxicity exhibited by ADFs. Table

13-2 at the end of this section summarizes the range of limitations for pollutants for which many airports typically monitor and their associated monitoring frequency. This table does not include additional permit provisions such as BMPs and structural controls.

13.3 Canadian Management Measures

In Canada, as in the United States, deicing and anti-icing activities using glycol-based fluids are an important part of winter operations at airports. Unlike the United States where propylene glycol-based fluids dominate, airlines in Canada primarily use ethylene glycol-based deicing/anti-icing fluids. Based on conversations with Canadian industry and government representatives, the main reason for using ethylene glycol-based fluids is that ethylene glycol is a more effective freezing point depressant than propylene glycol at low temperatures.

In the early 1990's, concern about the detrimental effects of glycols on aquatic ecosystems led to the development and promulgation of two different glycol guidelines: (1) the 1994 Canadian Environmental Protection Act (CEPA) Part IV Glycol Guidelines, which established a voluntary guideline recommending discharge limitations for glycol at federal airports; and (2) the 1997 Canadian Water Quality Guidelines for Glycols, which established a voluntary guideline recommending safe ambient concentrations from the discharge of glycols into the environment. These guidelines are described in detail in Sections 13.3.1 and 13.3.2.

In addition to providing environmental protection-based performance targets, the guidelines are designed to assist facilities in promoting compliance with the general pollution prohibitions of the [Canadian] Fisheries Act. The Fisheries Act Section 36(3) (the Act) requires that “no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter such water.” A deleterious substance is defined as “any substance that, if added to any water would degrade or alter...the quality of that water so that it is rendered deleterious to fish or fish habitat...” Ethylene glycol and propylene glycol as well as formulated ADFs may be considered

deleterious substances according to its definition in the Act. Individual air carriers are responsible for deicing their aircraft and ensuring that they are not in violation with local, provincial, or federal legislation. The Fisheries Act allows individuals to be held responsible for pollution and imposes criminal penalties such as fines and jail time. Therefore, an air carrier may be in violation of the Fisheries Act unless a “due diligence” defense (i.e., a reasonable degree of care and attention was given to avoid harming the environment or humans) is established. Due diligence may include compliance with the glycol guidelines through glycol pollution prevention and mitigation efforts, environmental monitoring, audits, etc.

13.3.1 Canadian Environmental Protection Act (CEPA)

CEPA, originally passed in June 1988, is the principle federal legislation aimed at protecting the environment and the health of Canadians from toxic substances and other pollutants. Part IV of CEPA gives the Minister of the Environment the authority to regulate waste handling and disposal practices and emissions and effluents from federal activities. It also gives the Minister the authority to establish regulations and guidelines that apply to federal lands where regulatory authority would not otherwise exist.

In February 1994, EC promulgated voluntary glycol guidelines for deicing practices at federal airports under Section 53 of CEPA. The guidelines recommend an “end-of-pipe” discharge limit at federal airports and requires that annual reports of the results from monitoring glycol be prepared after each deicing season.

Under the National Airports Policy (NAP), announced in 1994, the Canadian government is commercializing its airports. The largest and busiest airports are being transferred to Canadian Airport Authorities, while the smaller airports are being offered for sale to local community interests. There will be 26 airports that will form part of the NAP. The airports will remain federal property but be operated by an airport authority. Transport Canada will remain the owner/landlord of these airports. Thus, these airports will be subject to federal regulations and guidelines, including the CEPA Glycol Guideline. NAP airports include such facilities as

Vancouver, Victoria, Calgary, Edmonton, Winnipeg, Thunder Bay, Toronto, Ottawa, Dorval, and Montreal-Mirabel.

The glycol guideline established under CEPA sets a 100-mg/L limit for total glycol allowed at the point of discharge. It is based on the prevention of all impacts to aquatic life as determined by an assessment of the available information (pre-1994) on the impacts of glycols and their associated deicing/anti-icing fluids and a review by a multistakeholder working group. The Minister of the Environment decided upon the final CEPA Glycol Guidelines based on this expert scientific assessment and the recommendations of the government-industry working group which included considerations of technological feasibility and socioeconomic factors (5).

Based on the scientific knowledge at that time (pre-1994), the most sensitive effect level reported in scientific literature was based on a study with the common ciliated protozoan *Chilomonas paramecium*. Data gathered from Bringmann et al. (1980) determined that the 48-hour lowest concentration at which effects were observed (LOEC) for growth inhibition in *Chilomonas paramecium* is 112 mg/L of ethylene glycol. Following standard practices, a safety factor of 0.1 was applied to this lowest effect concentration to derive an acceptable concentration of approximately 10 mg/L. A safety factor is applied to account for the uncertainties associated with species-to-species and laboratory-to-field extrapolations. This concentration was then converted to a discharge concentration assuming an “end-of-pipe” dilution ratio of 1:10, resulting in the guideline of 100 mg/L. The sampling point for compliance is the airport’s effluent discharge point to a receiving stream (5).

In 1997, industry requested a review of the CEPA glycol guideline. Following the review, the 100 mg/L voluntary guideline remains in place.

13.3.2 Canadian Water Quality Guidelines

The national Canadian Water Quality Guidelines for surface water limits for glycols are developed and promulgated nationally under the auspices of the Canadian Council of Ministers for the Environment (CCME). The CCME comprises 14 intergovernmental (i.e., federal, territorial, and provincial) ministers and is a forum for discussion and joint action on environmental issues of national and international concern. Canadian Water Quality Guidelines are used to protect ecosystems, assess environmental quality problems, and manage competing uses of water resources. These guidelines do not constitute values for uniform national water quality and their use requires local water quality considerations. They are updated as new data become available. Environment Canada serves as the federal member and scientific and technical secretariat for the CCME guidelines task groups, providing the leadership in science assessments and drafting proposed guidelines for national review and approval.

Development of the Canadian Water Quality Guidelines program began in 1984. In 1987, the Water Quality Guidelines Task Group of the CCME published the Canadian Water Quality Guidelines for over 100 substances. Since that time, the Group has published revised guidelines for specific parameters. The guidelines are voluntary, scientifically based, and apply to all situations where glycols may enter the environment (e.g., releases from aircraft deicing, automotive coolants, pipeline dehydrators). They provide recommended ambient environmental concentrations for the protection of aquatic life both for freshwater and marine species. The current freshwater guideline is set at 192 mg/L for ethylene glycol, and at an interim limit of 500 mg/L for propylene glycol. There is currently no recommended freshwater guideline for diethylene glycol due to insufficient data, and no recommended marine guideline for ethylene glycol, propylene glycol, or diethylene glycol due to insufficient data (6).

The current CCME guidelines were derived from acceptable studies from the most sensitive species exposed to each glycol. Data gathered from the Aeroports de Montreal and Analex Inc. in 1994 determined that the LOEC for growth inhibition in green algae to be 1,923.5 mg/L for ethylene glycol. A safety factor of 0.1 is applied to the LOEC to establish a water

quality guideline for the protection of freshwater species, which results in the guideline of 192 mg/L. Data gathered from Dufresne and Pillard (1995) determined the 96-h LOEC for frond growth inhibition in duckweed to be 5,000 mg/L for propylene glycol. Applying the safety factor of 0.1 results in the guideline of 500 mg/L. The guideline is considered interim due to limited available data. Additional chronic studies are required to attain full guideline status (6).

The main difference between the CEPA Glycol Guidelines and the water quality guideline is how they were derived and where they are applied. The CEPA guidelines apply at the “end-of-pipe” discharge point at airports, and assume that glycol is combined with non-glycol-contaminated storm water. The limit derivation accounts for dilution. The CCME water quality guidelines apply to much more than airports, and, as a conservative estimate, do not factor other non-glycol-contaminated storm water sources into the limit because they were not specifically derived for airports.

Water quality guidelines for dissolved oxygen were developed as part of the original guidelines established in 1987 and are summarized below.

Species		Life stage	Minimum Dissolved Oxygen Concentration (mg/L)
Freshwater	Warm-water biota	Early	6
		Other	5
	Cold-water biota	Early	9.5
		Other	6.5
Marine	All	All	>8

Source: Reference (6).

However, even at glycol concentrations below the revised CCME guidelines, the ambient oxygen level may fall below the recommended dissolved oxygen guideline. All CCME jurisdictions recommend that the dissolved oxygen guidelines be used in conjunction with the glycol guidelines.

13.4 Federal Aviation Administration Regulations

The FAA is part of the Department of Transportation and is responsible for regulating and promoting civil aviation. To ensure the safety of air transportation, FAA issues Federal Aviation Regulations (FARs) and advisory circulars. FARs are published in Title 14 of the Code of Federal Regulations and are designed to ensure the safe operation of aircraft, including operation during snow and ice conditions. Advisory circulars provide standards, specifications, and guidance on a wide range of safety issues including winter operations at airports. Under the current regulations, carriers (e.g. airlines) and pilots are responsible for conducting adequate aircraft deicing, while airports are responsible for ensuring that runways, taxiways, and other aircraft operational areas are properly cleared of snow and ice.

13.4.1 FAA Winter Operating Regulations for Aircraft

Snow, ice, and frost on aircraft surfaces can drastically reduce lift, alter handling characteristics, and make the aircraft difficult to control. Because of the safety hazard this poses, FAA has developed regulations that prohibit takeoff when snow, ice, or frost is adhering to wings, propellers, control surfaces, engine inlets and other critical surfaces of an aircraft. This approach is referred to as the “clean aircraft concept.” Although FAA regulations for winter operations differ depending on the size of aircraft and type of operations, all require that snow, ice and frost be removed from aircraft surfaces prior to takeoff and make the pilot ultimately responsible for determining the airworthiness of his/her aircraft.

FAA regulations do not stipulate which methods or materials should be used to remove snow, frost, or ice but recommend that commercial carriers and owners of private aircraft use methods and materials approved by the Society of Automotive Engineers (SAE) (see Section 13.5). However, the FAA requires that the deicing and anti-icing method selected for a particular aircraft be approved for use on that aircraft by the aircraft manufacturer. This approach gives the industry the flexibility to select aircraft deicing and anti-icing methods best suited to their individual operation.

The FAA publishes advisory circulars to assist aircraft operators in developing safe winter operating practices and selecting appropriate aircraft deicing methods. The advisory circulars provide standards, guidelines, and advice designed to help aircraft operators comply with aircraft deicing regulations and operate safely in winter weather conditions. Current FAA advisory circulars recommend that aircraft operators use ethylene glycol- or propylene glycol-based aircraft deicing and anti-icing fluids that meet the standards set by SAE (i.e., SAE-certified fluids). SAE standards for deicing fluids (i.e., Type I fluids) can be found in Aerospace Material Specification (AMS) 1424 and for anti-icing fluids (i.e., Types II, III and IV fluids) in AMS 1428. SAE provides recommended methods for applying deicing and anti-icing fluids in Aerospace Recommended Practice (ARP) 4737.

FAA regulations for winter operations differ depending on the size of the aircraft and type of operations. The most stringent regulations for aircraft deicing/anti-icing are those for carriers conducting scheduled commercial operations of passenger and cargo aircraft. Carriers operating passenger aircraft with more than nine seats, passenger aircraft with turbojet engines, and cargo aircraft with payload capacities of more than 7,500 pounds must comply with regulations contained in FAR Part 121, and are commonly referred to as Part 121 carriers. Aircraft deicing/anti-icing regulations for these carriers are contained in FAR Part 121.629, “Operation in Icing Conditions.” This regulation requires Part 121 carriers to follow an FAA-approved aircraft deicing and anti-icing program. Carriers may follow the FAA-approved procedure or develop their own aircraft deicing plan. The FAA-approved procedure requires carrier personnel to conduct a pretakeoff contamination check from outside the aircraft within five minutes of takeoff during conditions in which ice, frost, or snow may adhere to aircraft surfaces. Aircraft deicing plans developed by carriers must be approved by the FAA and are reviewed and revised annually to ensure they incorporate any new information, practices, or procedures. Many carriers have developed their own aircraft deicing plans because this approach allows them more flexibility.

The FAA provides guidance to Part 121 carriers on developing an acceptable deicing plan in Advisory Circular 120-60, “Ground Deicing and Anti-icing Program.” Aircraft

deicing plans include: (1) a management plan describing operational responsibilities and communication procedures; (2) a description of the aircraft deicing and anti-icing methods used by the carrier; (3) flight and ground crew training procedures including annual reviews and testing; (4) procedures for preflight contamination checks; and (5) holdover tables for estimating snow and ice protection provided by ADFs and procedures for using the tables. Holdover tables included in a deicing plan must be approved by the FAA and must be used whenever deicing and/or anti-icing is performed. When takeoff occurs within the holdover time, carrier personnel are required to conduct a pretakeoff contamination check for frozen contamination within five minutes of takeoff. The pretakeoff contamination check may be made from inside the aircraft provided it is performed by trained personnel and takeoff occurs before the holdover time expires. If the holdover time is exceeded, carrier personnel must either repeat the aircraft deicing process, inspect the aircraft from the outside within five minutes of takeoff, or use an alternate FAA-approved procedure (e.g., wing-mounted ice sensors).

13.4.2 FAA Winter Operating Regulations for Airports

FAA regulates only airports that serve air carriers that operate aircraft with seating capacities of more than 30 passengers. The operations may be either a scheduled or unscheduled service. FAA regulations applicable to airports are published in Part 139 of the Federal Aviation Regulations and stipulate that these airports must be certified by the FAA and hold an operating certificate. For certification purposes, airports are required to compile a manual describing the airport's operating procedures, lines of succession for airport operational responsibilities, and the airport's facilities and equipment. The manual must be approved by the FAA, implemented by the airport, and revised when necessary.

The operating procedures described in the manual must comply with all operational specifications outlined in Subpart D of Part 139. Specifically, Section 313 of Subpart D includes provisions for a snow and ice control plan for airports located in regions where snow and icing conditions regularly occur. The snow plan must include: (1) operational requirements and procedures for the removal of snow, ice, and slush from runways, taxiways, and aircraft

parking ramps; (2) a description of the priorities assigned to individual taxiways and runways; (3) names of personnel responsible for implementation of the snow plan and their areas of responsibility; (4) the location of a snow removal coordination center (usually referred to as a snow control center); (5) a list of materials used for snow and ice control and procedures for their application; and (6) procedures for the prompt notification of all aircraft operators using the airport when any portion of the runways or taxiways is not safe for the operation of aircraft.

The FAA allows airports to use chemicals and mechanical methods, such as brooms and snow plows, to keep airfield pavements free of snow and ice. Chemicals used for deicing/anti-icing airfield pavements may be liquids (e.g., potassium acetate or glycol-based fluids) or solids (e.g., airside urea (also called carbamide), calcium magnesium acetate (CMA), sodium formate, and sodium acetate). The FAA requires that airports use only products that meet or exceed SAE specifications. SAE standards for liquid pavement deicers/anti-icers are provided in SAE AMS 1435, while those for solid pavement deicers/anti-icers are provided in SAE AMS 1431A. Airports may also use airside urea meeting the U.S. military specifications provided in MIL SPEC DOD-U-10866D. Vendors of chemical pavement deicers/anti-icers are required to provide the airport with a Material Safety Data Sheet and certification that their product conforms to SAE or U.S. military specifications. Granular materials, such as sand, may be used to improve aircraft braking.

Although there are currently no regulations concerning aircraft deicing with which airports must comply, the FAA recommends in their Advisory Circular 150/5200-30A, "Airport Winter Safety and Operations," that airports develop local aircraft deicing plans. The plan should include the locations of designated aircraft deicing areas, communication procedures, and traffic flow strategies. The FAA also recommends that airports establish a committee responsible for aircraft deicing issues. The committee members should include representatives from airport management, airline operations staff, fixed-base operators, air traffic control personnel, and other interested parties such as corporate tenants or the military. FAA recommends that the committee meet prior to the beginning of the deicing season to discuss and review the following issues: (1) Part 121 carrier aircraft deicing programs and their effects on airport operations; (2) ground flow

strategies to shorten taxiing routes and minimize holdover time for deiced aircraft; (3) takeoff clearances and departure slot allocation procedures; (4) locations for aircraft deicing/anti-icing, including locations for secondary deicing/anti-icing; (5) communication procedures between air traffic control and aircraft waiting to be deiced/anti-iced; and (6) airport collection practices for containment of wastewater generated during aircraft deicing/anti-icing activities, including the responsibilities of individual tenants.

13.5 Society of Automotive Engineers (SAE) Standards for Aircraft Deicing/Anti-Icing Operations

SAE is a professional organization dedicated to improving safety and promoting new technologies in all sectors of the transportation industry through the development of engineering standards. The SAE Aerospace Council is responsible for developing standards for the aircraft industry and is organized into technical committees, each with its own area of specialization. The committee responsible for aircraft deicing and anti-icing issues is the G-12 Committee.

13.5.1 SAE G-12 Committee

The G-12 Committee is a voluntary consensus body responsible for developing standards, material specifications, and recommended practices for all aspects of aircraft deicing and anti-icing. The following subcommittees perform the work of the G-12 Committee:

- Fluids Subcommittee;
- Deicing Facilities Subcommittee;
- Holdover Time Subcommittee;
- Training Subcommittee;
- Ice Detection Subcommittee;
- Methods Subcommittee;
- Future Deicing Technology Subcommittee; and
- Aircraft Ground Deicing Equipment Subcommittee.

Members serve on the G-12 Committee and its subcommittees on a voluntary basis. Members include representatives from the airlines, the FAA, Transport Canada, fixed-base operators (FBOs), airports, fluid manufacturers, equipment manufacturers, airframe manufacturers, and the Airline Pilots Association.

The standards developed by the G-12 Committee are published in a series of documents. SAE standards for aircraft deicing fluids (i.e., Type I fluids) are published in Aerospace Material Specification (AMS) 1424B, while those for aircraft anti-icing fluids (i.e., Types II, III, and IV) are published in AMS 1428C. SAE-recommended practices for the storage, transfer, and application of aircraft deicing and anti-icing fluids are published in Aerospace Recommended Practice (ARP) 4737C. This document also includes SAE-approved holdover tables for use with Type I, II, and IV fluids. SAE specifications for aircraft deicing vehicles are published in ARP 1971 for large-capacity trucks and ARP 4047 for small-capacity trucks. SAE ARP 4902 contains design standards and recommended operation practices for aircraft deicing facilities. Standards for airfield pavement deicing/anti-icing agents can be found in AMS 1435 for liquids and AMS 1431B for solids. Glycol-based airfield pavement deicers/anti-icers must conform to standards contained in AMS 1426C.

The G-12 Committee meets several times each year to review and revise these documents and often participates in joint meetings with the International Organization for Standardization (ISO), SAE's European counterpart. The SAE/ISO joint meetings provide a forum to exchange technical information and promote international cooperation for the development of uniform standards in Europe and North America.

13.5.2 SAE Standards and Certification for Aircraft Deicing/Anti-icing Fluids

SAE does not dictate the composition of ADFs, but requires that they contain a freezing point depressant and any additives that enable the fluid to meet SAE performance-based standards. To receive SAE certification, fluid formulators are required to submit a sample of the fluid to an independent laboratory for testing. The tests are conducted by the Scientific Material

International (SMI) laboratory in Miami and the Anti-Icing Materials Laboratory (AMIL) of the University of Quebec in Chicoutimi, Canada. The tests are designed to measure the physical properties, material compatibility, aerodynamic performance, anti-icing performance, and stability of the fluid. Physical properties measured include the flash point, specific gravity, pH, refractive index, freezing point, surface tension, and viscosity. SAE material compatibility tests include tests designed to measure the fluid's effect on aircraft parts, including metals, transparent plastics, and painted surfaces. Aerodynamic performance tests are used to ensure that the fluids flow off aircraft surfaces during take-off. Anti-icing performance tests measure the fluid's ability to prevent ice formation on test plates exposed to freezing conditions. Fluid stability tests are used to measure thermal and storage stability, and the effect of hard water and shearing on fluid performance. The fluid sample submitted must be representative of the fluid offered commercially. A new sample must be submitted for testing whenever changes in ingredients or manufacturing processes are made.

Although SAE standards do not specify which freezing point depressants should be used in aircraft deicing/anti-icing fluid formulations, all such fluids currently used in the U.S. contain propylene glycol or ethylene glycol as the freezing point depressant. Since industry specialists believe that glycol has the potential to cause fires in some aircraft electrical systems, SAE requires glycol-based fluids to contain a fire suppressant. Although SAE does not specify which fire suppressant should be used, fluid formulators state there are only two effective fire suppressants currently available for this application, tolyltriazoles and benzotriazoles, both of which are considered to be toxic to aquatic organisms (see Sections 9.2.1.3 and 9.2.2).

13.5.3 SAE Environmental Information Requirements

In addition to meeting performance-based specifications, formulators are required by SAE to provide the following environmental data for their fluids: (1) BOD; (2) total oxygen demand (TOD) or COD; (3) biodegradability; (4) aquatic toxicity; and (5) trace contaminants. To comply with SAE standards, BOD tests should be performed at an incubation temperature of 20°C for a period of 5, 15, 20 or 28 days. The TOD or COD for the fluid should be reported in

kilograms of oxygen per kilogram of fluid, while biodegradability should be reported as the ratio of BOD and TOD (or COD).

Aquatic toxicity data should be reported as an LC50 concentration in units of milligrams per liter. SAE requires the aquatic toxicity tests to be performed in accordance with EPA (40 CFR 797.1300 and 797.1400, revised July 1, 1989) or OECD (Organization for Economic Cooperation and Development Guidelines for Testing of Chemicals, Methods 202 and 203) protocols. SAE does not specify which species should be used for the toxicity tests, but requires formulators to use species that have been selected by regulatory agencies for inclusion in discharge permits.

SAE also requires fluid formulators to report the presence of trace contaminants of sulfur, halogens, phosphate, nitrate, and heavy metals (lead, chromium, cadmium, and mercury). Fluid formulators must report the concentration of trace contaminants either as percentage weight or parts per million, and indicate the analysis method used and the detection limits.

Because SAE does not specify the concentration of the fluid to be tested, airlines and FBOs are often unable to directly compare the environmental data provided by different formulators. To remedy this situation, the Air Transport Association (ATA), a trade association representing the principal U.S. passenger and air cargo carriers, asked SAE during the May 1999 meeting to consider incorporating standardized environmental testing and reporting protocols into the SAE fluid specifications for both aircraft and pavement deicing/anti-icing agents. Specifically, ATA recommended that SAE: (1) require that aquatic toxicity tests be performed in accordance with the EPA method for whole effluent toxicity (WET) tests using fluid concentrate as the test sample; (2) specify the test species to be used for WET tests; (3) require that toxicity data be reported in a standardized manner for the fluid concentrate and 50/50 mixture; (4) specify a standard BOD test (e.g., 5-day BOD at 20°C); (5) establish a May 1 reporting date requiring that formulators provide toxicity data for new and reformulated fluids or certification that their fluids have not changed; and (5) consider setting toxicity standards for aircraft deicing/anti-icing fluids using the toxicity of current formulations as the baseline. ATA believes these changes, if adopted

by SAE, will enable fluid purchasers to compare the environmental impact of competing fluid formulations and encourage formulators to develop fluids with lower aquatic toxicity. In response, the Fluids Subcommittee created an Environmental Workgroup, comprising representatives from SAE and ATA, which will review the current SAE requirements and assess ATA's recommendations.

13.6 References

1. 61 Federal Register 19542 - 19544 (DCN T10568).
2. U.S. Department of Health and Human Services. Toxicological Profile for Ethylene Glycol and Propylene Glycol. September 1997 (DCN T11084).
3. Meeting Summary for Albany Aircraft Deicing Summit. March 1999 (DCN T10542).
4. Portland International Airport, Portland, OR. NPDES Permit (DCN T11049).
5. Environmental Canada. Scientific Considerations in the Development of a Revised CEPA Glycol Guideline Value. November 1996 (DCN T10376).
6. Environment Canada/Transport Canada. Canadian Water Quality Guidelines for Glycols - An Ecotoxicological Review of Glycols and Associated Aircraft Anti-Icing and Deicing Fluids. May 1999 (DCN T11079).

Table 13-1

Airport Permit Data for ADF-Contaminated Wastewater

Airport	Type of Permit	Parameters Monitored	Effluent Limitation (mg/L unless otherwise noted)		Frequency
Cleveland Hopkins International (CLE)	POTW	COD NH ₃ -N Flow TSS pH	1,500 and 12,500 lbs/day 72 and 600 lbs/day 700 gpm and 1 MGD Monitor Monitor		Once/week Once/week Once/month Once/week Once/month
Tri-State (Huntington, HTS)	NPDES Storm Water (General)	pH, TSS, O&G, TOC, BOD ₅ , TKN, COD, Nitrate-Nitrite, Total P	Monitor		Once/year for all parameters
Des Moines International (DSM)	NPDES Storm Water (Individual)		Outfall A	Outfall B	Twice/week Twice/week Twice/week Twice/week Twice/week Once/month Once/month
		BOD ₅ NH ₃ -N EG pH DO BETX O&G	<u>Monthly Avg.</u> 100 1.0 125 6 - 9 > 1.0 Monitor Monitor	<u>Daily Max.</u> 150 1.6 190 6 - 9 > 1.0 Monitor Monitor	
	POTW	pH Flow COD	5.0 - 10.5 150,000 gpd 10,000 lbs/day		Once/week Continuously Daily or as necessary to control discharge
Duluth International (DLH)	NPDES Storm Water	BOD ₅ , COD, TSS, N, TKN, NH ₃ -N, P, EG, PG, DEG, O&G, pH	NPDES permit does not require monitoring; however, it is considered a BMP.		Sampling schedule varies yearly
Anchorage International (ANC)	NPDES Storm Water (General)	BOD ₅ , COD, TSS, O&G, EG, PG, urea, potassium, acetate, NH ₃ -N, pH, flow	Monitor		Once/year (during spring snow melt) for all parameters

Table 13-1 (Cont.)

Section 13.0 - Relationship to Other Regulations

Airport	Type of Permit	Parameters Monitored	Effluent Limitation (mg/L unless otherwise noted)	Frequency
Seattle-Tacoma International (SEA)	NPDES Storm Water (Individual)	TPH, TSS, Turbidity, Fecal coliform, BOD ₅ , EG, PG, Cu, Pb, Zn, LC ₅₀	Monitor	Eight times/year for all parameters
	NPDES Industrial (Interim)	Flow pH O&G TSS BOD ₅ Total glycols TPH Fecal coliform VOAs Semivoas Cu Pb Zn LC ₅₀	4,800 gpm 6 - 9 8 (monthly avg.); 15 (daily max.) 21 (monthly avg.); 33 (daily max.) Monitor Monitor Monitor Monitor Monitor Monitor Monitor Monitor Monitor Monitor Monitor	Once/day Once/week Once/week Once/week Once/month Once/month Once/month Once/month Once/year Once/year Once/year Once/year Once/year Once/year (based on previous results)
Billings Logan International (BIL)	NPDES Storm Water (Individual)	pH, O&G, BOD ₅ , COD, TSS, total glycol	Monitor	Monitoring waived until 2000
Newark International (EWR)	NPDES Industrial (Expecting storm water permit approval)	Flow pH TPH COD TSS	Monitor 6 - 9 15 100 100	Once/month Once/month Once/month Once/month Once/month
Logan International (BOS)	NPDES Storm Water (Interim)	O&G TSS pH	15 10 5 - 7	Three times/month Three times/month Three times/month
General Mitchell International (MKE)	NPDES Storm Water (General)	DO, BOD ₅ , COD, TSS, O&G, pH, TKN, NH ₃ -N, Total P, Total Glycol, Cu, Pb, Zn, Flow	Monitor	Four times/year for all parameters

Table 13-1 (Cont.)

Section 13.0 - Relationship to Other Regulations

Airport	Type of Permit	Parameters Monitored	Effluent Limitation (mg/L unless otherwise noted)		Frequency
Buffalo Niagara International (BUF)	POTW	Flow EG + PG BOD ₅ O&G pH TSS VOA Semivolatile organics	27,000 gallons/day 10,000 lbs/day 250 100 5 - 12 250 Monitor Monitor		Once/month for all parameters
	NPDES Storm Water	Flow O&G pH TKN NH ₃ -N BOD ₅ EG Surfactants Benzene Toluene	Monitor 15 (daily max) 6 - 9 Monitor 2.4 (daily avg.); 16 (daily max.) 30 (daily avg.) 500 (daily max.) Monitor Monitor Monitor		Once/month Once/month Once/month Once/month Once/month Once/month Once/month Once/month Four times/year Four times/year
Bradley International (BDL)	POTW	Max. daily flow Max. flow rate Flow per batch PG TSS BOD ₅ COD pH	288,000 gpd 200 gpm 20,000 gal 125 125 200 600 5.5 - 10		Weekly for all parameters during discharge to POTW
Salt Lake City International (SLC)	Storm Water Industrial	Flow O&G BOD ₅ COD Nitrate-Nitrite pH EG PG	<u>Apr.-Sept.</u> Monitor 10 daily max. Monitor Monitor Monitor Monitor N/A N/A	<u>Oct.-Mar.</u> Monitor 10 daily max. 25(a)/35(b) Monitor Monitor Monitor 70 70	Once/month Once/month Twice/yr. (Oct-Mr once/yr.) Twice/yr. (Oct-Mr once/yr.) Twice/yr. (Oct-Mr once/yr.) Once/month Once/month Once/month
Greater Rockford (RFD)	NPDES Storm Water	BOD ₅ , pH, TSS, N	Monitor		Unknown
Airborne Air Park (ABX)	NPDES Storm Water (Individual)	COD, TSS, pH, NH ₃ -N, DO, TDS, O&G	Monitor		Four times/month for all paramters (in winter) Once/month for all parameters (in summer)

Table 13-1 (Cont.)

Section 13.0 - Relationship to Other Regulations

Airport	Type of Permit	Parameters Monitored	Effluent Limitation (mg/L unless otherwise noted)		Frequency	
Denver International (DIA)	POTW	Flow	Monitor		Continuously	
		BOD	9 tons/day (daily max.); 7 tons/day (monthly avg)		Once/hour	
		As	0.33		Unspecified but representative of discharge	
		Cd	3.4			
	Cr	3.6				
	Cu	6.1				
	Pb	2.2				
	Hg,	0.13				
	Mo	0.71				
	Ni	5.6				
	Se	0.66				
	Ag	2.9				
	PERC	1.5				
	Zn	15.6				
NPDES Storm Water General			Wet Weather	Dry Weather/ Summer	Wet Weather	Dry Weather/ Summer
	COD	Monitor	Monitor	Monitor	Once/day	Monitoring is required whenever the DIA staff, during the inspection of outfalls, observes or suspects an illicit discharge.
	O&G	Monitor	Monitor	Monitor	Once/mo.	
	pH	Monitor	Monitor	Monitor	Once/mo.	
	TSS	Monitor	N/A	Monitor	Once/mo.	
	PG	Monitor	Monitor	Monitor	Once/mo.	
	EG	Monitor	N/A	Monitor	Four times/yr.	
	BOD	Monitor	N/A	Monitor	Four times/yr.	
	TPH	Monitor	Monitor	Monitor	Four times/yr.	
	Total P	Monitor	N/A	Monitor	Four times/yr.	
Nitrate-Nitrite	Monitor	N/A	Monitor	Four times/yr.		
TKN	Monitor	N/A	Monitor	Four times/yr.		
Flow	Monitor	N/A	Monitor	Four times/yr.		
Chloride	Monitor	N/A	Monitor	Four times/yr.		
DO	Monitor if COD > 75	N/A	Monitor	Once/week		
Albany International Airport (ALB)	POTW	BOD ₅	240		Once/day for all parameters	
		TSS	25			
		COD	Monitor			
		Total glycols	Monitor			
	NPDES Storm Water General	BOD ₅	500 lbs/acre (land applied)		Once/month for all parameters (except PG)	
		Benzene	0.008			
		o-xylene	0.005			
		m+p-xylene	0.01			
	Toluene	0.005		Once/day during deicing season		
	Lead	0.05				
	PG	1				

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Table 13-1 (Cont.)

Section 13.0 - Relationship to Other Regulations

Airport	Type of Permit	Parameters Monitored	Effluent Limitation (mg/L unless otherwise noted)		Frequency	
Portland International Airport (PDX)	NPDES Storm Water		Outfall A	Outfall B	During and one day following deicing events between Nov. 1 and Apr. 30	
					Outfall A	Outfall B
		Flow COD BOD ₅ DO Bioassay Methanol Ethanol Propanol	Monitor Monitor Monitor Monitor Monitor N/A N/A N/A	Monitor Monitor Monitor Monitor N/A Monitor Monitor Monitor	Once/hour Once/3 hours Once/6 hours Once/6 hours Twice/year N/A N/A N/A	Once/hour Once/3hrs Once/6hrs Once/day N/A Once/day Once/day Once/day
Baltimore/Washington International (BWI)	POTW	pH BOD ₅ TSS Phosphorus TPH Flow	6 - 10 7,000 lbs/day 300 mg/L 12 mg/L 100 mg/L Monitor		During each batch discharge from 600,000 gallon storage tank	
		Cadmium Chromium Copper Lead Nickel Zinc	0.21 mg/L 6.89 mg/L 6.59 mg/L 6.81 mg/L 2.82 mg/L 17.85 mg/L		Once/year	

Key: (a) Monthly average.
(b) 7-day average.

As - Arsenic
BOD₅ - 5-day Biochemical Oxygen Demand
BETX - benzene, ethylbenzene, toluene, and xylene
Cd - Cadmium
COD - Chemical oxygen demand
Cu - Copper
DEG - Diethylene glycol
DO - Dissolved oxygen
EG - Ethylene glycol
Hg - Mercury
LC₅₀ - Lethal concentration where 50% of test organisms die
Mo - Molybdenum
N/A - Not applicable
N - Nitrogen

NH₃-N - Ammonia as nitrogen
Ni - Nickel
O&G - Oil and grease
P - Phosphorus
PERC - Tetrachloroethylene
PG - Propylene glycol
TDS - Total dissolved solids
TKN - Total kjedahl nitrogen
TPH - Total petroleum hydrocarbons
TSS - Total suspended solids
VOA - Volatile organics
Zn - Zinc

Table 13-2**Summary of Available Permit Data**

Parameters Frequently Monitored	Range of NPDES Limitations	Range of POTW Limitations	Range of Sampling Frequency
Chemical Oxygen Demand (COD)	90-120 mg/L	600-1,500 mg/L 400-12,500 lbs/day	1/day - 1/year
Ammonia	1-55 mg/L	72 mg/L 600 lbs/day	1/day - 1/year
pH	5 - 9	5 - 12	1/day - 1/ year
Total Suspended Solids (TSS)	10-100 mg/L	25-300 mg/L	1/day - 1/year
Oil and Grease (O&G)	8-30 mg/L	100 mg/L	3/week - 1/year
5-day Biochemical Oxygen Demand (BOD ₅)	10-150 mg/L 7-9 tons/day 900 tons/year	200-250 mg/L 7,000 lbs/day	1/hour - 1/year
Ethylene Glycol	70-500 mg/L	NA	2/week - 1/year
Propylene Glycol	1 mg/L	10-125 mg/L	1/day - 1/year
Total Glycols	NA	10,000 lbs/day	1/day - 4/year
Copper	NA	6.1 - 6.59 mg/L	4/year - 1/year
Lead	NA	0.05-6.81 mg/L	1/month - 1/year
Zinc	NA	15.6 - 17.85 mg/L	4/year - 1/year

NA - Not available.

14.0 ECONOMIC PROFILE

This section presents a profile of significant economic and financial aspects of the air transportation industry as it relates to airport deicing operations. The demand for airport deicing operations is a derived demand; that is, deicing operations are performed solely to provide the service of transporting passengers and cargo by air. Thus, the economic conditions underlying airport deicing operations are those of the air transportation industry itself. This profile examines airports in Section 14.1, and airlines in Section 14.2. All tables appear at the end of this section.

14.1 Airports

Section 14.1 is divided into four major sections. Section 14.1.1 discusses Federal Aviation Administration (FAA) airport classification and the number of airports, their sizes, and their locations. Section 14.1.2 presents an overview of airport financial management, while Section 14.1.3 describes ownership and management patterns among airports. Finally, Section 14.1.4 discusses issues concerning airport capital financing.

14.1.1 Determining the Number, Sizes, and Locations of Airports

A number of classification systems are used to describe airport size and significance; Section 14.1.1.1 discusses the most important classification systems, and profiles the distribution of airports by level of activity. Section 14.1.1.2 then relates airport activity and snowfall, both likely determinants in the probability of an airport potentially performing significant deicing operations, to the profile developed in Section 4.1.1.1.

14.1.1.1 FAA Airport Size Classifications

The primary source of data on the locations and sizes of U.S. airports is the FAA's Air Carrier Activity Information System (ACAIS) databank. ACAIS contains revenue passenger enplanement and all-cargo data. The database supports the FAA's Airport Improvement Program

(AIP) entitlement activities. AIP funding is largely based on airport activity as determined by annual passenger boardings (by FAA definition, boardings include only revenue-earning customers on aircraft engaged in air commerce), although other criteria apply as well. The ACAIS database contains data for all airports reporting any passenger boarding activity (1).

Another data source is the FAA's congressionally mandated National Plan of Integrated Airport Systems (NPIAS). The NPIAS database identifies 3,344 existing airports that are significant to national air transportation and, therefore, eligible to receive grants under the AIP. Activity and geographical location largely determine inclusion in the NPIAS (2). NPIAS airports account for virtually all commercial airline activity and approximately 92% of general aviation (GA) with complete geographic coverage of the U.S. (3). Although there is some overlap in the airports included in both the ACAIS and NPIAS databases, the NPIAS includes a total of 3,344 existing airports, while the calendar year (CY) 1997 ACAIS database contains 1,715 airports.

EPA may find other airport classification systems more suited to its purposes should it choose to undertake an effluent guideline. However, in this report, EPA utilizes the FAA airport definitions because they are frequently used in the industry. The FAA defines airports in the ACAIS database according to passenger boardings. The FAA's definition of revenue passenger boardings is broad and includes enplanements for activities such as sightseeing flights. Although these activities are generally not large, at certain airports (e.g., Grand Canyon, AZ, Juneau, AK), they can form a significant share of aircraft boardings. Below are the descriptions of the different airport classifications.

The first distinction lies between commercial service airports and noncommercial service airports. Commercial service airports are defined as airports with both scheduled passenger service and a minimum of 2,500 revenue passenger boardings on aircraft engaged in air

commerce per year. Commercial service airports cannot be privately owned.¹ The number of commercial service airports declined from 568 in 1988 to 529 in 1997, a decrease of roughly 7 percent (3, 4).

Commercial service airports are further subdivided into primary airports, those commercial service airports with more than 10,000 enplanements per year, and nonprimary commercial service airports having between 2,500 and 10,000 annual enplanements. The number of commercial service airports classified as primary airports increased from 396 in 1988 to 417 in 1997. Thus, while the total number of commercial service airports fell between 1988 and 1997, the percentage of airports rated as “primary” increased from 70% of commercial service airports in 1988 to 79% in 1997 (3, 4).

Primary commercial service airports are further classified as hubs (large, medium, small and nonhubs). The designation of hub depends on the percentage of total passenger boardings occurring at that airport, and again, is used primarily for distributing AIP funds. Because definitions of airport size are determined by annual enplanements, the number of hubs and the designation of airports can change from year to year. For example, in CY 1993, FAA classified 65 airports as large and medium hubs. Washington Dulles International was ranked twenty-eighth, Tampa International twenty-ninth, and Baltimore-Washington International thirty-first in passenger boardings; all were medium hubs (5). In CY 1996, there were 71 large and medium hubs; Baltimore-Washington International was ranked twenty-eighth and Tampa International was ranked twenty-ninth in passenger boardings, but both were large hubs while Washington Dulles International was ranked thirty-first, and was still a medium hub.

Airlines also individually designate airports as hubs; these designations should not be confused with FAA hub designations. An airline will define an airport as a hub if that airport is

¹ Boardings at private airports or airports without scheduled commercial service are included in the ACAIS. For example, in CY 1996, Orlando Sanford boarded almost 280,000 passengers (ranked 144 in passenger service); because these were unscheduled commercial flights, Sanford could not be designated a nonhub primary airport. Sanford’s boardings were, however, included in total U.S. boardings used to determine the hub status of other airports (1).

used to facilitate connections between airline routes; airline hubs may also be large or small. Los Angeles International, for example, is a large hub by FAA definition, but a nonhub by airline definition because it is not used by any major airline to facilitate connecting service. Conversely, Cleveland Hopkins International is a large hub for Continental Airlines, because it facilitates connections for Continental's route structure, but is a medium hub by FAA definition. Unless otherwise noted, EPA uses FAA's definition of hub throughout this section.

Table 14-1 presents total passenger boardings and the number of airports by FAA definition for CY 1997. This table emphasizes the dominance of large hubs (those with more than 1% of total U.S. enplanements) in the air transportation network.² The 30 large hubs in CY 1997 (5.7% of commercial service airports) accounted for 68.6% of the 640.7 million total U.S. passenger boardings. As a group, large hub airports averaged over four times as many annual boardings as medium hubs (3.3 million average annual boardings), and 21 times as many boardings as small hubs (660,000 average annual boardings). Large and medium hubs combined accounted for almost 90% of total U.S. passenger boardings in 1997.

FAA also tracks data on cargo-only service at airports. Statistics are published for those airports where the total annual weight of arriving cargo-only aircraft is at least 100 million pounds.³ In 1997, 106 airports "qualified" as having significant cargo-only service; activity at qualifying cargo-only airports is also included in Table 14-1. Although qualifying airports generally correspond to large, medium, and small FAA hubs (e.g., 66% of large, medium and small hubs are also qualifying cargo-only airports), two nonprimary commercial service and four noncommercial service airports have a significant amount of cargo-only service.⁴

² FAA defines passenger *enplanements* as the number of revenue passenger boardings on aircraft engaged in air commerce at airports that receive scheduled passenger service.

³ Gross landed weight of cargo refers to the rated maximum gross landing weight of each cargo-only aircraft type (i.e., the maximum allowable weight of the plane and its potential cargo), and does not measure the actual weight of the cargo carried in those planes.

⁴ This includes airports such as Rickenbacker Airport in Columbus, OH, which reported zero boardings in 1997, but landed over 725 million pounds of cargo-only aircraft. Rickenbacker acts as an operational hub for Federal Express, and therefore operates large jet aircraft in poor weather conditions.

Although insufficient data are available to determine this statistically, there may be a trend towards the development of specialized airports with significant cargo service but relatively little passenger service. Airports that fit this pattern tend to be near large cities (e.g., Hulman Regional – Indianapolis, IN; Pease International – Boston, MA; Rickenbacker International – Columbus, OH; Greater Rockford – Chicago, IL; Willow Run – Detroit, MI). Much of the traffic at these airports is express package delivery that is time-sensitive. By utilizing smaller airports, the cargo service airlines avoid the delays common at large passenger airports, yet these smaller airports are convenient to major business sources. Also, from the airports' point of view, investment in cargo service infrastructure may be less costly than passenger service.

Less information is available about GA airports. Some GA airports may have scheduled commercial service, but because they have less than 2,500 annual enplanements, they are not ranked as commercial airports. The 1997 ACAIS database contains some information on 1,186 noncommercial service airports; however, the most current NPIAS contains data on 2,806 GA and reliever airports, and indicates that the U.S. has an additional 15,000 GA airports currently in existence (6).⁵

GA airports are subdivided into reliever airports (334 in 1998), and other GA airports. Airports are designated as relievers if they maintain a certain level of operations per year (50 based aircraft, 25,000 itinerant, or 35,000 local operations per year) or FAA has determined its location desirable for instrument training, and if they are located in a metropolitan statistical area with a population of 250,000. In essence, relievers reduce congestion at major airports in the area by providing an alternate airport for GA aircraft to operate from. Business/executive jets frequently operate out of relievers, and they may be more likely to fly in bad weather than other GA aircraft. Large cargo-only jet aircraft may also use relievers; for example, some qualifying cargo-only airports, such as Rickenbacker, OH and Willow Run, MI are relievers. Nonreliever GA airports are probably a relatively insignificant source of aircraft deicing fluid runoff due to the

⁵ GA airports excluded from the NPIAS include more than: 1,000 publicly owned-public use landing strips, 1,200 privately owned-public use landing strips, and 12,000 privately owned-private use landing strips.

level of activity at the airport and the types of aircraft flown at the airport; most GA aircraft apparently do not fly in weather poor enough to require any significant deicing.

Table 14-2 uses ACAIS data from 1993-1997 to track growth in overall air traffic and growth by airport definition. First, commercial service airports account for roughly 99% of all passenger boardings, based on the small difference between figures for total passenger boardings and total passenger enplanements. Overall, both enplanements and boardings grew at an average annual rate of 5.3 percent. Total enplanements at large hubs grew more quickly than total enplanements (an average annual rate of 7.2 percent). Some of this growth is due to increasing the average size of large hub airports, and some due to the increasing number of large hub airports; the average number of enplanements at large hub airports grew at a more moderate 3.9% per year. Nonprimary commercial service airports grew most slowly, both in terms of total enplanements (average annual growth rate of -6%) and average enplanements per airport (average annual growth rate of 0.2 percent).

14.1.1.2 Airports with Potentially Significant Deicing/Anti-Icing Operations

EPA has determined that aircraft operations are likely to be a better predictor of the level of deicing activity than enplanements. The FAA supplied EPA with aircraft operations data by airport; Table 14-3 characterizes airports by non-GA flight operations and FAA airport hub status. GA activities were excluded from the operations classification because GA aircraft either do not fly in weather requiring deicing, or require minimal use of aircraft deicing/anti-icing fluids (ADFs). While large hubs account for almost 70% of passenger enplanement activity (see Table 14-1), they account for less than 50% of non-GA aircraft operations. This reflects the larger size of aircraft operating from large hubs, a result of the large demand for passenger service to those hubs. Also, operations cannot be neatly correlated with hub status and enplanement activity. Within each hub definition, some airports have more operations than airports in the next higher hub grouping (e.g., the largest medium hub had over 311,000 non-GA operations, while the smallest large hub had 210,000 non-GA operations).

EPA cross-classified airports by operations data and snowfall data to estimate the number of airports with the potential for significant deicing/anti-icing operations. For the purposes of this study, EPA selected a benchmark of 10,000 operations per year (excluding general aviation) to represent significant operations, and excluded airports with less than 10,000 annual operations from further analyses. EPA did not include general aviation in its operation measurement because the Agency believes that most GA aircraft do not operate during deicing conditions. Also for the purposes of this study, EPA assumed that mean annual snowfall (including ice pellets and sleet) of less than 1 inch would not result in significant deicing operations; therefore, EPA excluded airports in regions with annual snowfall of less than 1 inch from further analyses. A total of 212 airports met the criteria for operations and average snowfall (see Section 4.3.1.1 for details concerning the criteria to determine these airports).

EPA divided operations data into five subcategories (7):

- Category A: $425,000 \leq \text{operations} < 850,000$ per year
- Category B: $210,000 \leq \text{operations} < 425,000$ per year
- Category C: $100,000 \leq \text{operations} < 210,000$ per year
- Category D: $50,000 \leq \text{operations} < 100,000$ per year
- Category E: $10,000 \leq \text{operations} < 50,000$ per year.

EPA divided snowfall data into four subcategories (8):

- Category 1: $60 \text{ inches} \leq \text{snowfall} < 120 \text{ inches}$ per year
- Category 2: $30 \text{ inches} \leq \text{snowfall} < 60 \text{ inches}$ per year
- Category 3: $15 \text{ inches} \leq \text{snowfall} < 30 \text{ inches}$ per year
- Category 4: $1 \text{ inch} \leq \text{snowfall} < 15 \text{ inches}$ per year.

Table 14-4 presents airports with the potential for significant deicing/anti-icing operations classified by operations, snowfall, and FAA size definition. Of the 212 airports that meet the operations and snowfall criteria, data for only 211 of these airports are contained in the ACAIS database. Therefore, Tables 14-4 and 14-5 are based on the 211 airports that meet both of EPA's criteria and are also in the ACAIS database.

Table 14-4 is organized so that the uppermost left cell contains the largest airports by operations classification and the largest average annual snowfall, while the lowermost right cell (excluding the subtotal row and column) contains the smallest airports with the least average annual snowfall. The classification by hub status is included because of the importance of large and medium hubs in the U.S. air transportation system. For example, based on the averages presented in Tables 14-1 and 14-2, the single large hub with "A" level operations and a minimum of 60 inches of snow probably accounts for more operations and passenger enplanements than the combined operations and enplanements of the 17 nonhub and noncommercial service airports that also average at least 60 inches of snow. A total of 21 large hubs (of 30 total) and 23 medium hubs (of 40 total) meet the snowfall and operations criteria.

Table 14-5 compares EPA's classification system with FAA's size classification for the 211 airports contained in both the ACAIS and NPIAS databases. Air carrier operations decline from 74% of non-GA operations in the highest operations category to 19% in the lowest operations category. As carriers fly the largest aircraft and are less likely to cancel flights due to weather, these operations may generate the most ADF use. While airplane operations decrease dramatically with airport size, carrier enplanements decrease much less dramatically since carriers use larger aircraft than air taxis. In the highest operations category, carrier enplanements account for 95% of average enplanements, while in the lowest operations category, they account for 78 percent. Finally, the number of GA operations increases as airport size decreases; in the largest category, GA operations are a fraction of non-GA operations (less than 8%), while at the smallest airports, GA operations are 264% of non-GA operations.

14.1.1.3 Analytic Issues and Evaluation of Data Availability

ACAIS data (enplanements and gross landed weight of cargo) are made available to the public approximately one year after the CY for which they are collected (e.g., the FAA finished compiling ACAIS data for CY 1997 by the end of October 1998, and reports based on that data were available on the Internet in December 1998). Components of the ACAIS database have also recently been made available in electronic format (Excel spreadsheet) at the FAA web site. Operations data are not currently available at the FAA web site and must be requested directly from the FAA. The FAA can provide data in electronic format to other government agencies if requested to do so, and in greater detail than is posted on the Internet (1).

The primary issues for airport activity data are data consistency and coverage. Databases used for this industry profile were generated by the FAA for its own internal purposes; therefore, not all databases contain data for all airports. For example, the 1997 ACAIS enplanement database contains data for 1,715 airports, while the operations database contains data for 449. Data for almost 1,300 airports in the enplanements database are not in the operations database while 31 airports in the operations database are not in the enplanements database. Furthermore, the number of airports with data in the enplanements database ranges from 1,703 to 1,909 between 1993 and 1997. It is not apparent why these inconsistencies exist. Presumably, a single request to the FAA for all necessary data will result in a single database containing all relevant information. If such a database cannot be obtained, care will be required not to overlook airports with potentially significant deicing/anti-icing operations not contained in the operations database. For example, by using regression analysis on available operations, enplanement and cargo-only service, EPA identified a handful of airports having a high probability of more than 10,000 non-GA operations per year that were not contained in the operations database. Such an analysis may be necessary to ensure that no airports are overlooked.

14.1.2 Airport Financial Management and Accounting

Section 14.1.2.1 presents an overview of the major features of airport financial management, followed by a discussion of data availability for airport financial analysis in Section 14.1.2.2 with a profile of airport finances based on the limited information that is available. Finally, Section 14.1.2.3 presents issues identified during the analysis of airport financial data, including the ability of an airport to pass costs through to airlines.

14.1.2.1 Overview

Airport financial management is fundamentally different from most other business enterprises, because many airports (including most large commercial airports) have traditionally used a *residual-cost* approach to finances. Under this approach, the airlines as a group assume the financial risk of running the airport by agreeing to pay any costs of running the airport not paid by other nonairline users. Under the alternative *compensatory* approach, the airport assumes the financial risk; airlines pay rates set equal to their estimated cost of using the facility. Using the compensatory approach, there is no guarantee the airport will cover costs; however, the airport can keep any surplus of revenues over cost and accumulate capital for future development. Many airports may combine the two approaches (9).

Airport financial statements are difficult to compare between airports and with other businesses due to differences in the size and objective of different airports, the type of airport ownership (e.g., private or public), financial approaches to operations, and legal restrictions on airport finances. For example, because most airports use a residual-cost approach, they receive sufficient revenues from airlines to pay the cost of capital investment and are unlikely to account for depreciation on assets the way most businesses do. Also, airports are legally prevented from using their revenues for nonairport purposes.⁶ Therefore, airport financial

⁶ Except in specific legal agreements signed prior to the 1982 law prohibiting such practices. Therefore, a few airport owners, such as the Port Authority of New York, still legally use airport revenues to subsidize nonairport activities. Periodic questions of “revenue diversion” do arise, the most notorious being the claim by the City of Los Angeles that it

statements do not meet the standards of Generally Accepted Accounting Principals (GAAP), and an airport's revenue surplus or loss is not equivalent to profit or loss (10).

Typical airport operating statements include the following categories (9):

- Operating revenues and operating expenditures on key “cost centers”:
 - Airfield area (e.g., runways, taxiways, aprons),
 - Terminal area concessions (e.g., food and beverage services, travel services such as car rentals, specialty shops, personal services, amusements, advertising, outside concessions such as terminal parking, ground transportation, hotels),
 - Airline leased areas (e.g., ground equipment rentals, offices, ticket counters, cargo terminals, hangers, operations and maintenance areas),
 - Other leased areas (e.g., fixed-based operators (FBOs), freight forwarders, government offices, businesses in airport industrial parks, equipment and cargo Terminals rented by nonairline users), and
 - other operating revenues and expenditures.
- Nonoperating revenues (e.g., grants-in-aid (AIP), interest on investments, subsidies by government, leasing of properties not related to operations);
- General and administrative expenses (e.g., expenses of overhead services: accounting, legal, planning, public relations); at some airports (such as small municipal airports), these expenses, including policing and firefighting expenses, may appear in the governing authority's budget, not the airport budget;
- Nonoperating expenses (e.g., interest on outstanding debt, contributions to government); and
- Depreciation.

Under a residual-cost approach, the airport determines costs and revenues from each general operational area above, and airlines' fees are set by the anticipated revenue shortfall. Any surplus is returned to airlines in the form of lower fees the following year; any loss would be made up in

was owed almost \$90 million by the Los Angeles Department of Airports for alleged unreimbursed capital and operating expenses relating to the sale of airport property (11).

higher fees the following year. Both terminal and landing fees, or landing fees only, may be adjusted by the airport⁷.

The compensatory approach may determine fees according to the actual cost of running the airport, or by market value. The latter is especially common for terminal concessions. A growing trend has been for airports to use a mix of the residual-cost and compensatory approaches. For example, an airport may operate terminal concessions using a compensatory approach that permits the airport to keep surpluses from concession rents and fees, while it runs air-side operations using the residual-cost approach.

The financial and operational relationship between airlines and airport is defined in the *airport-use agreement*. This document specifies how the risks and responsibilities of running the airport will be shared, how rates for using facilities and services are calculated, and how frequently these rates and fees may be adjusted.

One consequence of the residual-cost approach is that tenants at such airports tend to have very long-term leases (20 to 30 years) to assure the airport of revenue to finance capital expenditures. In this case, airlines typically have a *majority-in-interest* clause in the airport-use agreement. This clause gives airlines that represent most traffic at the airport the right to review and veto or defer any capital projects that would significantly increase the fees they pay. Airports using a compensatory approach to finance are not legally required to allow airlines to review capital improvement projects, but most do.

The post-deregulation trend in airport financial management has been towards (9):

- Shorter-term contracts of 5 years or less to new tenants or renewal of existing leases when they expire to permit greater flexibility in adjusting pricing, investment policy, and space allocation.

⁷ Wells (9) claims that airports such as Los Angeles and Honolulu have approached “negative” landing fees in recent years due to overall operating surpluses.

- Greater use of the compensatory approach instead of the residual-cost approach with modification or elimination of majority-in-interest clauses.
- Maximization of revenues through more frequent adjustment of fees, competitive bidding for concessionaires' contracts, and greater emphasis on marketing and developing properties (e.g., airport industrial parks). Perhaps the most important new source of revenues at large airports is the collection of passenger facility charges (PFCs).

In the rapidly changing environment of the air transportation industry since deregulation and the burgeoning growth of air travel, airports seem more confident of their ability to be financially self-sustaining without residual-cost agreements by more aggressively pursuing all forms of revenues. For example, revenues from concession operations at hub airports (of all sizes) may account for one-third of total airport revenues; at some airports, concession revenues exceed airline revenues (9). On the other hand, deregulation has made airport finances somewhat more risky because airlines can reduce or discontinue service to an airport with little warning.

14.1.2.2 Airport Financial Data

Consistent data on airport financial conditions are not readily available. One source of data on airport operating revenues is the American Association of Airport Executives' (AAAE) Survey of Airport Rates and Charges, 1997-1998 (12). Because of the way this survey was administered, EPA cannot draw statistically reliable inferences from the survey results. However, more than 50% of large, medium, and small hubs (by FAA definition) responded to the survey, as well as over 220 nonhub and GA airports. Tables 14-6 and 14-7 summarize the results of this survey. Because the survey was voluntary, not all respondents answered all questions; EPA summarized the data for only those airports that provided complete operating revenue and expense data.⁸

Table 14-6 indicates the type of operating agreements used by responding airports. Although residual-cost agreements have historically been the most common type of operating

⁸ In addition, EPA could not ensure the consistency or accuracy of the data contained in the survey.

agreement, the number of airports currently using compensatory or hybrid residual-cost/compensatory agreements exceeds the number of residual-cost agreement airports in all airport categories except medium hubs.

Table 14-7 summarizes operating revenues by major source, operating expenses, and government subsidies, by FAA airport definition. Average operating revenues for large hubs are five times those of the next largest airport type – medium hubs – while average large hub enplanements are approximately three times the average medium hub enplanements (see Table 14-1). Airline and air cargo revenues as a percentage of operating revenues diminish with airport size, while FBO and GA revenues as a percentage of operating revenues are inversely related to airport size. Parking and concessions are extremely important sources of airport operating revenues for all except GA airports.⁹ Finally, operating expenses exceed operating revenues for GA airports, making them more reliant on government subsidies than any other class of airport.

The AAAE survey provides data on overall operating expenses, but not the source of those expenses. Nor does the AAAE survey provide information on capital expenditures. EPA used its airport mini-questionnaires to focus on these issues. Nine airports were sent mini-questionnaires; in addition, one airport voluntarily responded. Because of the small sample size, these results cannot be considered statistically significant; however, it is the only current source of information on expenses available to EPA.¹⁰ To minimize burden to the respondent, airports were allowed to use “best professional judgement,” and therefore all answers should be considered approximate (13).

Table 14-8 characterizes airport expenditures by three key cost centers (airfield, terminal, and hanger areas), general and administrative (G&A) costs, debt service, and

⁹ For the large, medium, and small hubs as a group that responded to the AAAE survey, parking fees comprised almost 41% of parking and concession revenues, exceeding airline landing fees as a source of revenue.

¹⁰ The FAA utilized AAAE data from 1992 to characterize capital expenditures in its most recent NPIAS (6). As noted below, the FAA recently started systematically collecting airport financial statements. This information is not publicly available in electronic format suitable for data analysis, and airport expenses are not characterized by cost center (e.g., airside, terminals), but by cost type (e.g., labor, utilities, insurance).

depreciation; enplanement and operations data are also included to indicate relative airport size. With the exception of Airport #1, airfield operating and maintenance accounts for a range of 13% to 32% of all airport expenditure.¹¹ For large and medium hubs terminal expenditures are higher than airfield expenditures. This is presumably due to the passenger service at large and medium hubs. With one notable exception, larger airports are willing to incur more debt than smaller airports.

14.1.2.3 Analytic Issues and Evaluation of Data Availability

Little systematic analysis has apparently been done on airport finances. The AAAE Survey of Rates and Charges contains the largest readily available source of airport financial data. However, the AAAE Survey does not provide sufficient data for economic and financial impact analysis. First, coverage is incomplete. Second, because of the way the survey was administered, statistical estimates based on the responses are not reliable. Third, the responses do not deal with airport operating expenses or capital expenditures. AAAE has apparently performed some survey work of capital expenditures. The data cited by the FAA in the NPIAS are dated (1992).

Commercial service airports have recently been legally required to submit annual financial statements to the FAA. These financial statements are available for 1996 and 1997 on the Internet; in addition, the FAA will make an electronic version of these statements available to other federal agencies.¹² These financial statements are the best source of publicly available information to systematically analyze and summarize (e.g., for the industry profile) airport financial information. However, there are a few drawbacks to using this data source. It does not contain non-commercial service airports, and therefore does not include airports such as

¹¹ Airport #1 is a new airport, which may account for some of the apparent anomalies in its responses. For example, new facilities presumably require less maintenance, hence the low expenditures on the airfield and terminals relative to other airports, but may have relatively high debt to pay for them.

¹² These financial statements are available at <http://www.faa.gov/arp/arphome>; choose "Browse by Topic" from the menu and select "Financial Reports." Each year's reports are contained in a single PDF file that can be searched by the airport's location ID. Further detail is available for the "other" category, but only in hard copy at the FAA (10).

Rickenbacker, OH or Willow Run, MI that may have significant cargo-only operations. While these files contain detailed information on airport revenue sources, airport expense information is much less detailed, and probably not adequate for economic and financial impact modeling. Finally, because airports are not required to submit audited data, and because different airports may use different accounting bases (e.g., cash vs. accrual) for their reports, these summary financial statements may not be directly comparable between airports (14).

Airport to Airline Cost Pass-Through

A significant question concerning airport finances also cannot be answered by the information provided in the FAA files: what percentage of cost increases are typically passed through to airlines in the form of higher fees? At residual-cost airports, the airlines are legally responsible to cover the costs of the airport; this suggests that airports pass 100% of costs through to airlines. Airline representatives have stated that costs on airports, FBOs, and the FAA are all passed through to the airlines. Furthermore, according to the industry, landing fees – the most likely vehicle for passing through airport costs – are a significant factor in determining the level of airline service provided to cities; an increase in landing fees can cause an airline to reduce or halt service to the airport (15).

Landing fees account for roughly 2% to 3% of overall airline operating costs (9). ATA comments that although landing fees are a relatively small percentage of airline operating costs, airport costs, including landing fees, are one of the most rapidly rising components of costs. According to ATA, any cost component is of great concern to the industry if it is increasing, regardless of the level of the cost (15). Furthermore, many airline operating costs are difficult for airlines to directly control in the short run. For example, jet fuel prices are determined by market forces. Similarly, labor costs are generally determined through multiyear union contracts. Airlines therefore have incentive to control any component of operating cost over which they have leverage, including landing fees (16). Although landing fees comprise a relatively small percentage of overall operating costs, a substantial increase in landing fees can significantly affect airline operating costs. If, for example, Boston's Logan Airport increased its landing fees by

\$0.50 per 1,000 pounds (a 22% increase), the landing fees paid by U.S. Airways, Logan's most frequent user, would increase by approximately \$1.6 million per year (12, 17, 18).

The small sample of airports visited or surveyed by EPA provide mixed evidence on the issue of cost pass-through. Five of 10 respondents to the EPA airport minisurvey indicated that they would anticipate passing through to commercial air carriers at least 90% of any cost increase caused by improving wastewater treatment systems. One airport indicated that 100% of such costs would be passed through on a special assessment to commercial carriers, and two other airports anticipated other fee increases that would significantly impact commercial carriers. A ninth airport stated that it would pass through 100% of these costs, but would not specify on whom it would raise fees. One of these nine airports indicated that although it was likely to pass through 100% of hypothetical compliance costs to airlines, in practice its ability to do so may be limited by fixed escalator clauses in its airport-use agreements (13).

However, airports do not uniformly believe that all costs can be passed through to commercial air carriers. Of the airports EPA visited, Chicago O'Hare expressed a strong preference for increasing revenues through concessions and other sources rather than increasing landing fees (16). Nearby General Mitchell International stated that the proximity of Chicago O'Hare places makes it difficult to increase revenues through increased landing fees; if General Mitchell increases its landing fees, it risks losing a significant portion of its passenger service to Chicago O'Hare (19). Airports that use a compensatory approach to financial management may consult airlines before undertaking capital improvements, even though they are not required to and the airline is not legally responsible for project costs. Salt Lake City International, for example, negotiated an increase in landing fees of \$0.01 per 1,000 pounds with airlines that offset the costs of recycling aircraft deicing fluid; a \$0.01 increase in landing fees increased the cost of landing a Boeing 747F by less than \$7.00 (20). Finally, the tenth surveyed airport indicated it would not pass through any proposed wastewater treatment costs.

Perhaps the most important long-run determinant of the financial health of an airport is the demand to visit the city or region served by the airport. If the airport is a "terminal,"

people are going to that city. If an airport is a “hub,” people are only going there to get somewhere else. Thus, terminal (“origin-destination demand”) airports fare better than airline operational hub-and-spoke (“connecting demand”) airports in the bond market. Passenger enplanements are an indicator of demand for service to an airport (and therefore revenues). If an airline using an airport as an operational hub pulls out at short notice (which it can since deregulation), passenger enplanements will probably drop significantly. In such cases, airports may risk significant losses in revenues and financial stability by increasing landing fees. Smaller airports face the same problem; if the costs of serving the airport rise too much, the airport risks losing its airline service. Thus, cost pass-through may vary according to the specific circumstances of individual airports.

14.1.3 Airport Ownership and Management

Section 14.1.3.1 presents an overview of major patterns of airport ownership and management, followed by a discussion of data availability and analytical issues in Section 14.1.3.2.

14.1.3.1 Overview

Different types of airport ownership affect decision-making at the airport, and the airport’s access to funds for financing capital improvements. Typical ownership structures include:

- Municipal/county government: airport is owned by city/county and run as a department of that entity and managed by that entity’s board of directors (e.g., city council); sometimes there may be a separate airport commission or advisory board. Policy decisions are made in the context of the wider city plan and the airport has no independent authority to issue bonds (9).
- Multipurpose port authority: legally chartered institutions operating a variety of publicly owned facilities such as airports, harbors, toll roads, and bridges. The authority typically has considerable decision-making autonomy from city/state government including the authority to issue debt in the form of revenue bonds (9).

- Single-purpose airport authority: similar to a port authority but only runs airport (or airports); like a port authority, it can issue debt, but typically has a narrower revenue base to operate from (9).
- State-operated airports: typically run by the state's Department of Transportation that can issue general obligation or revenue bonds. The state may also raise revenues through aviation fuel taxes. Only a handful of large-/medium-sized commercial airports are run by states: Alaska, Connecticut, Hawaii, Maryland, Rhode Island. The federal government owns one airport: Pomona Airport, Atlantic City, NJ (9).
- Private ownership: privately owned and operated, these airports are typically, but not exclusively, small GA airports (9); ABX, for example, is privately owned and operated by Airborne Express, which uses it as their operational cargo hub.

The recent trend for airports is to use independent authorities. Airports often outgrow political jurisdictions and impact surrounding communities both negatively and positively. Independent authorities allow the airport to spread the tax burden to other communities that benefit from that airport. (Note that government subsidies are much more important for smaller airports, especially as a percentage of operating costs; no large hubs, for example, are subsidized – see Table 14-7). Such authorities also allow smaller, more specialized, on-the-scene decision-making organizations somewhat insulated from politics. In addition to delegating management to an independent authority, that authority may further delegate airport management to a private contractor (21).

Table 14-9 summarizes ownership patterns found among airports responding to the AAAE Survey of Rates and Charges. The majority of respondents are municipally owned, a pattern that holds for all airport hub classes. Furthermore, “multigovernment” airports are typically airports with joint ownership by multiple municipalities. Thus, airport ownership by cities is dominant among AAAE survey respondents.

14.1.3.2 Analytic Issues and Evaluation of Data Availability

Two issues arise out of differences in airport ownership. The first is related to financial accounting. A municipal airport run by a department of the municipal government may account for costs in a significantly different way than other airports. Specifically, many costs of the airport such as accounting, legal, public relations, even policing and firefighting may be attributed to other city departments, not the airport. Thus, its financial position may be more difficult to analyze than an airport run by an independent authority.

The second issue is based on the lack of information available concerning privately owned airports. They are not required to submit financial summary statements to the FAA. Also, private ownership may affect airport access to funds for capital improvement; a significant portion of capital for publicly owned airports is raised through the municipal bond market. However, most, but not all, privately owned airports are relatively small GA airports (3) and are unlikely to perform many deicing operations.

14.1.4 Financing Capital Improvements

Section 14.1.4.1 profiles major sources of capital funding for airports and their relative importance in the system. Section 14.1.4.2 discusses data availability and analytic issues concerning airport capital financing.

14.1.4.1 Overview

In general, airports rely on the following sources of funds to finance capital improvements:

- Federal funding through the FAA AIP: funding comes from the Airport and Airway Trust Fund with revenues raised from taxes on airfares and airfreight waybills, surcharges on international flights originating in U.S., taxes on aviation gas and jet fuel, and registration fees on aircraft. Almost

50% of AIP funds are “apportioned” to airports by formula for use on any project meeting the guidelines for AIP-funded projects. The remaining funds are distributed at the FAA’s discretion for specifically approved projects. Most AIP funding goes for runways, taxiways, aprons, runway lighting and navigational aids; it may be used for building deicing pads and purchasing snow removal equipment (22). AIP funding may not be used to build hangers, parking facilities, or most terminal development (3). All NPIAS airports are eligible for AIP funds (2). AIP grants accounted for 20% of airport capital expenditures in 1996 (23).

- **FAA-authorized Passenger Facility Charges (PFCs):** the FAA authorizes commercial airports to impose PFCs for funding certain types of capital improvements similar to those eligible for AIP funds. Airports may charge \$1, \$2, or \$3 per enplaned passenger and passengers may be charged PFCs no more than twice on each leg of a round-trip journey.¹³ Airports must notify airlines of intention to charge the PFC and present to them its capital plan and financing strategy. Large and medium-sized hubs that use PFCs must give up AIP funds (\$0.50 of AIP funds for every \$1.00 of PFCs collected up to a maximum of 50% of their AIP apportionment); half of the relinquished AIP funds go into a discretionary fund earmarked for small airports (22). PFCs accounted for 16% of 1996 airport capital funding (23).
- **State funding:** this varies widely by state; Alaska and Hawaii provide considerable assistance while other states (e.g., New Hampshire) provide minimal assistance. Funding comes from state fuel taxes, aircraft, airport, and pilot registration fees, and general funds. State funding accounted for 4% of airport capital expenditure in 1996 (23).
- **Bond market:** although some city and states may fund airport expansion with general obligation bonds, or self-liquidating general obligation bonds, more typically airports use tax-exempt general revenue bonds. Typically airport revenue bonds have 25 to 30 year terms. Tax-exempt bonds are by far the single most important source of airport capital, accounting for 58% of 1996 funding (23).

¹³ The FAA has proposed raising the maximum PFC charge. While endorsed by airports, this measure is opposed by airlines on the grounds that: (1) it helps most those airports that least need help (i.e., large airports with large levels of enplanements), (2) because projects funded with PFCs do not have to meet airline approval, they believe many unnecessary projects are funded, and (3) PFCs increase the cost of air travel and therefore decrease the quantity of air travel demanded (24, 15). Airports argue that incumbent airlines frequently oppose airport expansion in order to restrict airline competition (25).

- Airport revenues: capital improvements funded directly from airport revenue streams, whether airside or landside. Airport revenues accounted for 2% of capital funding in 1996 (23).

In addition:

- Airport may lease airport-owned land to a private individual or company who finances improvements (e.g., airlines that build their own terminal on airport property out of airline funds (9)).

Table 14-10 characterizes airport capital expenditure, and the sources of funding for that capital expenditure, for recipients of EPA's airport minisurvey. Small and nonhub capital expenditure is significantly smaller than large and medium hubs. Furthermore, while capital spending at small and nonhubs is primarily funded through AIP grants and PFCs, a large percentage of large and medium hub capital expenditures is financed through bonds. With one exception, all airports surveyed charge the maximum PFC (\$3 per passenger), and that single exception has applied for permission to charge PFCs starting in the year 2000. Finally, most of these airports do not have a majority-in-interest clause in the airport-use agreement; a majority-in-interest clause requires airline approval of capital improvement projects.

An FAA study released in 1996 evaluated the airport access to funding for capital improvements and the effectiveness of the AIP program (26). Some key points of this evaluation are:

- From 1985 through 1995, AIP funded 14% capital spending at large commercial airports, 28% at medium-sized commercial airports, and 41% at small airports (including relievers and GA).
- PFCs are generating roughly \$1 billion per year, 50% of which is concentrated at the 10 largest enplaning airports. PFCs are an important source of revenue for funding bond issues. Airports may be obligating the revenue stream from PFCs 10 to 15 years into the future (15).
- Airports tend to perform at least as well as any other borrowers in the municipal bond market. Of the 995 airport bond issued between 1985 and

1995, all but one were rated “investment grade” (48% of large airport bond issues and over 65% of medium and small airport bond issues by volume were rated AAA). The airport industry has never defaulted on a bond issue.

- The tax exempt status of municipal bonds saves airports approximately 2% in interest costs (estimated at \$1 billion per year).

The report concluded:

“The nation’s commercial airports today do not face systemic or widespread obstacles to finding willing investors, financing debt-service reserve funds, obtaining bond insurance and other debt guarantees, and generally exercising leveraging strategies that foster airport development.”

Although the report found no systemic problems:

“At large and medium-sized airports, where major airlines exert significant influence over the scope and timing of investment, near-term financial realities facing airline management can create divergent airport-airline perspectives on the appropriate timing and scope of capital improvements due to their immediate implications for landing fees and other airline costs. . . . At small airports there is evidence of financial barriers to the desired level of development of terminal and land-side facilities.”

These financial barriers were deemed to be caused by insufficient revenues to cover bond issues or a lack of state or local aid.

While a General Accounting Office (GAO) analysis of airport capital funding generally concurred with FAA’s conclusions, it was not as confident as FAA about the overall availability of capital funding for airports (23). GAO projected a \$4 billion per year shortfall of capital funds for airport improvements, although this conclusion must be qualified because the \$4 billion figure was based on planned capital expenditure and was not prioritized by need. GAO noted that on a percentage basis, the shortfall was more significant for small airports rather than large and medium hubs. GAO also found that small airports are most dependent on government funding for capital projects.

14.1.4.2 Analytic Issues and Evaluation of Data Availability

The issue of capital availability will be important if EPA decides to proceed with development of an effluent guideline regulation for airport deicing operations. Due to the size of airports, and the level of construction necessary to withstand heavy usage, airside capital projects are potentially quite expensive, and the availability of capital funding could be of concern. FAA airport financial statements provide substantial data for characterizing sources of capital funding of the industry. However, the problem of local financial barriers to raising capital may become an important component of any impact analysis necessary to develop an effluent guideline.

In addition, airports, especially smaller airports, tend to rely heavily of government funds, such as AIP grants, to pay for capital improvements. The availability of AIP and PFC funds for use in meeting an effluent guideline may be difficult to determine. AIP funding is determined each year and Congress generally limits distribution of AIP funds to a lower level than authorized (26). Discretionary AIP funds are granted for specific projects only. Although PFCs may be a more predictable long-run source of revenues for capital improvements, airports may be “earmarking” projects to be funded by PFCs well into the future (15). Also, note that PFC funds provide little capital for airports with relatively small enplanements.

Should EPA move forward with a deicing effluent guidelines regulation, it is unlikely that airports could reasonably anticipate financing much capital expenditure to meet those regulations through AIP or PFC sources. This is due to both the limited availability of AIP funds and the tendency for AIP and PFC funds to be earmarked for specific projects. Combined with the perceived shortfall of capital funds for airport improvements, airports might only be able to meet such a regulation by postponing other capital projects. Thus, availability of capital may be a crucial issue in analyzing potential impacts of an effluent guideline regulation on airport deicing operations.

14.2 Airlines

Civil aviation can be divided into two groups: air carriers, and GA. Air carriers are defined as a company or other organization that carries passengers or cargo for hire or compensation by air; GA constitutes all other civil aviation (27).

Aircraft utilized by air carriers are distinguished from GA aircraft by the size, frequency and intensity of use. Table 14-11 displays some comparisons between selected types of GA and air carrier aircraft. Although there exist 21 times as many fixed-wing GA aircraft as air carrier aircraft, 75% of GA aircraft are single-engine piston aircraft, and each GA aircraft operates less than one-fifth as many hours per year as the average air carrier aircraft. Although the number of GA twin-engine turbojets outnumbers air carrier twin-engine turbojets, the latter are typically much larger (i.e., Boeing 737s and Douglas DC-9s/McDonnell Douglas MD-80s and MD-90s, carrying a minimum of 100 passengers). GA twin-engine turbojets tend to be much smaller aircrafts such as Learjets, carrying less than 20 passengers, flying as corporate/executive aircraft. Because GA aircraft are unlikely to fly in weather bad enough to require deicing – or if they do deice, they are likely to need relatively small quantities of deicing fluids – the remainder of this section will focus on air carriers.

14.2.1 Types of Air Carriers

Section 14.2.1.1 presents an overview of U.S. air carriers, major definitions, and a profile based on traffic statistics. Section 14.2.2.2 discusses data availability.

14.2.1.1 Overview

Air carriers can be divided into separate categories using two classification systems. The first classification system is primarily based on aircraft size. Air carriers must, in general, obtain a “fitness” certificate (covering economic and financial criteria) from the U.S. Department of Transportation (DOT) and an “operating” certificate (covering safety, training and

other operating issues) from the FAA. Aircraft size is a primary determinant of the type of certificate airlines require from each agency. Air carriers may be classified as (28):

- Large certificated carriers: fly aircraft capable of carrying a minimum of 61 passengers, or payload capacity of 18,000 pounds, or conduct international operations. Large certificated carriers require a Section 401 fitness certificate from DOT, and a Part 121 operating certificate from FAA.
- Small certificated carriers: fly aircraft that carry less than 61 passengers, have a payload capacity of less than 18,000 pounds, and do not conduct international operations. Small certificated carriers also require a Section 401 fitness certificate from DOT, and a Part 121 or a Part 135 operating certificate from the FAA.¹⁴
- Commuter carriers: defined as air taxis that have a published service schedule of at least five round trips per week between at least two places. Commuters register with DOT under Section 298, but do not require a fitness certificate. They also need a Part 121 or a Part 135 operating certificate from the FAA.¹⁵

One significant factor about the definitions above is that DOT reporting requirements vary according to the above definitions. Large certificated carriers must report monthly traffic statistics and quarterly financial statistics to DOT's Bureau of Transportation Statistics (BTS); these statistics are regularly published. Small certificated carriers and commuters report scheduled service only on a quarterly basis, and, although they do report financial statistics, those are not published due to a confidentiality agreement.

Large certificated air carriers are also characterized by annual revenues. Airline classification by revenues include (29):

¹⁴ Part 121 operating certificates are required for aircraft carrying more than nine passengers, more than 7,500 pounds payload, or for turbojet aircraft regardless of passenger capacity. Part 135 operating certificates are required for aircraft carrying nine or fewer passengers, or less than 7,500 pounds payload. Prior to 1996, Part 135 certificates were required for aircraft carrying 30 or fewer passengers.

¹⁵ For EPA's purposes, small certificated and commuter airlines are essentially identical. They offer the same type of service and operate the same type of aircraft. Small certificated air carriers are basically commuter airlines that chose to get certificated rather than registered because: (1) certificated airlines have a better chance of obtaining lucrative mail contracts in Alaska than do registered air carriers, or (2) bankruptcy laws – no longer in effect – made it easier for banks to recover capital from bankrupt certificated carriers compared to registered carriers (28).

- Major airlines: annual revenues greater than \$1 billion;
- National airlines: annual revenues greater than \$100 million, but less than \$1 billion;
- Large regional airlines: annual revenues greater than \$20 million, but less than \$100 million; and
- Medium regional airlines: annual revenues greater than zero, but less than \$20 million.

Although DOT does not report small certificated/commuter airline data according to revenue classification, some private publications might.

National and regional airlines tend to focus their service in particular regions of the country – a market “niche” strategy where the niche is defined by the geographic region served. Major airlines generally provide nationwide and often worldwide service. The primary difference between national and regional large certificated carriers is the scale of service as indicated by the level of revenues earned. Small certificated carriers/commuter airlines generally follow the same regional marketing strategy, and are distinguished from large certificated regionals more by the size of the aircraft flown than the type of service provided (30). Appendix D presents a list, by revenue classification, of EPA’s estimate of U.S. airlines in operation as of June 1998, along with their key financial and traffic statistics, where available.

National and regional airlines often provide “feeder” services to major airlines by carrying passengers from smaller airports not served by major airlines to the major airlines’ operational hubs. Through “code-sharing” agreements, the regional airlines can schedule such feeder flights under the major airline’s scheduling code. The flight appears to be a “through” flight rather than a “connecting” flight, thus gaining a higher ranking in travel agents’ computer reservation systems and therefore having a greater probability of being booked (30). The major airline gains by appearing to schedule service to more cities, while the regional airline gains by having its service appear to the traveler as being provided by a major airline. Through code-

sharing agreements and non-code-shared feeder flights, major airlines and national/regional airlines often have more of a complementary relationship rather than a competitive relationship.

Table 14-12 presents summary traffic statistics by carrier type. A revenue passenger-mile (RPM) is defined as one revenue passenger transported one mile in revenue service and is a commonly used measure of the quantity of passenger service provided; an airline transporting one passenger 1,000 miles provides more service than an airline transporting one passenger 500 miles. Available seat-miles (ASM) is a commonly used measure of airline capacity: the number of seats available for revenue service multiplied by the number of miles those seats are flown. Load factor is a measure of the proportion of capacity actually used in revenue service, and is derived by dividing revenue passenger miles by available seat-miles (31).

As is the case for airports, the airline industry is dominated by a handful of very large entities. Thirteen major airlines (three of which provide only cargo service) account for 83% of passenger enplanements and 88% of cargo ton-miles. Flying larger aircraft over longer distances, as indicated by passengers per aircraft-mile and miles per passenger, major airlines account for over 90% of RPMs and ASMs.

14.2.1.2 Data Availability

BTS tracks a wide range of traffic and activity statistics on airlines at the level of the business entity (32). The BTS *Green Book* is published monthly and contains traffic statistics for all large certificated carriers. These data include key measures of airline capacity and capacity utilization, such as available seat-miles, revenue passenger-miles, passenger enplanements, passenger and cargo ton miles, aircraft departures and hours flown. Data are provided for both scheduled and unscheduled service, for each airline's entire route system, and domestic and international routes separately. Comparisons are provided between the latest month, the same month in the previous year, the latest 12 months in aggregate, and the previous 12 months.

The BTS *Blue Book* tracks activity for small certificated and commuter airlines (31). The *Blue Book* is published quarterly, and only scheduled service statistics are presented. Basic measures of airline capacity and capacity utilization, such as available seat-miles, revenue passenger-miles, passenger enplanements, passenger and cargo ton miles, aircraft departures and hours flown, are included; however, less detail is provided than in the *Green Book*. Comparisons are provided between the latest quarter, the same quarter in the previous year, the latest 12 months in aggregate, and the previous 12 months.

To determine airline service to individual airports, BTS also publishes Airport Activity Statistics for each calendar year (18). BTS provides passenger, freight, mail, and cargo (cargo equals the sum of freight and mail) enplaned at each airport by each large certificated carrier. BTS also publishes scheduled and unscheduled aircraft departures for each airline at individual airports by aircraft type. BTS does not publish the destinations of passenger and cargo enplanements or aircraft departures, nor does it publish data for small certificated/commuter airlines, intrastate traffic, or foreign airlines.

14.2.2 Air Carrier Finances

Section 14.2.2.1 profiles the air transportation industry based on financial characteristics. Section 14.2.2.2 summarizes availability of key data necessary for analyzing airline finances.

14.2.2.1 Overview

Table 14-13 presents air carrier financial statistics by carrier type for the 12-month period ending June 30, 1998 (29). Major carriers account for over 85% of total air carrier passenger revenues, operating revenues, and operating expenses, and almost 95% of operating profit. As a group, only major carriers and small certificated carriers earned positive net income in this period (operating profits minus tax and interest payments).

Although in the aggregate, approximately 72% of total operating revenues are earned from passenger service, for specific airlines this average figure is deceptive. Table 14-14 presents 1997 passenger revenues, cargo revenues, and total operating revenues for selected ATA members. Table 14-14 also includes the number of aircraft owned and full-time-equivalent employees to provide nonrevenue size comparisons. Airlines are clearly divided among those providing both passenger and cargo service, but earning the majority of their revenues from passenger service (a minimum of 82% among the nonrandom sample displayed in this table), and cargo-only airlines that earn zero revenues from passenger service.

Operating profits presented in Table 14-13 for the airline industry are misleadingly high in the 12-month period ending in June 1998. Since deregulation in 1978, the airline industry has been notable for its low profit rate. Between 1978 and 1997, the industry's average net profit margin has been -0.1 percent (-1/10 of 1 percent). The record profits earned the last three years have been well below U.S. industry's average (15). Roughly 40% of the record profits earned in the last three years (approximately \$2 billion out of 1997 net profits of \$5 billion) have been directly attributable to low interest rates (resulting in significant savings on the cost of purchasing or leasing jet aircraft) and low jet fuel prices (which account for approximately 10% of industry operating costs).

Table 14-15 presents scheduled airlines' operating revenues, expenses, profits, net profits and profit margin for the period from 1982 to 1997 (33, 34). In only four of the 16 years did operating profit exceed 5 percent.¹⁶ Moreover, in only one year did the airlines rate of return on investment exceed 12%; a 12% return on investment (pretax) is often considered a benchmark for the "normal" rate of return – that rate of return necessary to meet the opportunity cost of capital (35). If the opportunity cost of capital is not met, then in the long run, capital will flow out of the industry and the industry will contract.

¹⁶ Figures for 1992 include a one-time-only accounting loss due to changes in accounting procedures that affected all industries. However, these losses account for less than 50% of the operating loss for that year; hence, significant losses were still incurred in 1992 (35).

Although some of the low profit margin in the airline industry can be attributed to growing pains associated with relatively recent deregulation, the problem of low profits is most likely systemic in an industry like air transportation.¹⁷ Economists typically measure industry competitiveness by the market share accounted for by the four or eight largest companies (4- or 8-firm concentration ratios) or an index such as the Herfindahl that measures the number of “effective competitors.” Using such measures, the competitiveness of the airline industry has declined since deregulation due to mergers. However, air carriers do not really compete at the national level, but at the route level. As Morrison & Winston pointed out:

“Four effective competitors at the national level can operate in two very different ways: with each having a monopoly share on one-quarter of the routes or with each having a one-quarter share on all routes. Although the number of airlines is the same either way, the second situation is obviously more competitive because more airlines serve each route. Thus fewer effective competitors at the national level does not necessarily mean that the industry is less competitive.”

Although lower than its peak in 1985, competition has clearly increased at the route level since deregulation, leading to a decline in average air fares, and an increase in air travel (35).¹⁸

Two features of the airline industry are the key contributors to low profit margins: low marginal costs on established service, and few barriers to entry. On an already scheduled flight, the cost of flying one additional passenger is very low (e.g., the cost of flying 121 passengers, instead of 120 passengers, on an already scheduled flight): incremental fuel costs, food costs, travel agents’ commissions, and similar costs. Because marginal costs are so low, and because the opportunity cost of flying with empty seats is high (i.e., an empty seat on a flight represents an opportunity foregone to earn revenue from that seat on that flight), there is a lot of

¹⁷ Some financial problems can be attributed to airlines learning to operate in an entirely new, highly competitive market environment, such as dealings with labor unions in an environment where costs cannot simply be passed on to customers through regulated fares, the startup of many low-cost airlines (e.g. People’s Express), a wave of mergers (e.g., Frank Lorenzo and Texas Air), and a shake-out of weaker airlines exposed to competition (e.g., Eastern, Pan Am, (36)).

¹⁸ This view is not shared by all economists; see Shepherd & Brock (37), for example, for a less optimistic view of the degree of airline competitiveness. Also, competition may be restricted on certain routes due to “slot” restrictions at airports or the dominating presence of a single airline at an airport (“fortress hubs”); this issue is discussed in more detail in Section 14.2.4.4.

pressure in the air transportation industry to keep air fares low. Essentially, if an airline can sell a seat above marginal cost, the airline will earn more net revenue than if it flew with an empty seat, even if that price does not cover average cost of providing that seat (i.e., total cost of the flight divided by the number of seats on the flight (38)).

Low marginal cost is not, by itself, sufficient to keep profits low. If barriers exist that prevent other airlines from entering a market, the incumbent airline is not necessarily driven to offer fares as low as marginal cost. However, in many – but not all – airline markets, few barriers to entry exist; it is relatively easy and inexpensive for existing airlines to switch aircraft from one route to another.¹⁹ The existence of a second airline, or more, in a market provides the competitive impetus to drive air fares down towards marginal cost (38). Fare wars have been common in the airline industry since deregulation, often driven by airlines struggling to stay afloat financially, and willing to fly below average total cost if it will generate some positive cash flow (i.e., revenues exceed operating costs, but not full costs (36)).

One result of this downward pressure on prices has been that airlines have become extremely aggressive cost cutters.²⁰ Airlines are concerned with any cost component exhibiting rapid growth, regardless of the relative size of that cost component (15). Much investment in new aircraft, for example, is geared towards cost reductions: a Boeing 757 provides 40 more seats, uses 20% less fuel, and requires a two-person cockpit crew instead of three compared to a Boeing 727 (15).

¹⁹ Crandall argues that in addition to low barriers to entry for existing airlines to enter a market, there are few barriers to entry to the air transportation industry as a whole. New airlines can be started relatively cheaply to compete with existing airlines (e.g., without having to hire unionized labor, new airlines can start business with a significant cost advantage over existing airlines because labor costs comprise up to 45% of operating costs). Crandall argues further that there are barriers to exit: the high cost of leaving the airline industry causes airlines to stay in business even when they are consistently losing money. Such airlines become some of the most aggressive price cutters in order to generate any kind of positive cash flow (38).

²⁰ Robert Crandall, the legendary CEO of American Airlines, has been quoted as saying that one of his proudest achievements at AA was saving the company \$50,000 per year by reducing the number of cherry tomatoes in the in-flight salads from three to two.

Table 14-16 presents cost indices and cost components as a percentage of total operating costs (39). Labor, fuel, and aircraft costs are the three largest cost components, accounting for over 55% of airline operating costs. Landing fees comprised 2% of operating costs in 1997. However, note that landing fees did grow 68% between 1985 and 1992 – approximately 8% per year; this period of rapid growth probably accounts for the attention airlines have paid to landing fees in recent years.

14.2.2.2 Data Availability

A wealth of financial data is available at the business entity level for large certificated carriers in the Bureau of Transportation Statistics (BTS) *Yellow Book* (29). The *Yellow Book* is published quarterly and contains detailed income statements and balance sheets for each large certificated carrier. Income statements are presented system-wide as well as separately for domestic and international service. Comparisons are provided between the latest quarter, the same quarter in the previous year, the latest 12 months in aggregate, and the previous 12 months. DOT also publishes the Airline Quarterly Financial Review for major airlines (40); however, this information is available in the *Yellow Book* and *Green Book*.²¹

BTS does not publish financial data for small certificated/commuter airlines. BTS does collect income data on passenger service revenues, operating revenues, operating expenses, and net income for each airline in this category biannually. However, individual airline data are kept confidential for three years, and only group data are presented in the *Yellow Book*.²²

²¹ Although the Airline Quarterly Financial Review does contain financial ratios for major carriers not contained in the *Yellow Book*, the *Yellow Book* contains data that can be used to calculate important financial ratios.

²² BTS did indicate that this small certificated/commuter airline income data may be available to other government agencies under certain circumstances (28).

14.2.3 Airline Deicing Costs

Airlines do not, in general, track deicing costs at the corporate level. In addition, while deicing costs may be tracked by the airline at individual airports, not all costs are directly attributed to deicing operations. Thus, for example, labor used for deicing aircraft may not be tracked as such, as labor may be tracked simply by hours, not by task. Similarly, while a certain percentage of airport landing fees and other charges are properly attributable to both the direct operating costs (e.g., vacuum trucks, wastewater treatment operations), and capital costs (e.g., deicing pads, drains, retention ponds) of ADF collection and disposal, the exact percentage of those fees attributable to deicing may be difficult to infer. All deicing costs cited in this section have been estimated by airlines, some with the assistance of ATA (41).

The methodology used for estimating deicing costs followed the following procedure. Five major airlines each provided ATA estimates of their deicing costs at a single airport for the three most recent deicing seasons (October to May of the following year). Airports were selected to provide a spectrum of weather and operational conditions. ATA used these airline specific costs to provide a breakdown of deicing costs into major components. Using figures on aircraft operations by the airline reporting for a specific airport, and total operations at that airport during each deicing season, costs were extrapolated from the individual airline to the entire airport. Finally, each airport's deicing cost per departure was regressed on three different measures of weather severity at each airport during the deicing season.²³ By using the same measures of weather conditions, the regression equations were used to estimate the deicing cost per departure at 236 other airports at which air carriers maintain air service. These costs were then aggregated using scheduled aircraft departures at each airport to estimate total airline deicing costs for the three deicing seasons (41).

The largest cost of airline deicing operations is the delays caused to each carrier's schedule. Costs of delay measure the direct operational costs of delay to the airlines, but not the

²³ ATA used heating degree days (an engineering index of heating fuel requirements), the number of days with temperatures below 32° F, and inches of snow.

opportunity cost of passengers' time on the delayed aircraft (42). Labor and operating costs comprise the second largest component, accounting for 28.5% of deicing costs. The third largest component of deicing costs is materials, primarily ADF. Finally, capital costs comprise 5.7% of deicing costs; these only include capital costs incurred by airlines, but not those incurred by airports. Therefore, ATA believes that the capital costs of deicing operations incurred by airlines are most likely understated in its study. Furthermore, ATA-member airlines estimate that deicing costs per aircraft have increased by 20% to 25% over the last five years due to rising ADF prices, increased use of more expensive anti-icing fluids, regulatory compliance costs, and increased wages and equipment costs (41).

The importance of the cost of delays to the airline industry can be observed in the fact that many operational decisions concerning deicing are made on the basis of how they will impact on-time performance. For example, a carrier's operational preference for gate/apron deicing as opposed to central deicing pad deicing, where both types of deicing are available, will depend on which is less likely to cause delays; it may be more difficult to coordinate activities of several carriers at a common-use centralized deicing pad without causing delays. Similarly, the decision by a carrier to provide its own deicing services at an airport as opposed to using another airline's or an FBO's services may hinge on how it will affect on-time performance (41).

Table 14-17 presents the measures of weather severity and deicing costs for the five airports selected by ATA.²⁴ Two points are apparent from this table: (1) the wide range of deicing costs per departure at different airports, and (2) the difficulty of easily characterizing those costs. Excluding Airport C with its semi-desert climate and relatively minimal deicing costs, deicing costs per departure at the remaining airports range from \$84 to \$640. With relatively basic measures of weather severity, costs differ substantially between deicing seasons at one airport, and between airports. For example, by all three measures of weather, the deicing season was more severe at Airport E in the 1998-99 season than airport B, yet per departure deicing costs were 73% higher at Airport B than Airport E. Similarly, at Airport A, the 1996-97 deicing

²⁴ In addition to key operational characteristics, ATA described important features of each airport's glycol collection system.

season was more severe than the 1998-99 season, yet per departure costs were 20% higher in the 1998-99 season. Finally, the deicing costs of cargo-only operations at Airport D are significantly higher than the other airports.²⁵

EPA also received separate estimates of deicing costs from regional airlines. Minisurveys to regional airlines provided estimates of cost per aircraft deiced ranging from \$320 to \$360 at Northeastern, Midatlantic, and Midwestern regional airports. Although these costs appear somewhat higher than the estimates provided by ATA (with the exception of Airport D with cargo-only service), ATA's estimates include aircraft departures that did not receive deicing.²⁶ With that qualification, EPA considers the regional airline estimates similar to those provided by ATA for similar region airports (43).

Regional airline estimates of the percentage of costs accounted for by different components of deicing operations are not directly comparable to ATA estimates. Regional airlines provided estimates of the direct cost of deicing operations that excluded such items as the cost of delays, and the estimated increase in landing fees attributable to deicing operations. However, it can be noted that whereas ATA estimated that the percentage of costs attributable to labor (28.5%) were of roughly the same magnitude as costs attributable to materials (24.7%), regional airlines attributed a significantly larger percentage of direct deicing costs to materials (43). The reason for these differences are not immediately apparent.

Regional airlines also provided estimates for the price of some ethylene and propylene glycol-based deicing fluids. For Type I ethylene glycol-based fluids, the price was

²⁵ Cargo aircraft spend significantly longer periods of time on the ground, typically only "cycling once" per day (compared to a passenger aircraft that might have several take-off/landing cycles per day. Thus, a cargo-only aircraft may land in the morning, be deiced and anti-iced, then need deicing again before departing that night (42).

²⁶ Regional airline respondents to the EPA minisurvey estimated a range of 35 to 50 deicing episodes in the 1997-98 deicing season; assuming a 150-day deicing season (e.g., from mid-October through mid-April), these airlines were undertaking deicing operations of varying intensity every three to four days (note that some episodes may have lasted more than one day). Presumably deicing operations were less frequent in October and April, and more frequent in January and February. Northwest Airlines indicates that it deices aircraft almost daily at its Minneapolis hub during the October to April "deicing season."

estimated in the \$4.70 to \$5.00 per gallon range; propylene glycol-based Type I fluids were somewhat more expensive in the \$5.00 to \$5.30 per gallon range. For Type II ethylene glycol-based anti-icing fluids, the price was estimated in the \$6.15 to \$6.30 range. For Type IV propylene-glycol based anti-icing fluids, the price was estimated in the \$7.45 to \$7.60 range (43).

As discussed in detail above, ATA extrapolated deicing costs at 236 other U.S. airports at which air carriers maintain operations using the airport-specific deicing costs per deicing season operation and the three measures of weather severity. Table 14-18 summarizes ATA's estimates of U.S. national air carrier deicing costs. Estimates of national deicing costs range from a low of \$437 million in the 1997-98 deicing season (measured using days less than 32° F), to a high of \$549 million in the 1996-97 deicing season (measured using HDD).²⁷ National deicing costs averaged well under 1% of total national operating costs for these three deicing seasons. However, because of the small profit margins in the air transportation industry, deicing costs ranged from 9% to almost 20% of net industry profits in the same time period.

14.2.4 Air Transportation Industry Trends

Following is a brief discussion of some trends that may significantly impact the air transportation industry, and its deicing operations, over the next few years.

14.2.4.1 Projected Industry Growth

Between 1998 and 2009, the FAA projects that the demand for air transportation services, as measured by domestic passenger enplanements, will grow faster than that projected for U.S. Gross Domestic Product (GDP), 3.5% compared to 2.3% for GDP. For the 2010 to 2020 period, both air travel demand and GDP growth is projected to slow, to 2.9% and 1.9%

²⁷ ATA argued that estimates based on snowfall underestimate the true national costs of deicing because zero snowfall implies zero deicing costs, yet airlines do incur deicing costs even with zero or minimal snow, as can be seen in Table 14-17.

respectively (44).²⁸ Boeing projects somewhat slower growth for North American air transportation (approximately 2.9%) while Airbus forecasts significantly slower growth (approximately 2.2%) than the FAA between 1998 and 2017 (45, 46).

Of particular interest is that regional and commuter airline growth is forecast to exceed large commercial airline growth, approximately 5.5% compared to 3.5% for large airlines, between 1998 and 2009. Also, because the demand for air travel is expected to grow faster than air carrier fleets during the forecast period, air carriers are expected to accommodate some of the increased demand through higher load factors and more intensive utilization of existing aircraft (44, 45).²⁹ To the extent that increased passenger demand is accommodated through more intensive utilization of existing aircraft, rather than using fewer aircraft with larger passenger capacity, more flight operations will be required to meet the increased demand for air transportation. Total operations and deicing operations would then be expected to grow more quickly with projected passenger demand, rather than more slowly with projected aircraft fleet size. ATA notes, however, that historically operations have grown more slowly than passenger demand.

14.2.4.2 Regional Jets

Regional jets (RJs) are smaller jet aircraft with seating capacities ranging from 32 seats to approximately 100 seats. RJs are largely being ordered by regional and commuter airlines, both to replace existing turboprop aircraft in their fleets, and to expand their fleets. RJs should result in increased service on smaller routes now generally served by turboprops. RJs offer lower operating costs per ASM than turboprops, resulting in lower cost service on smaller routes (15, 45). RJs are especially competitive on “long thin” routes. Comair, for example, estimates that it can break even operating an RJ on such a route with 21 passengers; if its affiliate Delta

²⁸ Air transportation growth projections are largely dependent on GDP growth projections; the FAA based its projections on an average of DRI/McGraw-Hill’s and The WEFA Group’s forecasts.

²⁹ Although Boeing sees little growth in average aircraft capacity, the FAA expects average aircraft capacity to grow by approximately two seats per year, from 142.6 seats to 166.6 seats in 2009.

operates a Boeing 737 on the same route, the larger aircraft would require 81 passengers to break even (47). Perhaps as importantly, RJs are more popular with the public because they are perceived as safer and more comfortable than turboprops; one commuter airline's research suggested demand on some of their routes would grow by perhaps 20% simply due to the "turboprop avoidance factor" (47).

The importance of RJs is reflected in the faster growth for regional and commuter airlines projected by FAA. The combination of lower operating costs (an increase in supply), and increased demand on routes serviced with RJs could result in significantly increased air transportation service to smaller airports. This could have two implications for aircraft deicing. First, due to the increasing demand for service by small aircraft, the number of deicing operations will grow more quickly than overall passenger demand because smaller aircraft will carry fewer passengers per flight. (Note that because smaller aircraft require less deicing fluid than larger aircraft, the total volume of ADF-contaminated wastewater generated may not increase significantly.) Second, because the comparative advantage of RJ aircraft is in serving smaller airports with insufficient traffic to justify larger aircraft, more deicing operations will be undertaken at these smaller airports than is currently performed.

14.2.4.3 Free Flight

Free Flight is a concept that will reduce pilots' reliance on air traffic controllers under most conditions, allowing them to choose the most efficient and economical route for their flight. Potentially this is an important development because delays due to inefficiency in the current Air Traffic Control system imposes significant costs on airlines (48). By decentralizing decision-making, and devolving that responsibility, in most circumstances, from the air traffic controller to the pilot, Free Flight should result in lower operating costs through reduction in delays and reduced fuel usage. For example, American Airlines was able to reduce fuel costs by \$2.2 million in one year through the use of "negotiated wind routes;" other limited tests of the concept show substantial fuel savings for participants (49).

Due to decreased reliance on air traffic controllers, Free Flight may also allow air traffic capacity to expand more quickly than the air traffic control system, also saving the air transportation system significant infrastructure costs. Note that Free Flight will not increase capacity at airports; airport constraints and slot controls may cause bottlenecks in the system, decreasing the potential benefit of Free Flight. Free Flight is being implemented slowly, and in discrete steps; not all technology needed for full implementation of Free Flight has yet been developed (49). However, to the extent that Free Flight is able to lower airlines' operating costs, the resulting increase in air transportation supply could cause air traffic to grow more quickly than projected over the next 20 years.

14.2.4.4 Competitive Issues

A major issue in the air transportation industry is the degree of competition existing in the industry and the role of the government in fostering competition. Although economists may disagree over how competitive the industry is at the present time, most economists do agree that deregulation has, in general, caused air fares to fall and the quantity demanded of air transportation to increase (35, 37, 50, 51, 52, 53). In general, this has been caused by increased competition, both between existing airlines now able to compete head-to-head on routes of their choice, as well as through the entrance of new airlines into the industry undercutting the fares of existing airlines.

Although the benefits to consumers of deregulation have been large, and to most economists, indisputable, on a handful of routes competition has remained restricted. Fares on such routes have found to be significantly higher than comparable routes between other cities (52, 53). Airlines argue that these fare differentials are a result of traveler preferences on those routes, especially due to business travelers' willingness to pay a premium for frequent and nonstop service (53). Industry critics argue that the fare differentials are a result of factors minimizing competition at these airports including: (1) the dominant market position of a major airline at one of the airports, usually an operational hub (so-called "fortress hubs"), and (2) restricted access to an airport because of a lack of available gates at the airport ("gate-constrained") or FAA-

mandated limitations on landing slots (“slot-constrained” (34, 53, 54)). GAO has identified six airports as gate-constrained: Charlotte, Cincinnati, Detroit, Minneapolis, Newark, and Pittsburgh, and four more as slot-constrained: Chicago O’Hare, LaGuardia, Kennedy, and Ronald Reagan Washington National (52). The FAA is examining ways of reducing gate and slot constraints at airports.

Evidence concerning a potential “hub premium” at such airports is mixed. Large hub premiums have been found in highly publicized studies by Borenstein and by the GAO; however, these studies appear to be badly flawed (35, 55). Morrison and Winston found a small but significant hub premium, and confirmed this result after adjusting GAO’s study for methodological errors. On the other hand, a recent study by Gordon and Jenkins found a small but significant “hub discount” (55).

Other explanations of high fares have focused on allegations of anticompetitive behavior of incumbent airlines. Incumbent airlines have engaged in a variety of business practices, such as the use of frequent flier miles, bias in computer reservation systems, special bonus commissions to travel agents reaching certain goals for bookings on a specific airline, and codesharing alliances that can potentially provide them with a competitive advantage, especially against startup airlines. It should be noted that many of these business practices, including the previously discussed hub-and-spoke route systems, frequent flier programs, and computer reservation systems have benefited consumers as well as served as tools of inter-airline competition (53).

Of particular concern to some industry observers are allegations that incumbent airlines have engaged in predatory pricing behavior to drive new entrants out of markets. In short, incumbents have been accused of drastically cutting fares, perhaps even below costs, and dramatically increasing service on certain routes to a level with which new entrants cannot compete. After the new entrants are forced from the market, incumbents quickly revert to previous fare and service levels (52, 56). The U.S. Justice Department recently sued American Airlines for such antitrust violations, and is probing Delta and Northwest Airlines as well (57).

Concerns of anticompetitive behavior have been particularly prevalent in some quarters due to the failure rate of low-fare startups – point-to-point low-cost airlines, such as People’s Express that try to emulate Southwest Airline’s operating philosophy (36). The DOT believes that the success of airline deregulation has largely been due to low-fare startups (50). Incumbent airlines argue that the failure of low-fare airlines has been due to mismanagement (noting that the failure rate for new air carriers is virtually identical to the failure rate for new businesses of all types) and consumer preference for traditional airlines (15). Furthermore, incumbent airlines believe the decrease in new entrants is attributable to the slowdown in DOT approval of new airlines after the 1996 ValuJet crash (15, 48). Clearly, many of the low-fare airline failures – including People’s Express – have been caused by their business shortcomings (53). However, there is concern among industry observers that anticompetitive behavior has also been responsible for a lack of competition in certain markets (53, 56).

The DOT has proposed guidelines indicating practices that it will consider potential anticompetitive behavior. Under these proposed guidelines, which it continues to study, DOT would investigate such practices and take action against the airline if necessary (56). ATA argues that the DOT’s guidelines are vague and contradictory to established U.S. antitrust law; it perceives DOT’s guidelines as a move towards re-regulating the airline industry (15). Other observers, while also concerned with anticompetitive behavior in the industry, share ATA’s concern that DOT’s guidelines are too vague and will result in unnecessary increased regulation; these observers agree with ATA that allegations of illegal anticompetitive behavior should remain within the purview of the U.S. Department of Justice (53).

There is little or no support among economists for significant re-regulation by DOT of airline competition, although they do express concern about a relatively limited number of issues (35, 53). Indeed, many economists would argue that the historically low rate of return earned in the airline industry is inconsistent with allegations of market power that can systematically generate substantial price markups over cost. However, the key point for the purpose of this study is that the airline industry is facing intense scrutiny on a number of high-profile, potentially volatile issues. It is possible that government agencies could respond to these

issues by dramatically increasing regulatory oversight of airline competition. A fundamental change in the government's relationship with the air transportation industry could cause such significant changes to the structure and conduct of the industry that the state of the industry may appear, after a period of adjustment, quite different than reported in this profile.

14.2.5 Analytic Issues

Section 14.2.5 discusses three analytic issues EPA will face should it choose to go forward with an effluent guideline regulation for airport deicing operations. The impacts of a potential regulation are unlikely to be measurable in terms of facility closures; Section 14.2.5.1 describes how impacts are likely to be incurred in the airline industry, and how they might be analyzed. Section 14.5.2.2 revisits the issue of cost pass-through, this time, however, focusing on the pass-through of costs from airlines to their passengers. Finally, Section 14.2.5.3 briefly discusses how the compliance costs of a potential regulation may affect the decision to deice.

14.2.5.1 Assessing Potential Regulatory Impacts

In previous effluent guidelines efforts, EPA has typically relied on facility-level cash flow analysis to project regulatory impacts; this is not likely to be appropriate for the airport deicing operations industry. In manufacturing and many service industries, the cost of regulatory compliance is incurred by the facility, which may be able to recover some of its costs through increased price to customers. Facility-level impacts can be projected by analyzing the net impact on facility costs and revenues and comparing the result with some well-defined benchmark (e.g., is estimated post-regulatory cash flow greater than the facility's salvage value). In the airport deicing operations industry, the facility is the airport, but the product – air transportation services – is provided by intermediaries, the different airlines that use the airport.

The financial arrangements between airports and airlines mean that facility closures (e.g., airport closures) are unlikely to be an impact of effluent guidelines on the industry. Most commercial service airports, those most likely to be impacted by an effluent guideline regulation,

charge rents and fees on a residual cost basis. Airlines are bound by contract with the airport to pay any airport operating costs in excess of revenues, typically in the form of higher landing fees. Because of this financial structure, airports do not earn a profit or loss in the traditional accounting definitions of those terms, nor are they likely to go bankrupt (Section 14.1.2). Airports may incur other impacts from such a regulation, as discussed below, but facility closure is unlikely to be one of them.

Effluent guidelines regulating the airport deicing operations industry would likely result in increased operating costs to airlines, whether indirectly in the form of increased landing fees at airports or directly as increased costs of deicing. Such increased operational costs are likely to be at least partially passed on to the ultimate customer – the airline passengers – in the form of higher ticket prices. ATA estimates that the overall price elasticity of demand for air transportation is approximately unit elastic (i.e., -1.0), thus a 1% increase in ticket prices will on average cause a 1% decrease in the quantity of air transportation demanded (15). However, this will vary on individual routes; on some routes where the typical passenger is flying for vacation purposes (i.e., relatively elastic demand), the impact may be larger, while on routes flown by business travelers (i.e., relatively inelastic demand), the impact may be much smaller, but measurable. In the airline industry, however, a 1% decrease in passenger demand translates into empty seats and lost revenues on existing flights – with little decrease in operating costs – not a 1% reduction in flights and operating costs (38). Because empty seats reduce revenues more than costs, airlines may respond to decreased demand by reducing service (e.g., providing less frequent service, or using a turboprop instead of a jet) or terminating service on certain routes.

The complexities of airline pricing policies are one aspect of the difficulty in assessing potential regulatory impacts. Airlines calculate the viability of a route by comparing per unit revenues (i.e., yield, equal to revenue per revenue passenger mile) with the per unit cost of providing that service (i.e., cost per available seat mile (15)).³⁰ There is a wide range of publicly

³⁰ Clarification by ATA of airline pricing policy is necessary to fill out the details of this analysis. At an EPA meeting with ATA, for example, airline representatives stated that airlines compare yield with cost per available seat mile. However, these cost and revenue measures, while closely related, do not share a common denominator and are therefore

available information that would enable EPA to estimate per unit revenues and costs for individual airlines. However, such overall system-wide data would not enable EPA to estimate route-specific impacts. Unit costs, for example, are largely a function of the type of service offered on that route, especially flight length and aircraft type (the choice of aircraft type is not completely independent of flight length). For example, one analyst estimates that United Airlines' unit costs on routes of 500 miles or less are 23% greater than its overall system-wide average (58).

With the exception of low-cost single-fare airlines such as Southwest, unit revenues are determined by the complex procedure known as yield management. An aircraft seat is a perishable good just like fresh produce – once an aircraft leaves the gate, that seat's earning potential is lost for good. The marginal cost of filling an aircraft seat is very low, comprised of incremental fuel burn, baggage handling, ticketing and other incremental costs (assuming the flight's departure is not dependent on whether that passenger is on it). Therefore, an airline has incentive to offer very low fares rather than fly with empty seats that represent a forgone opportunity to earn revenue. However, filling an entire aircraft with passengers paying such a low fare to avoid empty seats is neither desirable, nor will it cover the operating costs of the aircraft (38). Filling a seat with a low-fare passenger when it could have been filled by a passenger willing to pay a higher fare also represents a lost opportunity to earn revenue. "Yield management" is the complex way in which airlines determine how many blocks of seating on each flight to offer at each fare in order avoid the twin pitfalls of lost revenue-earning opportunities (i.e., in economic terms, airlines practice "price discrimination" (59)). Because of yield management, it would be difficult to reliably determine the "average fare" on a specific route without obtaining airline and route specific data on realized per unit revenues.

Other factors contribute to the complexity of yield management. Two routes of similar length (and presumably similar unit costs) may realize dramatically different average fares due to characteristics of the routes. As discussed above, perhaps the most important factor is the

not directly comparable. In addition, while the discussion above is in the context of passenger airline service, even airlines offering primarily passenger service generate significant revenues from cargo service (15). Impacts on cargo service should be included in the economic analysis.

existence of or lack of competition on a route. It has been documented in numerous studies that average fares on routes without competition between major passenger airlines are substantially higher than average fares on routes with competition (15, 35, 50, 60). Second, the type of traffic on a route will affect average fares; the demand for vacation travel is much more price-elastic than business travel, which limits the ability of airlines to increase fares on routes dominated by vacationers (35, 59). Finally, airlines judge the viability of routes based on how they fit in their overall route structure. What is considered an acceptable spread between unit costs and revenues on one route may not be acceptable on another depending on the importance of the route within the overall scheme of the airline's system (39).

Other things constant, increased deicing costs, regardless of whether they are incurred indirectly through increased landing fees or directly through increased deicing costs, will decrease the airlines' margin between per unit cost and revenue. If a route is already operated on a slim margin, then the increased costs of deicing may be sufficient for an airline to reduce or terminate service (15); these are potentially the major impacts of an effluent guideline on the industry. In addition, passengers will most likely have to pay higher fares, in some cases for lower quality service (i.e., less frequent service, or a downgrade from jet to turboprop service). Finally, reduced or terminated service will indirectly affect airport revenues and employment even if the airport is unlikely to close. All these impacts would have to be evaluated.

To properly assess potential regulatory impacts, EPA would need airline-specific data concerning unit costs and revenues of routes using each airport, for each airline using that airport. To perform a systematic airport-specific modeling effort would likely require a very large data-collection effort. EPA identified 212 airports with potentially significant deicing/anti-icing operations. There are 13 major airlines, plus approximately another 85 national, regional, and small certificated/commuter airlines with thousands of routes.

One potential solution to this data problem would be to focus analysis on a small number of representative airports using the classification system based on operations and weather developed for this study. By focusing on a small number of airports, EPA could hopefully obtain

more detailed information on airline routes using that airport (e.g., number of flights with yield and per unit cost figures and type of aircraft used – the larger the aircraft the higher the landing fee) to model impacts on airline service to that airport. Under this modeling strategy, EPA may also have to estimate incremental compliance costs at other airports on that route (i.e., some routes may incur increased compliance costs at both airports on a route, Boston-to-Chicago for example, while other routes would likely incur costs only at one end, Chicago-to-Orlando for example).³¹

An alternate approach to analyzing route costs and revenues may also be viable. DOT maintains databases containing data on passengers fares and distances by city origin-destination pairs that may be usable for determining airline route revenues. DOT does not maintain similar information for operating costs between city pairs; however, one article has been identified that estimates airline unit costs by length of flight based on DOT's Domestic Fare Structure Costing Program (Version 6) using publicly available information (58). This may provide EPA with a template for performing similar calculations. Note that neither the accuracy of this methodology nor the availability of DOT's cost model have yet been determined.

14.2.5.2 Airline-to-Passenger Cost Pass-Through

Cost pass-through (CPT) from airports to airlines is discussed in Section 14.1.2.3. However, a second form of CPT needs to be considered: CPT to airline passengers. This can take three forms: passengers may incur direct CPT from airports (e.g., increased parking fees or passenger facility charges), indirect CPT from airports through airlines (i.e., higher landing fees due to ADF collection, containment, or treatment leading to increased ticket prices), and airlines may directly incur higher deicing operation costs (e.g., higher ADF costs) that are also passed through to passengers in the form of higher ticket prices. The second and third types of CPT are analytically similar.

³¹ An opinion article by Robert Bork in the *Wall Street Journal*, and the subsequent rejoinders by Gerald Smith and Alfred Kahn concerning the U.S. Justice Department's antitrust case against American Airlines illustrate the difficulty of accurately allocating costs among airline's routes (54, 61, 62).

Airports directly pass through capital costs to passengers in the form of passenger facility charges (PFCs). Because the PFC is collected as part of the ticket cost, the passenger probably does not distinguish between an increase in travel price caused by the PFC and an increase in travel price caused by an airline fare increase. However, if an airport incurs compliance costs that are not passed on to airlines in the form of higher landing fees, but instead pays for improvements through imposing or increasing PFCs, passengers still pay higher ticket prices.³² Airports can also increase revenues through charges on concessions, parking, and other fees. Because passengers are better able to avoid paying these higher fees by choosing not to park at the airport or not buying items at airport concession stands, CPT from this source may be small. The link between these increased costs of air travel and demand for air travel has not been examined.³³

CPT from the airlines to their passengers is conceptually easier to estimate. In a simple market transaction, CPT is determined by the relative price elasticity of supply and demand. However, airlines are able to charge different prices to different types of passengers precisely because different types of travelers have different price elasticities of demand. As previously mentioned, business travelers have fairly inelastic demand, which enables airlines to increase their fares more with little loss in travel. CPT for business travelers should therefore be larger than for vacation travelers with much more elastic demand. The difficulty in applying this to specific airline routes is that different routes are likely to carry different mixes of passengers thus affecting the CPT for that route.

³² As of calendar year 1996, 54 of 71 large and medium hubs had already imposed PFCs (ACAIS, 1997); however, there has been discussion of increasing the maximum PFC to \$4 or even \$6 (63). Should this happen, incremental increases in PFCs – if they can be attributed to deicing operation costs, and not other capital programs – would be part of the regulatory impact on consumers.

³³ Compliance costs incurred by airports and not passed through to airlines in the form of higher landing fees may still have impacts, although they may be more difficult to assess. In general, many airports do not have sufficient access to capital to pay for existing improvement and expansion plans; by not passing compliance costs through to airlines, an airport probably is paying for improvements by postponing other capital improvements. The impact of postponed or displaced capital improvements may be difficult to assess, but nonetheless could still potentially result from airport deicing operations effluent guidelines. For example, a number of airports are facing capacity constraints; the potential impact of postponed airport expansion plans, such as slower growth and higher fares, could be substantial, even though they may be difficult to quantify.

An assumption of 100% CPT from airports to airlines and zero CPT from airlines to passengers would be the most tractable to model, and would probably be the most conservative assumption as well. The maximum PFC at one airport probably represents a small percentage of the average airfare, and the majority of significant airports have already imposed PFCs. Thus, any incremental CPT from airports directly to passengers due to compliance with deicing operations effluent guidelines is likely to be small. The calculation of CPT from airlines to passengers is highly problematic because the relevant price elasticity of demand to determine CPT is route specific; the overall price elasticity of demand estimated by ATA provides little guidance in this case. The drawback of assuming 100% CPT from airports to airlines and zero CPT from airlines to passengers is that almost all projected impacts would be incurred by airlines. Even if the total dollar value of projected regulatory impacts is no higher under alternative assumptions about CPT, the distribution of impacts among airports, airlines, and passengers would differ.

14.2.5.3 Incentives

Both the airlines and the FAA have expressed their opinion that any proposed EPA effluent guidelines regulating discharges from airport deicing operations must not affect aircraft safety (i.e., the decision to deice aircraft and how much fluid to use). They are concerned that effluent guidelines potentially limiting the discharges of wastewater containing deicing agents may increase the cost of deicing operations and create an incentive for airlines to find ways to decrease the quantity of deicing agents used and deicing operations performed. However, this is unlikely due to the large liability surrounding air safety. The liability lies with the airline to ensure that an increase in the cost of deicing does not affect a pilot's decision to deice and judgement as to whether sufficient deicing has been performed.

However, a likely scenario may be that any compliance costs would be passed on to the airlines in the form of higher landing fees on all flights, not just those flights requiring deicing.³⁴ There should be no incentive for airlines to change their deicing decisions under such a

³⁴ Note that at least one airport in Canada has implemented a deicing surcharge on all flights.

scenario. It is the cost of using the airport regardless of whether deicing is performed or not that would increase. This could lead to a reduction or termination of service at the airport (although the extent to which costs are spread over all landings at the airport may help to mitigate those impacts), but should not affect the deicing decision.

14.3 **References**

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Table 14-1**Passenger and Cargo Activity by FAA Airport Definition, 1997**

Airport Type	FAA Airport Definitions Based on Percentage of National Boardings (Brd)	Number of Airports by Type	Passenger Activity				Cargo-Only Activity (a)	
			Total Boardings by Type	Average Boardings by Type	Maximum Boardings by Type	Minimum Boardings by Type	Number of Airports (b)	Total Gross Landed Weight of Cargo
Primary, Large Hub % of total	1% <= Brd	30	439,556,180 68.6%	14,651,873	33,249,963	6,467,195	28	53,580,799,092
Primary, Medium Hub % of total	0.25% <= Brd <1%	40	132,472,093 20.7%	3,311,802	6,318,523	1,634,578	29	53,966,253,749
Primary, Small Hub % of total	0.05% <= Brd < 0.25%	71	46,968,440 7.3%	661,527	1,553,700	324,521	34	19,371,974,805
Primary, Nonhub % of total	10,000 < Brd < 0.05%	276	21,191,850 3.3%	76,782	317,199	10,019	9	3,119,938,255
Nonprimary Commercial Service (c) % of total	2,500 <= Brd <= 10,000	112	550,755 0.1%	4,917	9,724	2,509	2	1,593,027,497
Noncommercial Service % of total	NA	1,186	824,388 0.1%	695	81,416	0	4	1,588,610,350
Total		1,715	641,563,706				106	133,220,603,748

(a) Data for “qualifying” airports only-those airports that land a minimum of 100 million pounds of cargo-only aircraft; other airports may land cargo-only aircraft. Gross landed weight cargo refers to the rated landing weight of the aircraft, not the weight of the cargo carried in the aircraft.

(b) Number of airports within FAA type landing at least 100 million pounds of cargo-only aircraft in addition to their passenger activities (e.g., there are 30 large hubs based on passenger activity; 28 of these large hubs also qualified as significant cargo-only airports).

(c) Noncommercial service airports reporting boarding activity in the ACAIS database; the NPIAS contains over 2,800 noncommercial service airports.

Source: Reference (4).

Table 14-2

Growth of Total and Average Enplanements at Commercial Service Airports by FAA Definition, 1993 - 1997

Passenger Enplanements						Enplanement Growth Rates					
Year	1993	1994	1995	1996	1997	1993	1994	1995	1996	1997	Average
Total Boardings (a)	528,920,496	573,575,959	586,326,851	621,613,161	641,563,706	NA	8.4%	2.2%	6.0%	3.2%	5.3%
Total Enplanements # of Airports	527,984,216 566	572,608,645 575	585,347,291 566	620,410,923 540	640,739,318 529	NA	8.5%	2.2%	6.0%	3.3%	5.3%
Total Enplanements by Airport Type						Growth Rates, Total Enplanements					
Large Hub Primary # of Airports	341,729,124 27	380,292,229 29	393,110,251 29	418,425,819 29	439,556,180 30	NA	11.3%	3.4%	6.4%	5.0%	7.2%
Medium Hub Primary # of Airports	118,290,399 38	126,220,983 40	129,792,590 42	137,813,925 42	132,472,093 40	NA	6.7%	2.8%	6.2%	-3.9%	3.0%
Small Hub Primary # of Airports	49,045,057 83	44,941,969 71	41,489,614 67	43,807,189 70	46,968,440 71	NA	-8.4%	-7.7%	5.6%	7.2%	-1.1%
Nonhub Primary # of Airports	18,193,093 269	20,396,930 281	20,197,540 273	19,748,437 272	21,191,850 276	NA	12.1%	-1.0%	-2.2%	7.3%	4.1%
Nonprimary # of Airports	726,543 149	756,534 154	757,296 155	615,553 127	550,755 112	NA	4.1%	0.1%	-18.7%	-10.5%	-6.0%
Average Enplanements by Airport Type						Growth rates, Average Enplanements					
Large Hub Primary	12,656,634	13,113,525	13,555,526	14,428,477	14,651,873	NA	3.6%	3.4%	6.4%	1.5%	3.9%
Medium Hub Primary	3,112,905	3,155,525	3,090,300	3,281,284	3,311,802	NA	1.4%	-2.1%	6.2%	0.9%	1.6%
Small Hub Primary	590,904	632,985	619,248	625,817	661,527	NA	7.1%	-2.2%	1.1%	5.7%	3.0%
Nonhub Primary	67,632	72,587	73,984	72,605	76,782	NA	7.3%	1.9%	-1.9%	5.8%	3.4%
Nonprimary	4,876	4,913	4,886	4,847	4,917	NA	0.7%	-0.5%	-0.8%	1.5%	0.2%

(a) Total boardings include revenue passenger boardings at noncommercial service airports; the difference between total boardings and total enplanements is small.

Average enplanements for all commercial service airports are not included because in this case; when both the numerator and denominator change, the estimate of growth is both deceptive and irrelevant.

Source: Reference (4).

Table 14-3**Airport Flight Operations by FAA Airport Definition, 1997**

Airport Type	Number of Airports by FAA Definition	Number of Airports Reporting Operations	Non-GA Operations Activity by Airport Definition				Average Operations by Aircraft Type and Airport Definition			
			Total Operations	Average Operations	Maximum Operations	Minimum Operations	Carrier	Air Taxi	Military	GA
Primary, Large Hub % of total	30	30	12,920,538 48.0%	430,685	847,901	209,827	306,706	119,661	4,317	44,424
Primary, Medium Hub % of total	40	40	5,592,685 20.8%	139,817	311,088	33,863	86,740	45,926	7,152	82,126
Primary, Small Hub % of total	71	70	3,967,527 14.7%	56,679	170,446	5,248	18,501	27,871	10,307	76,084
Primary, Nonhub % of total	276	157	3,423,075 12.7%	21,803	107,481	3,160	2,139	13,925	5,739	54,319
Nonprimary, Commercial Service % of total	112	11	171,669 0.6%	15,606	59,783	3,289	2,055	7,822	5,729	104,108
Noncommercial Service % of total	NA	110	830,379 3.1%	7,549	105,774	23	185	3,690	3,674	125,831
Total		418	26,905,873							

Based on 418 airports reporting operations data and contained in ACAIS database; operations data for the 4/1/97 - 3/31/98 time period, enplanements data for CY 1997.

Non-GA operations equals the sum of carrier, air taxi, and military operations.

Source: Reference (4, 7).

Table 14-4**Airports of Concern, by Operations, Snowfall, and FAA Size Definitions (a)**

Snowfall Categorization	FAA Definition	Operations Categorization (b)					Subtotal by Snowfall
		Ops "A"	Ops "B"	Ops "C"	Ops "D"	Ops "E"	
60" <= snow < 120"	Large Hub	1	0	0	0	0	1
	Medium Hub	0	1	0	0	0	1
	Small Hub	0	0	2	8	3	13
	Nonhub	0	0	0	0	14	14
	Nonprimary	0	0	0	0	0	0
	Noncomm. Svc.	0	0	0	0	3	3
	Subtotal	1	1	2	8	20	32
30" <= snow < 60"	Large Hub	5	1	0	0	0	6
	Medium Hub	0	1	3	2	0	6
	Small Hub	0	0	0	4	8	12
	Nonhub	0	0	0	1	31	32
	Nonprimary	0	0	0	0	1	1
	Noncomm. Svc.	0	0	0	0	5	5
	Subtotal	5	2	3	7	45	62
15" <= snow < 30"	Large Hub	2	7	0	0	0	9
	Medium Hub	0	0	5	1	0	6
	Small Hub	0	0	0	3	7	10
	Nonhub	0	0	1	1	22	24
	Nonprimary	0	0	0	0	1	1
	Noncomm. Svc.	0	0	1	0	4	5
	Subtotal	2	7	7	5	34	55
1" <= snow < 15"	Large Hub	2	3	0	0	0	5
	Medium Hub	0	2	5	3	0	10
	Small Hub	0	0	0	7	7	14
	Nonhub	0	0	0	3	25	28
	Nonprimary	0	0	0	1	2	3
	Noncomm. Svc.	0	0	0	0	2	2
	Subtotal	2	5	5	14	36	62
Subtotal by Ops	Large Hub	10	11	0	0	0	21
	Medium Hub	0	4	13	6	0	23
	Small Hub	0	0	2	22	25	49
	Nonhub	0	0	1	5	92	98
	Nonprimary	0	0	0	1	4	5
	Noncomm. Svc.	0	0	1	0	14	15
	Subtotal	10	15	17	34	135	211

(a) EPA identified 212 airports of concern based on snowfall and aircraft operations criteria; this analysis is based on 211 airports for which operations, snowfall, and 1997 ACAIS enplanement data could be matched.

(b) Ops "A": 425,000 <= Ops < 850,000; Ops "B": 210,000 <= Ops < 425,000; Ops "C": 100,000 <= Ops < 210,000; Ops "D": 50,000 <= Ops < 100,000; Ops "E": 10,000 <= Ops < 50,000.

Source: Reference (4, 7, 8).

Table 14-5**Airports with Potentially Significant Deicing Operations, by Operations and Enplanements (a)**

Operations (Ops) Categorization	Number of Airports	Average Operations within Airport Ops Class				Average Enplanements within Airport Class			
		Non-GA Operations	Carrier Operations	Air Taxi Operations	GA Operations	All	Large Carrier	Commuter	Air Taxi
425,000 <= Ops < 850,000	10	567,680	417,349	147,917	43,510	19,296,737	18,303,408	438,088	98
210,000 <= Ops < 425,000	15	320,679	204,549	111,314	49,822	8,991,676	7,896,227	564,009	2,812
100,000 <= Ops < 210,000	17	144,138	71,601	59,534	54,223	2,574,169	2,431,328	124,987	11,571
50,000 <= Ops < 100,000	34	74,236	28,037	33,253	76,477	962,463	854,836	92,478	5,330
10,000 <= Ops < 50,000	135	24,685	4,749	14,037	65,254	168,282	131,397	36,679	189
Total Airports of Concern	211								

(a) EPA identified 212 airports with potentially significant deicing operations based on snowfall and aircraft operations criteria; this analysis is based on 211 airports for which operations, snowfall, and 1997 ACAIS enplanement data could be matched.

Source: Reference (4, 7).

Table 14-6

**Airport Operating Agreements by Airport Type
AAAE Survey Respondents, 1997 - 1998**

Airport Type	Number of Respondents by Type	Type of Agreement			
		Residual	Compensatory	Hybrid	Other
Large Hub	18	4	5	6	3
Medium Hub	28	14	5	8	2
Small Hub	53	17	16	16	4
Nonhub	96	11	48	20	17
General Aviation					
Total	195	46	74	50	26

Source: Reference (12).

Table 14-7**Airport Revenues by Airport Type for AAAE Survey Respondents, 1997 - 1998**

Airport Type	Number of Respondent s by Type	Average Airline and Air Cargo Revenues	Average FBO/GA Revenues	Average Total Other Revenues	Average Total Operating Revenues	Average Total Operating Expenses	Average Total Government Subsidy	Average Total Operating Income
Large Hub % of total revenues	15	\$100,295,007 50%	\$5,160,219 3%	\$94,381,574 47%	\$200,090,311	\$106,506,742	\$0	\$93,583,569
Medium Hub % of total revenues	27	\$14,969,744 39%	\$1,840,125 5%	\$19,497,502 51%	\$38,039,780	\$22,145,663	\$177,642	\$16,071,759
Small Hub % of total revenues	49	\$3,295,032 41%	\$842,245 10%	\$4,304,924 53%	\$8,117,894	\$5,916,717	\$338,164	\$2,539,341
Nonhub % of total revenues	91	\$418,198 27%	\$358,565 23%	\$735,206 47%	\$1,551,172	\$1,463,673	\$221,324	\$308,823
General Aviation % of total revenues	92	\$37,554 4%	\$506,232 58%	\$264,471 31%	\$865,988	\$938,491	\$218,829	\$146,327
Total	274	\$119,015,535	\$8,707,385	\$119,183,677	\$248,665,145	\$136,971,286	\$955,959	\$112,649,818

Source: Reference (12).

Table 14-8**Airport Expenditures for EPA Airport Mini-Questionnaire Recipients, 1997**

	Large Hubs			Medium Hubs		Small Hubs	Primary Commercial Service Nonhubs			
	Airport #1	Airport # 2	Airport # 3	Airport # 4	Airport # 5	Airport # 6	Airport # 7	Airport # 8	Airport # 9	Airport #10
Enplanements	16,600,000	15,400,000	12,100,000	5,710,000	2,640,000	818,000	303,000	120,000	64,500	26,700
Non-GA Operations	476,000	445,000	381,000	278,000	214,000	67,000	41,800	21,500	13,400	44,400
Airfield Areas	4.0%	30.0%	13.0%	10.0%	22.6%	21.1%	32.0%	16.0%	3.2%	20.0%
Terminal Areas	16.0%	30.0%	32.0%	20.0%	24.8%	17.0%	20.0%	9.0%	5.9%	13.0%
Hangars, cargo facilities, and other areas	1.0%	(a)	1.0%	5.0%	3.2%	7.1%	7.0%	6.0%	1.2%	9.0%
General and Administrative	9.0%	20.0%	6.0%	24.0%	8.4%	12.6%	16.0%	20.0%	8.3%	20.0%
Other Agencies (b)	3.0%	0.0%	0.0%	6.0%	1.7%	10.5%	2.0%	0.0%	8.7%	0.0%
Debt Service	46.0%	20.0%	29.0%	35.0%	11.6%	13.0%	23.0%	0.0%	2.0%	0.0%
Depreciation	21.0%	(a)	18.0%	NA	27.7%	18.7%	0.0%	49.0%	6.6%	38.0%
Total	100.0%	100.0%	99.0%	100.0%	100.0%	100.0%	100.0%	100.0%	35.9%	100.0%

(a) Combined with previous answer.

(b) Payments to other agencies for services performed at airport (e.g., police, fire, accounting, legal).

Source: Reference (13).

Table 14-9

**Airport Ownership by Airport Type
AAAE Survey Respondents, 1997 - 1998**

Airport Type	Number of Respondents by Type	Type of Ownership			
		Municipal	Multi-government	Independent Authority	Other
Large Hub	18	10	4	2	2
Medium Hub	31	17	2	8	3
Small Hub	53	34	1	17	1
Nonhub	108	56	8	37	7
General Aviation	130	92	4	23	11
Total	340	209	19	87	24

Source: Reference (12)

Table 14-10**Airport Capital Expenditures for EPA Airport Minisurvey Recipients, 1997**

	Large Hubs			Medium Hubs		Small Hubs	Primary Commercial Service Nonhubs			
	Airport #1	Airport #2	Airport #3	Airport #4	Airport #5	Airport #6	Airport #7	Airport #8	Airport #9	Airport #10
Enplanements	16,600,000	15,400,000	12,100,000	5,710,000	2,640,000	818,000	303,000	120,000	64,500	26,700
Non-GA Operations	476,000	445,000	381,000	278,000	214,000	67,000	41,800	21,500	13,400	44,400
Capital Expenditures	\$55,423	\$537,000	\$109,153	\$69,600,000	\$28,125	\$12,000	\$2,756	\$1,418	\$1,452,196	\$341
Airport Improvement Grants	25.7%	9.0%	19.5%	4.0%	14.4%	28.0%	67.0%	75.0%	89.3%	90.0%
Passenger Facility Charges	33.7%	40.0%	18.8%	13.0%	0.0%	15.0%	18.0%	10.0%	8.3%	5.0%
Other Government Grants	0.0%	0.0%	0.0%	0.0%	7.7%	0.0%	0.0%	10.0%	2.4%	0.0%
Bonds	33.1%	51.0%	40.9%	80.0%	60.1%	23.0%	0.0%	0.0%	0.0%	0.0%
Rates and Charges	7.5%	(c)	12.9%	3.0%	17.7%	28.0%	15.0%	5.0%	0.0%	5.0%
Other Revenue	0.0%	(c)	8.0%	0.0%	0.0%	6.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.1%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%
Majority-in-Interest Clause	No	No	Yes	Yes	Yes	No	No (b)	No	No	No

(a) Only airport in sample not charging a PFC, but has applied to start charging a PFC in 2000; all other airports in sample charge maximum PFC (\$3).

(b) No majority-in-interest clause, but does have a contractual ceiling on capital expenditures.

(c) Combined with previous answer.

Source: Reference (13).

Table 14-11

**Aircraft in Operation, Hours Flown, and Hours per Aircraft,
Selected Aircraft Type, U.S. Air Carriers, and General Aviation, 1996**

Aircraft Type	Number of Aircraft	Total Flight Hours	Hours per Aircraft
Air Carriers			
Total	7,478	14,784,409	1,977
4-Engine Turbojet % of Total	440 5.9%	934,572 6.3%	2,124
3-Engine Turbojet % of Total	1,212 16.2%	2,378,145 16.1%	1,962
2-Engine Turbojet (a) % of Total	3,270 43.7%	8,715,239 58.9%	2,665
2-Engine Turboprop % of Total	1,639 21.9%	2,602,374 17.6%	1,588
General Aviation (b)			
Total (Fixed-wing)	160,577	22,719,550	141
2-Engine Turbojet % of Total	3,971 2.5%	1,355,034 6.0%	341
2-Engine Turboprop % of Total	4,551 2.8%	1,243,572 5.5%	273
1-Engine Piston % of Total	150,980 94.0%	17,156,396 75.5%	114

(a) All but 216 air carrier twin engine turbojets carry a minimum of 100 passengers.

(b) Includes "on demand" air taxis, but excludes commuter aircraft; see text for further details.

Source: Reference (27).

Table 14-12**Air-Carrier Traffic Statistics by Carrier Type, June 1997 - June 1998**

Carrier	Number	Passenger Enplanements (x 1,000)	Cargo Ton-miles (x 1,000)	Revenue Passenger-miles (x 1,000)	Available Seat-miles (x 1,000)	Load Factor (%)	Passengers per Aircraft-mile	Miles per Passenger
Major % of Total	13 9.0%	534,040 83.4%	18,491,148 87.7%	573,632,137 92.2%	807,270,192 91.2%	71.1%	112.6	1,074.1
National % of Total	28 19.4%	62,605 9.8%	2,390,465 11.3%	35,052,261 5.6%	53,843,361 6.1%	65.1%	63.2	559.9
Large Regional % of Total	15 10.4%	7,768 1.2%	199,559 0.9%	4,066,632 0.7%	6,490,996 0.7%	62.7%	46.0	523.5
Medium Regional (a) % of Total	88 61.1%	36,288 5.7%	13,937 0.1%	9,238,469 1.5%	17,886,124 2.0%	51.7%	16.4	254.6
Total	144 100%	640,701 100%	21,095,109 100%	621,989,499 100%	885,490,673 100%	70.2%	98.7	970.8

(a) Including small certificated carriers.

Source: Reference (31).

Table 14-13**Air-Carrier Financial Statistics by Carrier Type, June 1997 - June 1998**

Carrier	Total Passenger Revenues (x \$1,000,000)	Total Operating Revenues (x \$1,000,000)	Total Operating Expenses (x \$1,000,000)	Operating Profit (Loss) (x \$1,000,000)	Operating Profit Margin (%)	Net Income(a) (x \$1,000,000)	Net Profit Margin (%)
Major % of Total	\$74,336.4 88.6%	\$100,506.2 86.6%	\$91,436.0 85.9%	\$9,070.2 94.8%	9.0%	\$5,821.6 101.5%	5.8%
National % of Total	\$5,756.0 6.9%	\$9,837.7 8.5%	\$9,454.8 8.9%	\$382.9 4.0%	3.9%	(\$16.7) -0.3%	-0.2%
Large Regional % of Total	\$636.7 0.8%	\$1,706.3 1.5%	\$1,686.7 1.6%	\$19.6 0.2%	1.1%	(\$56.5) -1.0%	-3.3%
Medium Regional % of Total	\$62.5 0.1%	\$286.5 0.2%	\$317.8 0.3%	(\$31.3) -0.3%	-10.9%	(\$36.0) -0.6%	-12.6%
Small Certificated % of Total	\$2,123.2 2.5%	\$2,417.8 2.1%	\$2,276.1 2.1%	\$141.7 1.5%	5.9%	\$41.5 0.7%	1.7%
Commuter % of Total	\$1,029.8 1.2%	\$1,267.3 1.1%	\$1,278.4 1.2%	(\$11.1) -0.1%	-0.9%	(\$18.5) -0.3%	-1.5%
Total	\$83,944.6 100.0%	\$116,021.8 100.0%	\$106,449.8 100.0%	\$9,572.0 100.0%	8.3%	\$5,735.4 100.0%	4.9%

(a) Operating profit calculates profit before tax and interest payments; net profits are calculated after taxes and interest.

Source: Reference (29).

Table 14-14

Passenger and Cargo Revenues for ATA Member Airlines, 1997
(x \$1,000,000)

Airline	Number of Aircraft	Employees (FTEs)	Passenger Revenues	Cargo Revenues	Total Operating Revenues	% Passenger Revenues
Majors with Passenger Service						
Alaska	78	8,016	\$1,256	\$82	\$1,457	86.2%
America West	103	10,195	\$1,753	\$51	\$1,887	92.9%
American	641	80,321	\$14,284	\$678	\$15,856	90.1%
Continental	388	31,705	\$5,686	\$205	\$6,361	89.4%
Delta	559	62,934	\$12,773	\$588	\$14,204	89.9%
Northwest	405	46,753	\$8,722	\$788	\$9,984	87.4%
Southwest	261	23,749	\$3,639	\$95	\$3,817	95.3%
Trans World	184	22,930	\$2,924	\$119	\$3,328	87.9%
United	571	83,324	\$15,069	\$891	\$17,335	86.9%
U.S. Airways	376	39,734	\$7,112	\$177	\$8,501	83.7%
Majors with Cargo-only Service						
DHL	27	8,564	—	\$664	\$1,226	0.0%
Federal Express	581	105,649	—	\$5,360	\$12,730	0.0%
United Parcel Service (a)	214	4,349	—	\$404	\$1,863	0.0%
Nationals with Passenger Service						
Aloha	17	1,901	\$195	\$30	\$233	83.7%
Hawaiian	22	2,357	\$332	\$20	\$404	82.2%
Midwest Express	24	1,689	\$273	\$11	\$310	88.0%
Nationals with Cargo-only Service						
Airborne Express	105	4,626	—	\$890	\$894	0.0%
Atlas (a)	19	592	—	\$80	\$401	0.0%
Emery (a)	77	967	—	\$256	\$262	0.0%
Evergreen (a)	20	429	—	\$208	\$256	0.0%
Polar Air Cargo	16	481	—	\$288	\$344	0.0%

Excludes members: American Trans Air and Reeve, due to data questions, and 3 non-U.S.-owned associate members.

(a) Includes nonscheduled service.

Source: Reference (34).

Table 14-15

Operating Revenues, Expenses, and Profits, 1982 - 1997
(in millions of dollars)

Year	Revenue Passenger Miles (x 1,000,000)	Total Op. Revenues	Total Op. Expenses	Total Op. Profits	Interest Expense	Net Profit	Operating Profit Margin	Net Profit Margin	Rate of Return on Investment
1982	259,644	\$36,408	\$37,141	(\$733)	\$1,384	(\$916)	-2.0%	-2.5%	2.1%
1983	281,829	\$38,954	\$38,643	\$310	\$1,482	(\$188)	0.8%	-0.5%	6.0%
1984	305,116	\$43,825	\$41,674	\$2,152	\$1,540	\$825	4.9%	1.9%	9.9%
1985	336,403	\$46,664	\$45,238	\$1,426	\$1,588	\$863	3.1%	1.8%	9.6%
1986	366,546	\$50,525	\$49,202	\$1,323	\$1,693	(\$235)	2.6%	-0.5%	4.9%
1987	404,471	\$56,986	\$54,517	\$2,469	\$1,695	\$593	4.3%	1.0%	7.2%
1988	423,302	\$63,749	\$60,312	\$3,437	\$1,846	\$1,686	5.4%	2.6%	10.8%
1989	432,714	\$69,316	\$67,505	\$1,811	\$1,944	\$128	2.6%	0.2%	6.3%
1990	457,926	\$76,142	\$78,054	(\$1,912)	\$1,978	(\$3,921)	-2.5%	-5.1%	-6.0%
1991	447,955	\$75,158	\$76,943	(\$1,785)	\$1,777	(\$1,940)	-2.4%	-2.6%	-0.5%
1992	478,554	\$78,140	\$80,585	(\$2,444)	\$1,743	(\$4,791)	-3.1%	-6.1%	-9.3%
1993	489,684	\$84,559	\$83,121	\$1,438	\$2,027	(\$2,136)	1.7%	-2.5%	-0.4%
1994	519,382	\$88,313	\$85,600	\$2,713	\$2,347	(\$344)	3.1%	-0.4%	5.2%
1995	540,656	\$94,578	\$88,718	\$5,860	\$2,424	\$2,314	6.2%	2.4%	11.9%
1996	578,663	\$101,938	\$95,729	\$6,209	\$1,981	\$2,804	6.1%	2.8%	11.5%
1997	605,434	\$109,535	\$100,924	\$8,611	\$1,749	\$5,195	7.9%	4.7%	14.9%

Notes: Federal Express began reporting as a section 401 carrier in 1986 and is included in 1986 and later years.

Excludes fresh start accounting extraordinary gains of Continental and Trans World in 1993.

Source: References (33,34).

Table 14-16**Airline Operating Costs, Selected Components, 1982 - 1997**

Year	Labor			Fuel			Aircraft Fleet (a)			Interest			Insurance			Maintenance Material		
	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses
1982	100.0	—	34.6%	100.0	—	27.5%	100.0	—	5.6%	100.0	—	4.0%	100.0	—	0.4%	100.0	—	2.0%
1983	107.7	7.7%	35.5%	88.3	-11.7%	24.7%	107.5	7.5%	6.1%	99.0	-1.0%	4.1%	95.7	-4.3%	0.4%	101.7	1.7%	2.1%
1984	108.4	0.6%	33.9%	84.6	-4.2%	24.0%	114.9	6.9%	6.4%	106.3	7.4%	3.9%	109.3	14.2%	0.5%	108.2	6.4%	2.3%
1985	110.6	2.0%	33.8%	79.6	-5.9%	22.3%	123.7	7.7%	6.8%	98.0	-7.8%	3.5%	155.3	42.1%	0.6%	119.9	10.8%	2.5%
1986	108.1	-2.3%	35.8%	55.5	-30.3%	15.5%	127.8	3.3%	7.4%	91.8	-6.3%	3.5%	212.0	36.5%	0.9%	147.7	23.2%	3.2%
1987	110.8	2.5%	34.7%	55.4	-0.2%	15.0%	135.1	5.7%	7.4%	88.7	-3.4%	3.2%	201.8	-4.8%	0.8%	153.1	3.7%	3.2%
1988	113.9	2.8%	34.2%	53.0	-4.3%	13.5%	146.9	8.7%	7.9%	91.9	3.6%	3.1%	151.7	-24.8%	0.6%	166.4	8.7%	3.3%
1989	117.4	3.1%	33.9%	59.7	12.6%	13.9%	162.2	10.4%	8.0%	99.4	8.2%	2.7%	114.5	-24.5%	0.4%	176.8	6.3%	3.2%
1990	123.0	4.8%	31.5%	77.2	29.3%	17.3%	177.0	9.1%	7.9%	96.0	-3.4%	2.6%	68.2	-40.4%	0.3%	190.5	7.7%	3.4%
1991	130.1	5.8%	32.4%	69.4	-10.1%	14.5%	187.1	5.7%	8.5%	81.4	-15.2%	2.4%	81.3	19.2%	0.3%	193.2	1.4%	3.3%
1992	136.5	4.9%	32.8%	65.0	-6.3%	13.5%	202.6	8.3%	9.0%	97.3	19.5%	2.2%	109.3	34.4%	0.4%	177.1	-8.3%	3.0%
1993	143.4	5.1%	33.3%	59.7	-8.2%	12.4%	208.0	2.7%	9.2%	81.2	-16.5%	2.6%	139.4	27.5%	0.5%	166.2	-6.2%	2.9%
1994	148.5	3.6%	34.1%	54.4	-8.9%	10.7%	217.5	4.6%	9.5%	87.6	7.9%	2.8%	110.8	-20.5%	0.7%	157.2	-5.4%	2.6%
1995	155.5	4.7%	34.4%	55.3	1.7%	11.5%	222.8	2.4%	9.5%	93.5	6.7%	3.0%	111.6	0.7%	0.7%	153.4	-2.4%	2.7%
1996	159.5	2.6%	33.6%	64.6	16.8%	13.0%	230.0	3.2%	9.6%	86.9	-7.1%	2.2%	111.5	-0.1%	0.7%	169.4	10.4%	2.9%
1997	162.4	1.8%	33.9%	62.7	-2.9%	12.5%	224.1	-2.6%	9.0%	72.1	-17.0%	1.8%	95.4	-14.4%	0.6%	191.2	12.9%	3.2%

(a) Passenger airlines only; includes lease, aircraft, and engine rentals, depreciation, and amortization.

Table 14-16 (Continued)

Year	Landing Fees			Traffic Commission			Communications			Advertising & Promotion			Passenger Meals			Composite Cost Index	
	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate	% Op. Expenses	Cost Index (1982=100)	Growth Rate
1982	100.0	—	1.7%	100.0	—	5.9%	100.0	—	1.5%	100.0	—	2.2%	100.0	—	2.9%	100.0	—
1983	99.6	-0.4%	1.7%	104.4	4.4%	6.5%	98.7	-1.3%	1.5%	99.6	-0.4%	2.3%	101.4	1.4%	3.1%	101.1	1.1%
1984	101.0	1.4%	1.7%	113.9	9.1%	7.1%	98.4	-0.3%	1.5%	97.9	-1.7%	2.3%	104.7	3.3%	3.2%	102.5	1.4%
1985	99.9	-1.1%	1.6%	112.9	-0.9%	7.3%	96.6	-1.8%	1.6%	96.2	-1.7%	2.3%	98.9	-5.5%	3.2%	102.8	0.3%
1986	108.8	8.9%	1.8%	117.7	4.3%	8.1%	105.2	8.9%	1.8%	103.6	7.7%	2.5%	99.4	0.5%	3.4%	99.6	-3.1%
1987	117.7	8.2%	1.9%	126.3	7.3%	8.6%	98.2	-6.7%	1.6%	91.0	-12.2%	2.2%	102.5	3.1%	3.4%	101.9	2.3%
1988	124.8	6.0%	1.9%	145.4	15.1%	9.5%	109.0	11.0%	1.7%	97.1	6.7%	2.2%	108.6	6.0%	3.5%	105.9	3.9%
1989	130.5	4.6%	1.8%	157.7	8.5%	9.5%	111.8	2.6%	1.6%	103.2	6.3%	2.2%	118.8	9.4%	3.5%	112.3	6.0%
1990	139.0	6.5%	1.8%	169.2	7.3%	9.4%	111.2	-0.5%	1.4%	97.8	-5.2%	2.0%	128.4	8.1%	3.5%	122.6	9.2%
1991	153.4	10.4%	1.9%	188.1	11.2%	10.4%	116.6	4.9%	1.4%	89.9	-8.1%	1.8%	139.0	8.3%	3.8%	126.2	2.9%
1992	168.4	9.8%	2.1%	184.9	-1.7%	10.4%	124.5	6.8%	1.5%	81.1	-9.8%	1.7%	140.5	1.1%	3.9%	128.7	2.0%
1993	170.1	1.0%	2.1%	193.0	4.4%	10.9%	120.0	-3.6%	1.5%	72.4	-10.7%	1.5%	128.5	-8.5%	3.6%	130.5	1.4%
1994	171.6	0.9%	2.0%	163.3	-15.4%	9.6%	118.2	-1.5%	1.5%	69.7	-3.7%	1.5%	120.6	-6.1%	3.5%	129.9	-0.5%
1995	176.6	2.9%	2.2%	139.4	-14.6%	8.5%	116.0	-1.9%	1.5%	63.6	-8.8%	1.5%	110.9	-8.0%	3.3%	131.4	1.2%
1996	178.3	1.0%	2.1%	130.8	-6.2%	7.9%	114.8	-1.0%	1.5%	58.4	-8.2%	1.3%	104.0	-6.2%	3.1%	136.8	4.1%
1997	183.2	2.7%	2.0%	127.0	-2.9%	7.7%	110.4	-3.8%	1.4%	54.6	-6.5%	1.3%	102.9	-1.1%	3.1%	137.7	0.7%

Source: Reference (39).

Table 14-17**Estimated Deicing Costs and Weather Conditions at 5 Selected Airports**

Airport and Airport Characteristics	Deicing Season	Heating Degree Days	Days < 32° F	Snowfall (inches)	Deicing Season Departures	Reported Deicing Cost	Reported Deicing Cost per Departure
<u>Airport A</u>							
Northern Tier	1996-97	7,966	165	73.6	88,964	\$26,304,455	\$296
241,436 departures, 1998	1997-98	6,536	105	50.3	90,334	\$27,047,433	\$299
11 Major Carriers	1998-99	6,599	91	56.5	60,670	\$21,507,999	\$355
Operational Hub							
<u>Airport B</u>							
Northeastern Tier	1996-97	4,468	28	12.9	69,253	\$5,843,691	\$84
234,732 departures, 1998	1997-98	3,989	7	0.8	76,410	\$7,986,294	\$105
7 Major Carriers	1998-99	4,110	25	12.5	81,037	\$18,871,331	\$233
Operational Hub							
<u>Airport C</u>							
Semi-desert Climate	1996-97	1,545	5	0	25,518	\$166,211	\$7
136,673 departures, 1998	1997-98	1,527	0	0	23,272	\$148,712	\$6
9 Major Carriers	1998-99	1,162	2	0	22,979	\$182,253	\$8
Not an Operational Hub							
<u>Airport D</u>							
Southeastern Tier	1996-97	4,109	27	5.3	30,111	\$16,597,728	\$551
86,002 departures, 1998	1997-98	3,850	19	22.8	26,424	\$14,319,099	\$542
8 Passenger/2 Cargo Airline	1998-99	3,580	27	13.3	21,202	\$13,590,916	\$641
Cargo Operational Hub							
<u>Airport E</u>							
Western Arid Climate	1996-97	4,798	34	63.3	56,575	NA	NA
182,667 departures, 1998	1997-98	5,060	37	65.2	54,949	\$14,876,599	\$271
8 Passenger Airlines	1998-99	5,027	36	31.2	52,855	\$7,086,810	\$134
Operational Hub							

Source: Reference (41).

Table 14-18

National Estimate of Total Deicing Costs at US Airports, 1997 - 1998

Deicing Season	Deicing Cost Based on:			Deicing Cost Characteristics				
	HDD	Days <32° F	Snowfall	Average (a)	Total Op. Costs	Deicing as % of Op. Costs	Net Profits	Deicing as % of Net Profits
1996-97	\$548,974,570	\$537,591,582	\$411,725,552	\$543,283,076	\$95,729,000,000	0.57%	\$2,804,000,000	19.38%
1997-98	\$522,624,773	\$437,407,901	\$390,349,428	\$480,016,337	\$100,982,000,000	0.48%	\$5,170,000,000	9.28%
1998-99	\$506,479,210	\$482,485,870	\$415,862,888	\$494,482,540	\$104,034,000,000	0.48%	\$4,894,000,000	10.10%

(a)Average for HDD and Days < 32° F; snowfall excluded from the estimate because zero snowfall implies zero deicing costs, yet airlines do incur deicing costs even with zero snowfall.

Source: Reference (41).

15.0 GLOSSARY

AAAE - American Association of Airport Executives.

ACAIS - Air Carrier Activity Information System database.

ACI - NA - Airports Council International - North America.

Acute Exposure - Exposure to a chemical for short amount of time relative to the test species lifespan. It is often contrasted with chronic exposure.

Additive - A component of aircraft deicing/anti-icing fluids. Chemical additives along with ethylene glycol or propylene glycol are necessary to meet various performance standards. Additives can include flame retardants and corrosion inhibitors, surfactants, dyes, pH buffers, and 1,4-dioxane.

ADF-Contaminated Wastewater -Wastewater, runoff, or storm water that has come in contact with or contains propylene and/or ethylene glycol-based deicing/anti-icing fluids.

Air Carrier - Airlines holding a certificate issued under section 401 of the Federal Aviation Act of 1958 that operate aircraft designed to have a maximum seating capacity of more than 60 seats or a maximum payload capacity of more than 18,000 pounds, or conduct international operations. The four types of air carriers are: majors, nationals, large regionals, and medium regionals.

Aircraft Deicing/Anti-icing Fluid (ADF) - Fluids that are applied to aircraft surfaces to remove and/or prevent snow and ice accumulation. They must be approved by the Society of Automotive Engineers (SAE) and typically contain either ethylene glycol or propylene glycol, together with a suite of chemical additives to meet various performance standards. There are three types of ADFs currently in use in the U.S.: Type I, Type II, and Type IV. Type I is a deicing fluid and Types II and IV are anti-icing fluids. ADFs are applied to ensure that the freezing point of any water on aircraft remains at a temperature not greater than 20°F below the ambient air or aircraft surface temperature, whichever is lower (FAA Advisory Circular No. 20-117). All deicing fluids must lower the freezing point of water to -18°F or lower when applied.

Aircraft Site Identification Database - A database that contains information for 3,957 facilities that potentially perform aircraft exterior cleaning and/or aircraft or pavement deicing/anti-icing operations.

Airline - A business defined by the type of service it offers, annual revenues, and the type of aircraft used. All federal safety requirements are pegged to aircraft size.

Airport Improvement Program (AIP) - A program administered by the FAA whereby federal funds are dispersed for projects that will maintain current airport infrastructure and increase the capacity of facilities in order to commodate growing passenger and cargo traffic.

Airport Matrix - An EPA database designed for this study containing current information on all aspects of airfield pavement and aircraft deicing for the airports for which detailed information were obtained from EPA site visits or questionnaires.

Air Taxi - An aircraft designed to have a maximum seating capacity of 60 seats or less or a maximum payload capacity of 18,000 pounds or less carrying passengers or cargo for hire or compensation. (See Air Carrier.)

AMIL - Anti-Icing Materials Laboratory located at the University of Quebec, Chicoutimi, Canada.

AMS - Aerospace Material Specification.

Anti-icing Operations - The prevention of the accumulation of frost, snow, or ice on aircraft or pavement. These operations are typically discussed with deicing operations. There are two types of deicing/anti-icing operations: dry-weather and wet-weather.

ARP - Aerospace Recommended Practice.

ATA - Air Transport Association.

Biochemical Oxygen Demand (BOD₅) - Five-day biochemical oxygen demand. A measure of biochemical decomposition of organic matter in a water sample. It is determined by measuring the dissolved oxygen consumed by microorganisms to oxidize the organic matter in a water sample under standard laboratory conditions of five days and 20°C (see Method 405.1). BOD₅ is not related to the oxygen requirements in chemical combustion.

BTS - Bureau of Transportation Safety.

Calcium Magnesium Acetate (CMA) - A solid runway deicer/anti-icer.

Canadian Environmental Protection Act (CEPA) - A Canadian federal statute that provides the authority for the establishment of the Part IV Glycol Guidelines in 1994 which included a voluntary guideline recommending discharge limitations for glycol at Canadian federal airports.

Canadian Water Quality Guidelines for Glycol - Established a voluntary guideline in 1997 recommending safe environmental levels from the discharge of glycols into the environment.

Carcinogen - A chemical capable of inducing cancer.

Cargo - Anything other than passengers, carried for hire, including both mail and freight.

Cargo Carrier - Airlines that primarily carry cargo using aircraft called "freighters." Freighters are essentially passenger aircraft with all or nearly all of the passenger seats removed.

CFR - Code of Federal Regulations, published by the U.S. Government Printing Office. A codification of the general and permanent rules published by the Federal Register by the Executive departments and agencies of the federal government.

Chemical Oxygen Demand (COD) - A nonconventional, bulk parameter that measures the oxygen-consuming capacity of refractory organic and inorganic matter present in water or wastewater. COD is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test (see Methods 410.1 through 401.4).

Chronic Exposure - Exposure to a chemical for a long duration, relative to the test species lifespan. It is often contrasted with acute exposure.

Civil Landing Area - FAA-approved landing site for aircraft, helicopters, or seaplanes. Civil landing areas are not associated with military areas.

Commercial Service Airports - Public airports receiving scheduled passenger service and having 2,500 or more enplaned passengers per year. There are 538 commercial service airports in the U.S.

CERCLA - Comprehensive Environmental Response, Compensation and Liability Act.

CWA - Clean Water Act. The Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251 et seq.), as amended, inter alia, by the Clean Water Act of 1977 (Public Law 95-217) and the Water Quality Act of 1987 (Public Law 100-4).

Deicing Operations - The removal of frost, snow, or ice from aircraft or pavement. These operations are typically discussed with anti-icing operations. There are two types of deicing/anti-icing operations: dry-weather and wet-weather.

Developmental Toxicity - The occurrence of adverse effects on the developing organism that may result from exposure to a chemical prior to conception, during prenatal development, or postnatally to the time of sexual maturation. Adverse developmental effects may be detected at a point in the lifespan of the organism.

Direct Discharger - A facility that conveys or may convey untreated or facility-treated process wastewater or nonprocess wastewater directly into surface waters of the United States, such as rivers, lakes, or oceans. (See Surface Waters definition.)

Discharge - The conveyance of wastewater to: (1) United States surface waters such as rivers, lakes, and oceans, or (2) a publicly owned, federally owned, or other treatment works.

DO - Dissolved oxygen. The oxygen freely available in water, vital to fish and other aquatic life and for the prevention of odors. DO levels are considered a most important indicator of a water body's ability to support desirable aquatic life (see Methods 350.1 and 350.2).

Dry-Weather Deicing/Anti-icing - Also referred to as clear-ice deicing, may be performed whenever ambient temperatures are cold enough to form ice on aircraft wings (below 55°F). Dry-weather deicing/anti-icing is also used to defrost windshields and wingtips on commuter planes. May also be performed as necessary on some types of aircraft whose fuel tanks become super-cooled during high altitude flight, resulting in ice formation at lower altitudes and after landing. Dry-weather deicing is usually conducted throughout the entire deicing/anti-icing season.

EC - Environment Canada.

EC₅₀ - The median effective concentration. The concentration of a substance that causes a specified effect (generally sublethal rather than acutely lethal) in 50% of the test organisms.

Effluent - Wastewater discharges.

Effluent Limitation - Any restriction, including schedules of compliance, established by a state or the Administrator on quantities, rates, and concentrations of chemical, physical, biological, and other constituents that are discharged from point sources into navigable waters, the waters of the contiguous zone, or the ocean. (CWA Sections 301(b) and 304(b).)

Enplanements - The number of passengers boarding a flight.

EPA - The U.S. Environmental Protection Agency.

Ethylene Glycol - A commonly used freezing point depressant in aircraft deicing/anti-icing fluids and pavement deicers.

FAA - Federal Aviation Administration.

FDA - Food and Drug Administration.

FIFRA - Federal Insecticide, Fungicide, Rodenticide Act.

Fixed-Based Operators (FBOs) - Companies that have contracts with the airport authority/airlines to conduct business operations on airport property.

FR - Federal Register, published by the U.S. Government Printing Office, Washington, D.C. A publication making available to the public regulations and legal notices issued by federal agencies.

Freight - All air cargo excluding mail.

GAO - General Accounting Office.

General Aviation (GA) Airports - Airports that do not receive commercial service, have at least 10 locally owned aircraft, and are at least 20 miles from the nearest NPIAS airport.

General Aviation Operations - Takeoffs and landings of all civil aircraft, except those classified as air carriers or air taxis.

Glycol-Contaminated Wastewater - Wastewater, runoff, or storm water that has come in contact with or contains propylene and/or ethylene glycol-based deicing/anti-icing fluids.

GRAS - Generally Recognized as Safe.

HAP - Hazardous Air Pollutant.

Hexane Extractable Material (HEM) - A method-defined parameter that measures the presence of relatively nonvolatile hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases, and related materials that are extractable in the solvent n-hexane (see Method 1664). HEM has replaced the freon-based oil and grease method.

Holdover Time - The period of time when ice or snow is prevented from adhering to the surface of an aircraft (i.e., the amount of time between application and takeoff).

Hubs - A term used by the FAA to identify very busy commercial service airports.

Immunological Toxicity - The occurrence of adverse health effects on the immune system that may result from exposure to chemicals.

Indirect Discharger - A facility that discharges or may discharge pollutants into a publicly owned treatment works (POTW).

ISO - International Standards Organization.

Isopropanol - A freezing point depressant that may be used in aircraft or pavement deicing/anti-icing fluids.

Large Regional Carrier - A type of air carrier with annual operating revenues between \$20 million and \$100 million.

LC₅₀ - Concentration at which exposure for specific length of time is expected to cause death in 50% of a defined experimental population.

LD₅₀ - The dose of a chemical that has been calculated to cause death in 50% of a defined experimental population.

Lethal Dose - The lowest dose of a chemical introduced by a route other than inhalation that is expected to have caused death in humans or animals.

Lowest-Observed-Adverse-Effect Level (LOAEL) - The lowest dose of chemical in a study, or a group of studies, that produces statistically or biologically significant increases in frequency or severity of adverse effects between the exposed population and its appropriate control.

Major Carrier - A type of air carrier with annual operating revenues greater than \$1 billion.

MCL - Maximum Concentration Level.

MEBT - 5-methyl-1H-benzotriazole or TTZ or tolyltriazole.

Medium Regional Carrier - A type of air carrier with annual operating revenues between \$0 and \$20 million.

Military Operations - All classes of military operations at FAA air traffic facilities.

MIL-SPEC - Military performance specifications for aircraft and pavement deicers/anti-icers. Similar to SAE performance specifications.

Mutagen - A substance that causes mutations (i.e., a change in the genetic material in a body cell).

NASA - National Aeronautics and Space Administration.

National Carrier - A type of air carrier with annual operating revenues between \$100 million and \$1 billion.

National Plan of Integrated Airport Systems (NPIAS) - A plan submitted to Congress in accordance with Section 47103 of Title 49 of the United States Code. Identifies airports that are important to national transportation, and, therefore, eligible to receive grants under the Airport Improvement Program (AIP). Does not apply to stand-alone military airports.

NOI - Notice of Intent.

Nondetect Value - A concentration-based measurement reported below the sample-specific detection limit that can reliably be measured by the analytical method for the pollutant.

No-Observed-Adverse-Effect Level (NOAEL) - The dose of chemical at which there were no statistically or biologically significant increases in frequency or severity of adverse effects seen between the exposed population and its appropriate control. Effects may be produced at this dose, but they are not considered adverse.

Nonprimary Commercial Service Airports - Commercial service airports with less than 10,000 annual enplanements. There are 125 nonprimary commercial airports in the U.S.

NPDES - The National Pollutant Discharge Elimination System authorized under Sec. 402 of the CWA. NPDES requires permits for discharge of pollutants from any point source into waters of the United States.

NRDC - Natural Resources Defense Council.

Octanol-Water Partition Coefficient (K_{ow}) - The equilibrium ratio of the concentrations of a chemical in n-octanol and water, in dilute solution.

OECD - Organization for Economic Cooperation and Development.

Operational Hub - See Section 14.0 - but used to describe airlines main airport for connections in the hub & spoke system.

Pollution Prevention - The use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes. It includes practices that reduce the use of hazardous and nonhazardous materials, energy, water, or other resources, as well as those practices that protect natural resources through conservation or more efficient use. Pollution prevention consists of source reduction, in-process recycle and reuse, and water conservation practices.

Potassium Acetate - A liquid runway deicer.

POTW - Publicly owned treatment works, as defined at 40 CFR 403.3(o).

Primary Commercial Airports - Commercial service airports with more than 10,000 annual enplanements. There are 413 primary commercial airports in the U.S.

Propylene Glycol - A commonly used freezing point depressant in aircraft deicing/anti-icing fluids.

RAA - Regional Airline Association.

Regional Carriers - Airlines whose services are generally limited to a single region of the country and have annual revenues of less than \$100 million. These carriers are divided into three groups: large, medium, and small.

Reliever Airports - Included in the NPIAS. High-capacity general aviation airports in major metropolitan areas. There are 334 reliever airports in the U.S.

Reproductive Toxicity - The occurrence of adverse effects on the reproductive system that may result from exposure to a chemical.

RWIS - Road/Runway Weather Information System.

Screening Questionnaire - The EPA 1993 Screening Questionnaire for the Transportation Equipment Cleaning Industry.

SIC - Standard industrial classification. A numerical categorization system used by the U.S. Department of Commerce to catalogue economic activity. SIC codes refer to the products, or group of products, produced or distributed, or to services rendered by an operating establishment. SIC codes are used to group establishments by the economic activities in which they are engaged. SIC codes often denote a facility's primary, secondary, tertiary, etc. economic activities.

Silica Gel-Treated Hexane Extractable Material (SGT-HEM) - A method-defined parameter that measures the presence of mineral oils that are extractable in the solvent n-hexane and not adsorbed by silica gel (see Method 1664). SGT-HEM is also referred to as nonpolar material.

Small Regional Carrier - The largest segment of the regional airline business and mostly operate planes that have less than 30 seats. They are often called “commuters.” There is no revenue cut-off for this group.

SMI - Scientific Material International.

Society of Automotive Engineers (SAE) - A professional organization dedicated to improving safety and promoting new technologies in all sectors of the transportation industry through the development of engineering standards. The SAE Aerospace Council is responsible for developing standards for the aircraft industry and is organized into technical committees, each with its own area of specialization. The committee responsible for aircraft deicing and anti-icing issues is the G-12 Committee.

Sodium Acetate - A solid runway deicer.

Sodium Formate - A runway deicer typically applied in a pellet form and mixed with corrosion inhibitors to meet performance standards.

Storm Water - Storm water runoff, snow-melt runoff, and surface runoff and drainage.

Surface Waters - Waters including, but not limited to, oceans and all interstate and intrastate lakes, rivers, streams, mudflats, sand flats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, and natural ponds.

TECI - Transportation Equipment Cleaning Industry.

Teratogen - A chemical that causes structural defects that affect the development of an organism.

TMDL - Total Maximum Daily Load.

TOC - Total organic carbon. A measure of total organic content of wastewater. Unlike five-day biochemical oxygen demand (BOD₅) or chemical oxygen demand (COD), TOC is independent of the oxidation state of the organic matter and does not measure other organically bound elements, such as nitrogen and hydrogen, and inorganics that can contribute to the oxygen demand measured by BOD₅ and COD. TOC methods utilize heat and oxygen, ultraviolet irradiation, chemical oxidants, or combinations of these oxidants to convert organic carbon to carbon dioxide (CO₂). The CO₂ is then measured by various methods.

TOD - Total oxygen demand. A theoretical measure of the amount of oxygen required to break down a substance to its simplest parts. The COD of a substance may be used as a surrogate for the TOD.

TRI - Toxics Release Inventory.

TSCA - Toxic Substances Control Act.

TSS - Total suspended solids. A measure of the amount of particulate matter that is suspended in a water sample. The measure is obtained by filtering a water sample of known volume. The particulate material retained on the filter is then dried and weighed, see Method 160.2.

TTZ - Tolyltriazole or 5-methyl-1H-benzotriazole. A common additive in aircraft deicing/anti-icing fluids that is used as a corrosion inhibitor and flame retardant.

Type I ADFs - The most commonly used fluid. They are primarily used for aircraft deicing. They have the shortest holdover time of any type of fluid. Type I ADFs typically contain either ethylene glycol or propylene glycol, water, and additives.

Type II ADFs - Primarily used for aircraft anti-icing. They have a holdover time between Type I and Type IV fluids. They are typically composed of either ethylene glycol or propylene glycol, a small amount of thickener, water, and additives.

Type III ADFs - Designed for aircraft anti-icing for smaller, commuter aircraft. They have a holdover time between Type I and Type II fluids; however, they are believed to be obsolete.

Type IV ADFs - Primarily used for aircraft anti-icing. They have the longest holdover time of any type of fluid. They are typically composed of either ethylene glycol or propylene glycol, a small amount of thickener, water, and additives.

UCAR - A runway deicer manufactured by Union Carbide that contains urea, ethylene glycol, and water.

Urea - A runway deicer that is typically applied to pavement and runway areas in granular form.

U.S.C. - The United States Code.

USGS - United States Geological Survey.

VOCs - Volatile organic compounds. Any organic compound that participates in atmospheric photochemical reactions except those designated by EPA as having negligible photochemical reactivity.

Wet-Weather Deicing/Anti-icing - Occurs during storm events that include precipitation such as snow, sleet, or freezing rain.

WSDDM - Weather Support to Deicing Decision Making.

Appendix A

SELECT U.S. AIRPORT LOCATIONS

Appendix A

Select U.S. Airport Locations

Airport Code	Airport Name	Location
ILN	Airborne Air Park	Wilmington, OH
ALB	Albany International	Albany, NY
ANC	Anchorage International	Anchorage, AK
BWI	Baltimore/Washington International	Baltimore, MD
BIL	Billings Logan International	Billings, MT
BDL	Bradley International	Windsor Locks, CT (services Hartford, CT/ Springfield, MA)
BUF	Buffalo International	Buffalo, NY
ORD	Chicago O'Hare International	Chicago, IL
CVG	Cincinnati/Northern Kentucky International	Covington/Cincinnati, KY/OH
CLE	Cleveland Hopkins International	Cleveland, OH
DFW	Dallas/Ft. Worth International	Dallas-Ft. Worth, TX
DAY	Dayton International	Dayton, OH
DIA	Denver International	Denver, CO
DSM	Des Moines International	Des Moines, IA
DTW	Detroit Metropolitan Wayne Country	Detroit, MI
DLH	Duluth International	Duluth, MN
MKE	General Mitchell International	Milwaukee, WI
RFD	Greater Rockford	Rockford, IL
MCI	Kansas City International	Kansas City, MO
MEI	Key Field (Meridian)	Meridian, MS
LGA	LaGuardia	New York, NY
STL	Lambert-St. Louis International	St. Louis, MO
BOS	Logan International	Boston, MA
SDF	Louisville International-Standiford Field	Louisville, KY
MSP	Minneapolis-St. Paul International	Minneapolis-St. Paul, MN
BNA	Nashville International	Nashville, TN
EWR	Newark International	Newark, NJ
PIT	Pittsburgh International	Pittsburgh, PA
PDX	Portland International	Portland, OR
RIC	Richmond International	Richmond, VA
DCA	Ronald Reagan Washington National	Arlington, VA (services Washington, DC)

Appendix A (Continued)

Airport Code	Airport Name	Location
SEA	Seattle-Tacoma International	Seattle, WA
SLC	Salt Lake City International	Salt Lake City, UT
SYR	Syracuse Hancock International	Syracuse, NY
PVD	T.F. Green	Providence, RI
ITH	Tomkins County	Ithaca, NY
HTS	Tri-State (Huntington)	Huntington, WV
HPN	Westchester County	White Plains, NY
IAD	Washington Dulles International	Chantilly, VA (services Washington DC)

Appendix B

**MEAN ANNUAL SNOWFALL (THROUGH 1995)
FOR SELECT U.S. CITIES**

Appendix B

Mean Annual Snowfall (Through 1995) for Select U.S. Cities

City, State	Mean Annual Snowfall (in.)
VALDEZ, AK	325.8
MT. WASHINGTON, NH	253.9
YAKUTAT, AK	197.6
MARQUETTE, MI	130.6
SAULT STE. MARIE, MI	117.1
TALKEETNA, AK	115.0
SYRACUSE, NY	114.7
CARIBOU, ME	110.7
LANDER, WY	102.2
JUNEAU, AK	100.7
FLAGSTAFF, AZ	100.3
MUSKEGON, MI	97.9
MCGRATH, AK	94.2
BUFFALO, NY	91.8
ROCHESTER, NY	90.3
ERIE, PA.	86.5
ALPENA, MI	85.7
BINGHAMTON, NY	82.8
BETTLES, AK	82.5
CASPER, WY	79.1
DULUTH, MN	78.9
BURLINGTON, VT	78.0
KODIAK, AK	77.4
ELKINS, WV	76.7
HOUGHTON LAKE, MI	75.0
GRAND RAPIDS, MI	71.8
SHERIDAN, WY	71.7
SOUTH BEND, IN	70.9
PORTLAND, ME	70.8
ANCHORAGE, AK	70.0
FAIRBANKS, AK	69.5
WORCESTER, MA	67.6

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
INTERNATIONAL FALLS, MN	64.6
KALISPELL, MT	63.9
ALBANY, NY	63.8
CONCORD, NH	63.5
COLD BAY, AK	60.8
DENVER, CO	60.3
BECKLEY, WV	60.0
BLUE HILL, MA	59.5
NOME, AK	58.8
GREAT FALLS, MT	58.4
HOMER, AK	57.7
SALT LAKE CITY, UT	57.7
ST. PAUL ISLAND, AK	56.7
BILLINGS, MT	56.3
YOUNGSTOWN, OH	56.1
CLEVELAND, OH	55.7
CHEYENNE, WY	55.4
GULKANA, AK	50.7
MINNEAPOLIS-ST. PAUL, MN	49.5
SPOKANE, WA	49.5
BETHEL, AK	49.4
LANSING, MI	49.0
ANNETTE, AK	48.9
ELY, NV	48.9
ROCHESTER, MN	48.6
AVOCA, PA	48.1
HARTFORD, CT	47.9
KOTZEBUE, AK	47.6
AKRON, OH	47.4
MILWAUKEE, WI	47.2
HELENA, MT	47.0
GREEN BAY, WI	46.7
KING SALMON, AK	46.1
MISSOULA, MT	45.5

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
FLINT, MI	45.2
SAINT CLOUD, MN	44.9
MADISON, WI	43.9
BIG DELTA, AK	43.8
DUBUQUE, IA	43.6
PITTSBURGH, PA	43.5
POCATELLO, ID	42.7
BISMARCK, ND	42.7
LA CROSSE, WI	42.5
COLORADO SPRINGS, CO	42.3
MANSFIELD, OH	42.1
WILLIAMSPORT, PA	41.9
BOSTON, MA	41.7
SCOTTSBLUFF, NE	41.5
DETROIT, MI	41.3
BURNS, OR	41.3
HURON, SD	40.1
SIOUX FALLS, SD	40.1
WILLISTON, ND	39.5
RAPID CITY, SD	39.4
FARGO, ND	38.9
CHICAGO, IL	38.2
GOODLAND, KS	38.2
UNALAKLEET, AK	38.0
ELKO, NV	37.6
TOLEDO, OH	37.0
ABERDEEN, SD	36.5
ROCKFORD, IL	35.9
PROVIDENCE, RI	35.9
MIDDLETOWN/HARRISBURG INTL APT	35.0
ALAMOSA, CO	33.9
PUEBLO, CO	33.5
VALENTINE, NE	33.5
DES MOINES, IA	33.3

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
CHARLESTON, WV	33.1
FORT WAYNE, IN	32.8
WATERLOO, IA	32.3
ALLENTOWN, PA	32.1
SIOUX CITY, IA	31.7
OMAHA (NORTH), NE	31.2
GRAND ISLAND, NE	30.5
NORFOLK, NE	30.5
MOLINE, IL	30.4
NORTH PLATTE, NE	30.4
OMAHA EPPLEY AP, NE	29.8
NEW YORK C.PARK, NY	28.3
BARROW, AK	28.2
COLUMBUS, OH	27.9
GLASGOW, MT	27.7
DAYTON, OH	27.7
NEWARK, NJ	27.5
LINCOLN, NE	26.8
HUNTINGTON, WV	26.0
NEW YORK (LAGUARDIA AP), NY	25.8
BRIDGEPORT, CT	25.5
PEORIA, IL	24.8
GRAND JUNCTION, CO	24.7
RENO, NV	24.4
YAKIMA, WA	23.6
WINNEMUCCA, NV	23.5
GREATER CINCINNATI AP	23.4
SPRINGFIELD, IL	23.1
COLUMBIA, MO	23.1
INDIANAPOLIS, IN	22.9
NEW YORK (JFK AP), NY	22.9
JACKSON, KY	22.8
ROANOKE, VA	22.5
WASHINGTON DULLES AP, D.C.	22.3

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
CLAYTON, NM	22.0
CONCORDIA, KS	21.6
TOPEKA, KS	20.8
PHILADELPHIA, PA	20.8
BOISE, ID	20.7
ISLIP, NY	20.5
BALTIMORE, MD	20.4
WILMINGTON, DE	20.3
DODGE CITY, KS	19.9
KANSAS CITY, MO	19.9
ST. LOUIS, MO	19.5
PENDLETON, OR	17.7
LYNCHBURG, VA	17.7
SPRINGFIELD, MO	17.2
OLYMPIA, WA	16.8
WASHINGTON NAT'L AP, D.C.	16.4
LOUISVILLE, KY	16.1
LEWISTON, ID	15.8
LEXINGTON, KY	15.8
WICHITA, KS	15.7
ATLANTIC CITY AP, NJ	15.7
BRISTOL-JHNSN CTY-KNGSPRT,TN	15.4
AMARILLO, TX	15.0
ASHEVILLE, NC	14.9
RICHMOND, VA	13.7
EVANSVILLE, IN	13.6
QUILLAYUTE, WA	13.0
KNOXVILLE, TN	11.6
SEATTLE SEA-TAC AP, WA	11.3
ROSWELL, NM	11.1
ALBUQUERQUE, NM	10.8
PADUCAH KY	10.6
WINSLOW, AZ	10.5
NASHVILLE, TN	9.9

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
LUBBOCK, TX	9.9
OAK RIDGE, TN	9.5
TULSA, OK	9.4
OKLAHOMA CITY, OK	9.2
GREENSBORO-WNSTN-SALM-HGHPT, NC	8.5
WALLOPS ISLAND, VA	8.4
BISHOP, CA	8.2
NORFOLK, VA	7.4
MEDFORD, OR	7.2
RALEIGH, NC	6.9
SEATTLE C.O., WA	6.8
SALEM, OR	6.6
PORTLAND, OR	6.5
NORTH LITTLE ROCK, AR	6.3
EUGENE, OR	6.3
FORT SMITH, AR	6.2
GREENVILLE-SPARTANBURG AP, SC	5.9
WICHITA FALLS, TX	5.7
CHARLOTTE, NC	5.4
EL PASO, TX	5.3
LITTLE ROCK, AR	5.1
MEMPHIS, TN	5.1
ABILENE, TX	4.6
ASTORIA, OR	4.3
CHATTANOOGA, TN	4.3
MIDLAND-ODESSA, TX	4.2
REDDING, CA	2.9
TUPELO, MS	2.9
SAN ANGELO, TX	2.9
HUNTSVILLE, AL	2.7
DALLAS-FORT WORTH, TX	2.5
ATHENS, GA	2.4
ATLANTA, GA	2.0
CAPE HATTERAS, NC	1.9

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
WILMINGTON, NC	1.9
COLUMBIA, SC	1.7
BIRMINGHAM AP,AL	1.5
SHREVEPORT, LA	1.5
WACO, TX	1.4
TUCSON, AZ	1.2
MERIDIAN, MS	1.2
LAS VEGAS, NV	1.2
AUGUSTA,GA	1.1
MACON, GA	0.9
JACKSON, MS	0.9
AUSTIN, TX	0.9
DEL RIO, TX	0.9
CHARLESTON AP,SC	0.7
SAN ANTONIO, TX	0.7
COLUMBUS, GA	0.5
MOBILE, AL	0.4
MONTGOMERY, AL	0.4
SAVANNAH, GA	0.4
HOUSTON, TX	0.4
LAKE CHARLES, LA	0.3
PORT ARTHUR, TX	0.3
EUREKA, CA.	0.2
PENSACOLA, FL	0.2
BATON ROUGE, LA	0.2
NEW ORLEANS, LA	0.2
FRESNO, CA	0.1
VICTORIA, TX	0.1
SANTA BARBARA, CA	0
FORT MYERS, FL	0
KEY WEST, FL	0
MIAMI, FL	0
HILO, HI	0
HONOLULU,HI	0

Appendix B (Continued)

City, State	Mean Annual Snowfall (in.)
KAHULUI, HI	0
LIHUE, HI	0
GUAM, PC	0
KOROR, PC	0
KWAJALEIN, MARSHALL IS., PC	0
MAJURO, MARSHALL IS, PC	0
PAGO PAGO, AMER SAMOA, PC	0
POHNPEI, CAROLINE IS., PC	0
CHUUK, E. CAROLINE IS., PC	0
WAKE ISLAND, PC	0
YAP, W CAROLINE IS., PC	0

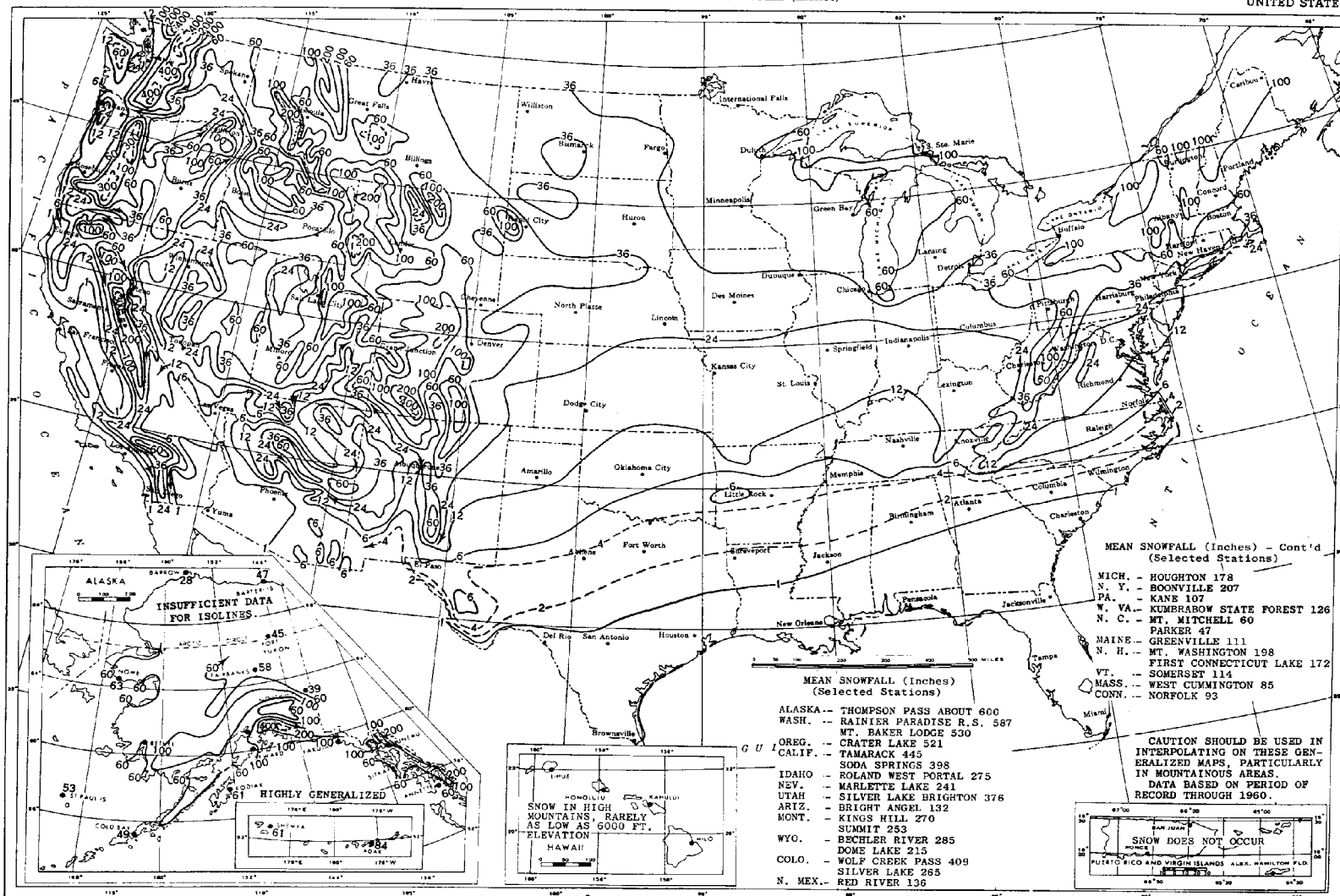
Source: National Oceanic Atmospheric Administration.

Appendix C

CLIMATE CONTOUR MAP OF THE U.S.

MEAN ANNUAL TOTAL SNOWFALL (Inches)

CLIMATIC MAPS
OF THE
UNITED STATES



Prepared by Office of Data Information

*Note.-- Formerly Sheet of the National Atlas
of the United States

Revised 1966

Appendix D

SELECTED FINANCIAL AND SCHEDULED SERVICE TRAFFIC STATISTICS

U.S. Large Certificated Air Carriers, 1997 - 1998

Air Carrier	12 month period ending 6/30/98								
	Operating Revenues	Net Income	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	HQ State	Notes [3]
Majors									
Alaska	\$1,527,189	\$105,841	12,548	9,900,889	14,743,618	1,073,610	77,693		
America West	\$1,938,366	\$102,971	17,826	15,969,799	23,772,818	1,596,980	113,748		
American	\$16,229,821	\$1,017,980	81,192	107,640,234	154,188,327	10,764,023	2,053,551		
Continental	\$6,870,111	\$427,490	40,150	47,639,667	66,422,995	4,763,967	737,402		
Delta	\$14,328,259	\$1,000,505	104,050	101,056,563	139,995,366	10,105,656	1,744,996		
DHL Airways	\$1,284,853	(\$32,962)	0	0	0	0	358,264		
Federal Express	\$13,414,818	\$441,887	0	0	0	0	6,518,002		
Northwest	\$9,881,713	\$536,386	54,506	72,408,489	97,219,704	7,240,849	2,226,434		
Southwest	\$3,994,409	\$376,467	57,286	29,935,657	45,978,282	2,993,566	131,828		
Trans World	\$3,370,128	(\$60,897)	24,112	25,510,913	36,025,463	2,551,092	310,055		
United	\$17,329,571	\$924,935	84,500	121,683,332	170,943,723	12,168,333	2,972,682		
United Parcel	\$1,842,455	(\$22,203)	0	0	0	0	895,094		
US Airways	\$8,494,535	\$1,003,208	57,869	41,051,381	56,773,242	4,105,139	349,414		
Nationals									
Air Transport Int'l	\$117,749	\$8,911	0	0	0	0	0	AR	NSS
Air Wisconsin	\$155,265	\$3,917	2,045	645,827	1,025,905	64,583	521	WI	
Air Trans [2]	\$197,217	(\$3,407)	2,261	1,494,612	2,487,706	149,461	947	FL	
Valuejet	\$183,424	(\$70,179)	2,339	1,203,597	2,392,198	120,396	2,153		
Aloha	\$235,350	\$6,526	5,312	734,974	1,112,337	73,498	9,416	HI	
American Eagle[3,4]	\$645,073	\$33,198	6,829	1,477,972	2,423,606	147,797	606	TX	
Flagship									
Simmons									
Wings West									
American Int'l.	\$437,568	(\$17,166)	0	0	0	0	82,314	MI	
American Trans Air	\$824,896	\$28,663	3,776	5,259,538	7,163,577	525,954	0	IN	
Arrow	\$89,363	(\$19,941)	0	0	0	0	96,540	FL	
Atlantic Southwest	\$396,451	\$57,804	3,876	976,055	1,818,538	97,605	611	GA	
Atlas	\$392,674	\$30,782	0	0	0	0	0	NY	NSS
Carnival	\$63,299	(\$28,063)	971	1,052,291	1,554,150	105,229	1,525	FL	
Challenge Air Cargo	\$134,928	\$2,713	0	0	0	0	215,969	FL	
Continental Express [4]	\$516,630	\$50,918	5,261	1,358,487	2,355,329	135,849	536	TX	
Continental Micronesia	\$670,352	(\$28,163)	2,432	4,206,328	6,178,542	420,633	134,949	HI	
Emery	\$556,661	(\$7,389)	0	0	0	0	0	CA	NSS
Evergreen	\$274,871	(\$4,172)	0	0	0	0	538,171	OR	
Executive [4]	\$96,138	\$4,142	1,446	276,806	463,382	27,681	10	PR	
Frontier	\$155,474	(\$15,226)	1,348	1,104,154	1,945,860	110,415	5,262	CO	
Hawaiian	\$409,838	\$2,008	4,934	3,152,308	4,357,865	315,231	56,782	HI	

U.S. Large Certificated Air Carriers, 1997 - 1998 (Continued)

Air Carrier	12 month period ending 6/30/98								
	Operating Revenues	Net Income	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	HQ State	Notes [3]
Horizon Air [4]	\$322,395	\$10,688	3,930	980,848	1,590,185	98,085	3,469	WA	
Midway	\$197,415	\$13,471	1,538	842,662	1,300,572	84,266	763	NC	
Midwest Express	\$333,483	\$30,046	1,747	1,498,079	2,323,706	149,808	18,442	WI	
Polar Air Cargo	\$337,239	(\$30,155)	0	0	0	0	1,113,913	CA	
Reno	\$392,027	(\$12,791)	5,248	2,830,249	4,428,320	283,025	5,412	NV	
Southern Air	\$124,336	(\$31,641)	0	0	0	0	0	OH	NSS
Sun Country	\$245,899	(\$4,772)	0	0	0	0	0	MN	NSS
Tower	\$487,212	(\$8,876)	1,459	3,920,610	5,162,146	392,061	97,895	NY	
Trans States	\$211,165	\$24,990	2,370	480,040	935,877	48,004	0	MO	
US Air Shuttle	\$173,664	\$5,987	1,516	302,491	685,793	30,249	294	NY	
World	\$289,588	(\$4,359)	0	0	0	0	0	VA	NSS
Large Regionals									
Amerijet	\$71,817	\$4,033	0	0	0	0	97,520	FL	
Champion	\$53,565	(\$26,456)	0	0	0	0	0	MN	NSS
Express One	\$111,552	(\$1,910)	0	0	0	0	0	TX	NSS
Fine	\$87,610	(\$6,575)	0	0	0	0	0	FL	NSS
Florida West	\$64,267	\$2,724	0	0	0	0	65,263	FL	
Gemini Air Cargo	\$95,472	\$11,488	0	0	0	0	0	DC	NSS
Kitty Hawk	\$117,667	\$7,701	0	0	0	0	0	TX	NSS
Kiwi	\$73,447	(\$22,084)	609	558,891	988,784	55,889	914	NJ	Chap. 11
Mesaba	\$303,270	\$21,862	3,749	926,228	1,708,509	92,623	279	MN	
Miami Air	\$78,399	\$1,278	0	0	0	0	0	FL	NSS
North American	\$60,665	\$1,467	0	0	0	0	0	NY	NSS
Northern Air	\$40,918	\$4,112	0	0	0	0	17,890	AK	
Pan American	\$38,264	(\$20,119)	333	538,284	795,823	53,828	9,615	FL	
Reeve	\$29,827	(\$2,230)	57	35,607	83,619	3,561	4,002	AK	
Ryan Int'l.	\$110,568	\$4,547	0	0	0	0	0	KS	NSS
Spirit	\$102,661	\$3,909	1,088	871,324	1,109,572	87,132	0	MI	
Sun Pacific	\$11,785	\$287	0	0	0	0	0	AZ	NSS
TransMeridian	\$29,682	(\$2,337)	0	0	0	0	0	GA	NSS
UFS	\$57,689	\$1,063	670	106,306	211,065	10,631	0	MO	
USA Jet	\$76,188	\$4,700	0	0	0	0	0	MI	NSS
Vanguard	\$84,907	(\$17,411)	1,078	674,740	1,088,814	67,474	846	MO	
Zantop	\$12,138	(\$1,892)	0	0	0	0	0	MI	NSS
Small Regionals									
Capital Cargo	\$16,920	\$375	0	0	0	0	0	FL	NSS
Casino Express	\$15,692	(\$2,676)	205	201,846	239,369	20,184	0	NV	
Custom Air	\$10,388	(\$146)	0	0	0	0	0	FL	

U.S. Large Certificated Air Carriers, 1997 - 1998 (Continued)

Air Carrier	12 month period ending 6/30/98								
	Operating Revenues	Net Income	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	HQ State	Notes [3]
Eastwind	\$22,641	(\$8,684)	240	102,118	308,701	10,212	0	NC	
Falcon	\$13,955	\$1,265	0	0	0	0	0	FL	NSS
Lynden Air Cargo	\$20,395	(\$5,761)	0	0	0	0	6,527	AK	
Nations Air	\$6,724	\$299	0	0	0	0	0	GA	NSS
Omni	\$24,955	\$1,141					0	OK	
Pace	\$4,914	\$256	0	0	0	0	0	NC	NSS
Panagra	\$3,610	(\$1,071)	0	0	0	0	0	FL	NSS
Pro Air	\$11,247	(\$18,849)	161	73,399	308,727	7,340	0	WA	
Renown	\$8,599	(\$1,033)	0	0	0	0	0	CA	NSS
Sierra Pacific	\$6,650	\$631	0	0	0	0	0	AZ	NSS
Sunworld	\$7,696	(\$914)	19	27,234	57,486	2,723	0	KY	PNSS
Tatonduk	\$7,248	\$1,127	NA	453	1,784	45	39	AK	
Tradewinds	\$14,965	(\$665)	0	0	0	0	0	NC	6 mos.
Trans Continental	\$22,719	\$1,172	0	0	0	0	0	MI	NSS
Trans-Air-Link	\$1,930	(\$220)	0	0	0	0	0	FL	NSS
Winair	\$4,939	(\$1,150)	0	0	0	0	0	UT	6 mos.

[1] Notes: NSS: provided unscheduled services only.

Chap. 11: Kiwi Airlines filed for Chapter 11 bankruptcy protection 3/16/99.

6 mos.: financial data for 6 month period ending 6/30/98.

[2] Valujet merged with AirTran 3/98.

[3] Flagship, Simmons, and Wings West merged to become American Eagle, 6/1/98.

[4] Wholly owned subsidiary of a major air carrier.

Source: References (29, 32)

U.S. Small Certificated and Commuter Airlines, 1997 - 1998

Air Carrier	12 month period ending 6/30/98						
	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	Code-Sharing [1]	HQ State
Fourth Quartile							
Comair	5,005,338	1,883,205	3,048,664	188,320,481		Y	OH
Mesa	4,151,202	1,044,158	1,856,093	104,415,813		Y	NM
Third Quartile							
Allegheny [3]	2,029,870	377,435	749,700	37,743,527	200,897	Y	PA
Piedmont [3]	2,906,282	585,507	1,026,577	58,550,692	285,102	Y	NC
Sky West	3,212,231	772,072	1,484,829	77,207,248		Y	UT
Second Quartile							
Atlantic Coast	1,854,888	584,279	1,085,484	58,427,900		Y	VA
Business Express	1,290,122	283,542	741,247	28,340,677	2,587	Y	NH
CC Air	776,663	141,304	254,142	14,130,398	1	Y	NC
Express Airlines I [3]	1,291,814	369,664	618,605	36,966,354		Y	TX
PSA [3]	1,190,126	393,392	611,206	39,239,146		Y	
Westair	1,467,951	231,378	391,277	23,137,785			CA
First Quartile							
Action	1,670	103	156	10,281			
Air Midwest	474,024	91,841	199,493	9,184,096			KS
Air Nevada	41,536	7,488	9,665	748,751			HI
Air St. Thomas	11,071	1,032	1,877	103,189			
Air Sunshine	26,860	3,278	7,449	327,750			
Air Vegas	117,528	21,425	29,581	2,142,549			
Alaska Seaplane Service	2,513	152	680	14,510	5,865		AK
Aloha Island	470,637	31,407	53,727	3,140,677		Y	
Alpine Air	6,129	1,056	4,744	105,640	3		
Astral Aviation	291,822	71,791	161,175	7,179,148	100,167		WI
Austin Express [2]	3,322	701	3,671	70,120	42		
Baker Aviation	17,840	1,352	5,256	135,229	97,590		AK
Bemidji	25	5	102	500	24,119		
Bering Air	45,699	6,178	15,602	617,784	243,102		AK
Big Sky	43,118	9,163	29,637	43,118	10,209		MT
Cape Air	388,348	21,212	41,717	2,121,183	8,464		
Cape Smythe Air	43,712	5,704	14,826	570,416	299,202		AK
Casino [2]	2,632	190,299	1,199,470	19,029,892			
Chautauqua	704,775	157,891	317,604	15,789,078	56,232	Y	
Coastal Air Transport	2,409	361	520	36,135	723		
Colgan Air	97,225	16,506	51,620	1,461,525	133,493	Y	
Commutair	630,827	117,374	271,088	11,737,425		Y	
Corporate Flight Management	160,177	37,189	86,824	3,718,930	1,322		

U.S. Small Certificated and Commuter Airlines, 1997 - 1998 (Continued)

Air Carrier	12 month period ending 6/30/98						
	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	Code-Sharing [1]	HQ State
Eagle Canyon	199,079	35,834	50,227	3,583,422			NV
Ellis Air Taxi	400	52	200	4,175	1,441		
Era Aviation	418,640	51,950	104,071	5,195,049	385,973	Y	AK
Exec Express II	227,333	99,198	249,878	9,919,828	116,142	Y	TX
Flying Boat	35,413	3,180	5,213	318,004			
Forty-Mile Air	2,367	176	1,031	17,650	20,927		AK
Freedom Air	77,201	2,557	12,438	255,721	35,783		
Frontier Flying Service	37,548	9,471	26,572	947,058	476,619		AK
F.S. Air Service	1,203	152	772	15,168	10,253		AK
Grand Canyon Helicopters	1,156	70	113	6,960	77		
Grant Aviation	20,692	3,288	10,858	328,834	112,466		AK
Great Lakes Aviation	668,149	195,734	395,072	19,573,445		Y	
Gulf Air Taxi	242	23	108	1,644	1,198		
Gulfstream Int'l.	583,118	111,145	205,692	11,114,522	1,023,024	Y	
Hageland Aviation	54,098	5,171	15,364	517,134	285,006		AK
Haines	22,874	762	1,607	76,212	38,680		AK
Harbor	63,956	4,499	13,908	449,920	3,837	Y	
Iliamna Air Taxi	450	10	261	1,041	12,941		AK
Island Express	15,164	2,888	6,417	288,756	17,266		
Jim Air	860	144	629	14,425	27,635		AK
Katmai Air [2]	8,348	275	511	27,549	1,334		AK
Kenmore Air Harbor	51,974	4,155	7,730	415,515			
Larry's Flying Service	7,569	990	5,353	98,956	99,270		AK
Las Vegas	8,340	749	1,077	74,944	2,191		
L.A.B. Flying Service	32,966	2,215	3,477	221,480	99,285		AK
Merlin Express	52,216	15,423	42,272	1,542,263	116,986		
New England	25,031	426	958	25,031	559		
Olson Air Service	4,883	423	2,736	42,229	40,192		AK
Pacific Island	89,895	5,455	10,613	545,524	545,524		
Paradise Island	242,066	42,612	75,957	4,261,205			
Peninsula	179,334	45,976	99,724	4,597,570	320,674	Y	AK
Pine State	1,545	390	1,319	39,013	2		
Pro Air	160,602	73,399	308,727	7,339,767			WA
Promech	18,667	661	2,166	66,082	17,697		AK
Redwing	2,566	331	1,598	33,101			
Samoa Aviation	71,675	6,972	10,244	696,949	8,576		
Scenic	286,418	49,861	67,382	4,986,054			
Seaborne Aviation	63,275	2,385	3,637	238,547			AK

U.S. Small Certificated and Commuter Airlines, 1997 - 1998 (Continued)

Air Carrier	12 month period ending 6/30/98						
	Passenger Enplane-ments (x 1,000)	Revenue Passenger Miles (x 1,000)	Available Seat Miles (x 1,000)	Passenger Ton-miles (x 1,000)	Cargo Ton-miles (x 1,000)	Code-Sharing [1]	HQ State
Skagway Air Service	10,099	803	1,711	80,292	15,849		AK
Southcentral Air	42,158	2,873	10,258	287,285	65,777		AK
Springdale Air	1,065	154	456	15,443	2,668		
Sunrise [2]	448	59	226	5,869			
Tanana Air Service	4,329	369	2,612	36,912	70,118		AK
Taquan Air Service	113,304	3,375	17,500	312,398	147,036		AK
Viesques Air Link	76,815	2,434	3,934	243,366			
Village Aviation	196	1	22	112	251		AK
Warbelow's Air Ventures	32,418	6,855	17,724	685,543	584,609		AK
Ward Air	43	1	9	96	25		
West Isle Air	26,436	1,029	2,602	102,925	976		
Wings of Alaska	29,234	1,414	4,454	141,358	35,725		AK
Wright Air Service	10,755	1,729	5,139	172,850	81,796		AK
Yute Air Alaska	74,223	5,804	17,410	580,351	237,778		AK

[1] Carrier has code-sharing arrangements with one or more major airlines;

source: RAA website: <http://www.raa.org/newsdesk/archive/Codeshare.htm>.

[2] Carrier started service within 12 month period; less than full year's data provided.

[3] Wholly-owned subsidiary of a major air carrier.

Source: Reference (31)



United States
Environmental Protection
Agency

Technical Development Document for the Final Effluent Limitations Guidelines and New Source Performance Standards for the Airport Deicing Category

April 2012

**U.S. Environmental Protection Agency
Office of Water (4303T)
Engineering and Analysis Division
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1. LEGAL AUTHORITY

Effluent limitation guidelines and standards for the Airport Deicing Category are promulgated under the authority of sections 301, 304, 306, 307, 308, and 501 of the Clean Water Act, 33 U.S.C. 1311, 1314, 1316, 1317, 1318, and 1361.

1.1 Clean Water Act

Congress passed the Federal Water Pollution Control Act Amendments of 1972, also known as the Clean Water Act (CWA), to “restore and maintain the chemical, physical, and biological integrity of the Nation’s waters” (section 101(a)). To implement the Act, the United States Environmental Protection Agency (EPA) is to issue effluent limitation guidelines, pretreatment standards, and new source performance standards for industrial dischargers. These guidelines and standards are summarized briefly in the following sections.

1.1.1 *Best Practicable Control Technology Currently Available (BPT)*

Traditionally, EPA establishes BPT effluent limitations based on the average of the best performances of facilities within the industry, grouped to reflect various ages, sizes, processes, or other common characteristics. EPA may promulgate BPT effluent limits for conventional, toxic, and nonconventional pollutants. In specifying BPT, EPA looks at a number of factors. EPA first considers the cost of achieving effluent reductions in relation to the effluent reduction benefits. The Agency also considers the age of the equipment and facilities, the processes employed, engineering aspects of the control technologies, and required process changes, non-water-quality environmental impacts (including energy requirements), and such other factors as the Administrator deems appropriate. See CWA section 304(b)(1)(B)). If, however, existing performance is uniformly inadequate, EPA may establish limitations based on higher levels of control than are currently in place in an industrial category when based on an Agency determination that the technology is available in another category or subcategory, and can be practically applied.

1.1.2 *Best Conventional Pollutant Control Technology (BCT)*

The 1977 amendments to the CWA required EPA to identify additional levels of effluent reduction for conventional pollutants associated with BCT technology for discharges from existing industrial point sources. In addition to other factors specified in section 304(b)(4)(B), the CWA requires that EPA establish BCT limitations after consideration of a two-part “cost-reasonableness” test. EPA explained its methodology for the development of BCT limitations in July 1986 (51 FR 24974). Section 304(a)(4) designates the following as conventional pollutants: biochemical oxygen demand over 5 days (BOD₅), total suspended solids (TSS), fecal coliform, pH, and any additional pollutants defined by the Administrator as conventional. The Administrator designated oil and grease as an additional conventional pollutant on July 30, 1979 (44 FR 44501; 40 CFR 401.16).

1.1.3 *Best Available Technology Economically Achievable (BAT)*

BAT represents the second level of stringency for controlling direct discharge of toxic and nonconventional pollutants. In general, BAT effluent limitation guidelines represent the best economically achievable performance of facilities in the industrial subcategory or category. The

factors considered in assessing BAT include the cost of achieving BAT effluent reductions, the age of equipment and facilities involved, the process employed, potential process changes, and non-water quality environmental impacts including energy requirements, and such other factors as the Administrator deems appropriate. The Agency retains considerable discretion in assigning the weight to be accorded these factors. An additional statutory factor considered in setting BAT is economic achievability. Generally, EPA determines economic achievability based on total costs to the industry and the effect of compliance with BAT limitations on overall industry and subcategory financial conditions. As with BPT, where existing performance is uniformly inadequate, BAT may reflect a higher level of performance than is currently being achieved based on technology transferred from a different subcategory or category. BAT may be based upon process changes or internal controls, even when these technologies are not common industry practice.

1.1.4 *New Source Performance Standards (NSPS)*

NSPS reflect effluent reductions that are achievable based on the best available demonstrated control technology. New facilities have the opportunity to install the best and most efficient production processes and wastewater treatment technologies. As a result, NSPS should represent the most stringent controls attainable through the application of the best available demonstrated control technology for all pollutants (i.e., conventional, nonconventional, and priority pollutants). In establishing NSPS, EPA is directed to take into consideration the cost of achieving the effluent reduction and any non-water quality environmental impacts and energy requirements.

1.1.5 *Pretreatment Standards for Existing Sources (PSES)*

Pretreatment standards apply to discharges of pollutants to publicly owned treatment works (POTWs) rather than to discharges to waters of the United States. PSES are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of POTWs. Categorical pretreatment standards are technology-based and analogous to BAT effluent limitation guidelines. The General Pretreatment Regulations, which set forth the framework for the implementation of categorical pretreatment standards, are found at 40 CFR Part 403. These regulations establish pretreatment standards that apply to all nondomestic dischargers. See 52 FR 1586 (January 14, 1987).

1.1.6 *Pretreatment Standards for New Sources (PSNS)*

Section 307(c) of the Act calls for EPA to promulgate PSNS at the same time it promulgates NSPS. Such pretreatment standards must prevent the discharge of any pollutant into a POTW that may interfere with, pass through, or may otherwise be incompatible with the POTW. EPA promulgates categorical PSES based principally on BAT technology for existing sources. EPA promulgates PSNS based on best available demonstrated technology for new sources. New indirect discharges have the opportunity to incorporate into their facilities the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS as it considers in promulgating NSPS.

1.2 Effluent Guidelines Plan

In 2004, EPA issued its biannual effluent guidelines plan under section 304(m) of the CWA. This plan announced the initiation of rulemaking for the Airport Deicing Category (69 FR 53705, September 2, 2004).

2. APPLICABILITY AND SUBCATEGORIZATION

This document presents the information and rationale supporting the effluent limitation guidelines and standards for the Airport Deicing Category. Section 2 highlights the applicability and subcategorization basis of this regulation.

2.1 Applicability of the Regulation

Airports in the scope of this regulation are defined as Primary Commercial Airports that conduct deicing activities.

2.2 Subcategorization

The CWA requires EPA to consider a number of different factors when developing effluent limitation guidelines. For example, when developing limitations that represent the BAT for a particular industrial category, EPA must consider among other factors the following: the age of the equipment and facilities in the category, location, manufacturing processes employed, types of treatment technology to reduce the effluent discharges, costs of effluent reductions, and non-water-quality impacts (CWA section 304(b)(2)(B)). The statute also allows EPA to take into account other factors that the EPA Administrator deems appropriate and requires the BAT model technology chosen by EPA to be economically achievable, which generally involves considering both compliance costs and overall financial condition of the industry.

For this rulemaking, EPA evaluated the characteristics of the Airport Deicing Category to determine their potential to provide the Agency with a means to differentiate effluent quantity and quality among facilities. EPA also evaluated the design, process, and operational characteristics of the different industry segments to determine technology control options that might be applied to reduce effluent quantity and improve effluent quality. Based on this analysis, below are the factors that EPA evaluated to determine whether subcategorizing the Airport Deicing Category would be appropriate:

- Aircraft deicing fluid (ADF) usage;
- Federal Aviation Administration (FAA) classifications; and
- Land availability.

2.2.1 *ADF Usage*

Ethylene glycols (EG) and propylene glycols (PG) are the main ingredients in ADF. Through EPA's research, it became apparent that the volume of glycol required to deice a single aircraft varied greatly depending on a number of variables including weather conditions, aircraft size, and operator training. EPA reviewed industry questionnaire responses and determined that ADF usage is the best indicator for the volume of deicing operations that occur at an airport. ADF usage can range from zero to hundreds of thousands of gallons per year at airports across the United States.

2.2.2 *FAA Classification*

The Airport and Airway Improvement Act (AAIA) and the FAA classify airports by size based on the volume of commercial traffic. (Noncommercial airports, commonly known as "General Aviation" airports, are not specifically defined by the AAIA.) EPA utilized this classification system to organize its data collection and analysis of the aviation industry. The AAIA defines airports by categories of airport activities, including Commercial Service (Primary and Nonprimary), Cargo Service, and Reliever. Commercial Service Airports are publicly owned airports that have at least 2,500 passenger boardings each calendar year and receive scheduled passenger service. The definition also includes passengers who continue on an aircraft in international flight that stops at an airport in any of the 50 states for a nontraffic purpose, such as refueling or aircraft maintenance rather than passenger activity. Primary Commercial Service airports have more than 10,000 passenger boardings each year. Primary Commercial Service airports are further subdivided into Large Hub, Medium Hub, Small Hub, and Non-hub classifications, based on the percentage of total passenger boardings within the United States in the most current calendar year ending before the start of the current fiscal year.

Early in the regulatory process, EPA assumed that the majority of the deicing in the United States would occur at Primary Commercial Service airports and particularly those with nonpropeller departures. General aviation aircraft, as well as smaller commercial propeller driven aircraft are expected to suspend flights during inclement weather, whereas commercial aircraft with scheduled service are much more likely to deice to meet customer demands.

2.2.3 *Land Availability*

EPA is aware that airports across the country have different amounts of land that may be available for facility modifications, such as installing environmental controls. EPA collected some basic information from airports on their current configurations. However, neither the aviation industry nor the FAA has developed a standard definition of land availability.

As part of the public comments on the proposed rule, commenters requested that EPA subcategorize airports that would be prohibited from installing deicing pads due to gate, runway, and taxiway space constraints and lack of available land. EPA did not set a spent ADF collection requirement as part of BAT in the final rule and therefore did not separate these airports into their own subcategory.

2.2.4 *Conclusions*

EPA concludes that establishing formal subcategories is not necessary for the Airport Deicing Category; rather, EPA structured the applicability of the final rule to address the relevant factors and established a set of requirements that encompasses the range of situations that an airport may encounter during deicing operations.

3. DATA COLLECTION ACTIVITIES

To characterize airport deicing operations and to develop the final effluent limitation guidelines and standards, EPA collected and evaluated technical and economic data from a variety of sources. This section describes the following data sources used for the Airport Deicing Category rulemaking effort:

- Section 3.1 – Preliminary Data Summary
- Section 3.2 – Site Visits
- Section 3.3 – Industry Questionnaires (Surveys)
- Section 3.4 – Field Sampling
- Section 3.5 – Permit Review
- Section 3.6 – Deicing Pad Costs
- Section 3.7 – Industry-Supplied Data
- Section 3.8 – Literature Reviews
- Section 3.9 – Data Collected as Part of Public Comments

3.1 Preliminary Data Summary

EPA's initial source of wastewater discharge information for the aviation industry was the *Preliminary Data Summary (PDS): Airport Deicing Operations*, which was published in August 2000 (USEPA, 2000). This study focused on approximately 200 U.S. airports with potentially significant deicing/anti-icing operations. For the study, EPA collected information from industry questionnaires, engineering site visits, wastewater sampling activities, meetings with industry and regulatory agencies, and technical and scientific literature. See Section 3.0 of the PDS for detailed information on the study's data collection activities.

The questionnaires that EPA reviewed included the 1993 Screener Questionnaire for the Transportation Equipment Cleaning Industry and a set of questionnaires distributed during the study to major and regional airports and airlines, technology vendors, and POTWs.

From September 1997 through March 1999, the Agency conducted 16 airport site visits and six sampling episodes to collect information about deicing processes, deicing equipment, and deicing wastewater generation, collection, handling, and treatment technologies.

EPA met with the FAA, deicing fluid manufacturers and formulators, airlines, industry associations, technology vendors, and other interested parties to discuss environmental and operational issues related to aircraft deicing and anti-icing operations.

Literature searches provided information on the toxicity, industry usage, and mitigation techniques for ADFs. The literature also covered topics such as alternative fluid types, pollution prevention practices, economic and financial data, and environmental impacts.

3.2 Site Visits

Between December 2004 and November 2005, EPA conducted 20 airport site visits to collect current information about aircraft and airfield deicing practices, deicing equipment, deicing stormwater generation, collection, handling, and control. During these site visits, EPA also evaluated potential sampling locations for the sampling program described in Section 3.4.

EPA used information collected from the PDS, updated airport literature searches, and other Agency-supplied data to assess potential airports for site visits. EPA also solicited recommendations from industry trade associations, including the Air Transport Association (ATA), the American Association of Airline Executives (AAAE) and Airports Council International-North America (ACI-NA). EPA considered the following criteria in evaluating which airports to visit:

- Hub size and location of the airport;
- ADF handling practices;
- Deicing stormwater collection and control practices; and
- ADF-contaminated stormwater discharge practices.

In general, EPA visited Medium Hub and Large Hub airports operating in northern climates that conduct aircraft and airfield deicing operations each winter. EPA also visited some Small Hub airports to evaluate potential issues related to an airport's size. The Agency visited airports that use a variety of deicing practices (such as gate deicing, centralized deicing pads (CDPs), deicing trucks and stationary booms, infrared deicing hangars) and various deicing stormwater collection and control technologies (such as dedicated deicing stormwater collection systems, stormwater treatment through biological systems, and glycol recovery systems). Table 3-1 lists the 20 airports visited in 2004 and 2005, the visit dates, and EPA's rationale for selecting each for a site visit. This table also lists a post-proposal site visit conducted at Boston Logan airport.

During the site visits, EPA collected the following information:

- General airport and deicing operations information, including size and age of the airport, permit status, information on the entities that perform deicing operations (both aircraft and airfield), and current airline tenant information;
- Description of the deicing/anti-icing operations conducted at the airport, including the types of equipment used, locations of deicing operations, and information on any pollution prevention or "state-of-the-art" systems in use at the airport that improved their deicing operations;
- Deicing chemicals used, including ADF type (e.g., Type I-IV), pavement deicer type, and any chemical usage information available;
- Description of the deicing stormwater collection and control systems used at the airport, including any glycol recovery or stormwater treatment systems and their effectiveness and any available cost information for these systems; and
- Airport monitoring and discharge of deicing stormwater, including pollutants monitored and frequency of monitoring.

This information is documented in the Site Visit Report (SVR) for each airport visited.

Table 3-1. Airports Visited

Airport Name	Airport Code	Date of Visit	Airport Details
Washington Dulles International	IAD	12/1/2004	Local Large Hub airport, ADF-contaminated stormwater collection and glycol recovery, indirect discharger
Baltimore-Washington International	BWI	12/15/2004	Local Large Hub airport, deicing pads, ADF-contaminated stormwater collection, indirect discharger
Chicago O'Hare International	ORD	1/26/2005	Large Hub airport, ADF-contaminated stormwater collection with indirect discharge, upgrades to system since the PDS site visit
General Mitchell International (Milwaukee)	MKE	1/27/2005	Medium Hub airport, ADF-contaminated stormwater collection and indirect discharge, extensive monitoring data in collaboration with U.S. Geological Survey (USGS)
Detroit Metropolitan Wayne County	DTW	1/28/2005	Large Hub airport, deicing pads, ADF-contaminated stormwater collection with glycol recovery, both direct and indirect discharger
Ronald Reagan Washington National	DCA	2/1/2005	Local Large Hub airport, changes in ADF practices since PDS site visit, ADF-contaminated stormwater collection
Syracuse Hancock International	SYR	2/9/2005	Small Hub airport, deicing pads, aerated stormwater lagoons, indirect discharger
Albany International	ALB	2/10/2005	Small Hub airport, ADF-contaminated stormwater collection with anaerobic and aerobic treatment, direct discharger, upgrades to system since PDS site visit
Pittsburgh International	PIT	2/10/2005	Large Hub airport, deicing pads, glycol recovery and treatment (ultra filtration and reverse osmosis) of ADF-contaminated stormwater, direct discharger
Cincinnati/Northern Kentucky International	CVG	2/11/2005	Large Hub airport, variety of ADF-contaminated stormwater-related activities, recommended by FAA as a site visit location, on-site aerobic treatment, direct and indirect discharger
Richmond International	RIC	2/16/2005	Local Small Hub airport
Minneapolis/St. Paul International/World-Chamberlain	MSP	2/18/2005	Large Hub airport, ADF collection with glycol recovery, direct and indirect discharger
James M Cox Dayton International	DAY	2/25/2006	Small Hub airport, centralized deicing with ADF-contaminated stormwater collection
Portland International (Oregon)	PDX	7/26/2005	Medium Hub northwestern airport, indirectly discharges high-strength deicing stormwater, sends low-strength deicing stormwater to detention pond and then to direct discharge
Seattle-Tacoma International	SEA	7/27/2006	Large Hub northwestern airport, industrial stormwater treatment on site
LaGuardia (New York)	LGA	10/11/2005	Large Hub airport, direct discharger, part of New York City area visits

Table 3-1 (Continued)

Airport Name	Airport Code	Date of Visit	Airport Details
John F. Kennedy International (New York)	JFK	10/11/2005	Large Hub airport with a high percentage of international flights, direct discharger, part of New York City area visits, future plans for infrared deicing
Newark Liberty International	EWR	10/12/2005	Large Hub airport, infrared deicing technology since 1999
Salt Lake City International	SLC	11/8/2005	Large Hub western airport, ADF-contaminated stormwater collection with glycol recovery
Denver International	DEN	11/9/2005	Large Hub western airport, deicing pads, ADF-contaminated stormwater collection with glycol recovery
General Edward Lawrence Logan International	BOS	3/21/2011	Space-constrained airport with no ADF-contaminated stormwater collection and direct discharge

3.3 Industry Questionnaires (Surveys)

EPA distributed three questionnaires to directly support the Airport Deicing rulemaking. Section 3.3.1 discusses the recipient selection process, distribution, and mail-out results for the three airport deicing questionnaires. Section 3.3.2 discusses the organization of and type of technical information requested in each questionnaire.

3.3.1 *Recipient Selection and Questionnaire Distribution*

EPA distributed a screener questionnaire followed by a detailed airline questionnaire to airlines, and a questionnaire to airports. The overall focus of the questionnaires was on airports and airlines that perform deicing and anti-icing on aircraft and/or airfield pavement. EPA selected airports for the airport questionnaire by airport type (i.e., Large Hub, Medium Hub, Small Hub, and Non-hub), days and amount of snow or freezing precipitation, and the number of departures. EPA performed a census design for large and Medium Hub¹ airports and a stratified random sample design for small and Non-hub airports (see the *Statistical Support Memorandum* DCN AD01208).

EPA selected recipients for the airline screener questionnaire by identifying airlines with greater than 1,000 departures per year at those airports selected for the airport questionnaire. EPA selected airlines for the detailed airline questionnaire based on the airline screener questionnaire responses (which identified whether an airline deiced its aircraft or used some other entity) at the specified airports. To reduce respondent burden, EPA asked the selected

¹FAA classifies large commercial airports into size categories of “hubs,” based on the number of annual enplanements that occur at the airport. Enplanements represent the number of passengers boarding the plane for departure. Large Hubs are airports that represent more than 1 percent of total U.S. passenger enplanements. Medium Hubs are airports that account for more than 0.25 percent but less than 1 percent of total passenger enplanements. Small Hubs enplane 0.05 to 0.25 percent of the total passenger enplanements. Airports with less than 0.05 percent of the total passenger enplanements but more than 10,000 annual enplanements are considered Non-hub primary airports.

airlines to provide data on a limited subset of the airports they served for which they were expected to use the maximum amount of deicing chemicals.

Table 3-2 summarizes the number of questionnaires distributed in each category and their response rates.

Table 3-2. Deicing Questionnaire Response Rates

Questionnaire Type	Distributed	Returned Undelivered	Returned Completed	Not Returned
Airport Deicing Questionnaire	153	0 (0%)	150 (98%)	3 (2%) ¹
Airline Screener Questionnaire ²	72	1 (1%)	70 (97%)	1 (1%)
Airline Deicing Detailed Questionnaire	58	0 (0%)	49 (84%)	9 (16%)

¹ EPA determined that one airport recipient was out of scope and removed it from the sample frame.

² Information was collected from an additional 22 foreign carriers.

3.3.1.1 Airport Questionnaire

EPA selected 153 airports to receive the airport questionnaire and distributed the questionnaire to these airports in April 2006. Of the 153 airport questionnaires distributed, 150 were completed and returned. EPA removed one of the three nonrespondent airports from the sample frame because it was a city airport operating as a tenant at a military airport. EPA determined that its selection was based on data for the military airport operations, not the city airport, and military airports were not included in the sample frame.

3.3.1.2 Airline Screener Questionnaire

EPA initially selected 72 airlines as recipients of the screener questionnaire. The recipient group comprised a random sample of airlines with greater than 1,000 departures per year operating at the airports selected for the airport questionnaire. In April 2006, the Agency distributed the airline screener questionnaire to the 72 airlines. EPA also identified 22 additional foreign airlines for which information would be useful in developing effluent guidelines, but that were not captured by the random sample. EPA collected aircraft deicing and anti-icing information for these 22 foreign carriers through contacts with airport managers where the carriers operated.

Of the 72 screener questionnaires distributed, 70 were completed and returned to EPA. Of the two not returned, one questionnaire was returned undelivered, as the airline had ceased operations.

3.3.1.3 Airline Detailed Questionnaire

Using the responses from the airline screener questionnaire, EPA selected and sent a more detailed questionnaire to 58 airlines that responded they deice planes at any of the airports that received an airport questionnaire. This questionnaire was distributed in March 2007. The selection included 448 airline/airport combinations. The Agency categorized the airline/airport combinations according to the entity that performed most of the deicing for the 2002/2003, 2003/2004, and 2004/2005 winter seasons as listed below:

- Airline/airport combinations that deice their own aircraft;
- Airline/airport combinations that contract to fixed-base operators (FBOs) for deicing services; or
- Airline/airport combinations that contract to other airlines for deicing services.

Of the 58 airline detailed questionnaires sent, 49 were completed returned and nine were not returned.

3.3.2 Questionnaire Information Collected

EPA designed the questionnaires to collect current information with sufficient detail to support development of effluent guidelines. The questionnaires collected information on deicing operations performed on aircraft and airfield pavement, including deicing stormwater generation, collection, characterization, management, and treatment. The airline screener supported the selection of recipients for the airline detailed questionnaire. This section describes the technical information collected and the purpose of each of the three questionnaires.

3.3.2.1 Airport Questionnaire

EPA divided the airport deicing questionnaire into the following parts and sections:

PART A: TECHNICAL INFORMATION

- Section 1: General Airport Information
- Section 2: Airport Deicing and Anti-Icing Operations
- Section 3: Deicing Stormwater Containment and/or Collection
- Section 4: Deicing Stormwater Treatment/Recovery
- Section 5: Analytical Data
- Section 6: Pollution Prevention Practices

PART B: FINANCIAL AND ECONOMIC INFORMATION

- Section 1: Ownership and Management Structure
- Section 2: Airport Finances
- Section 3: Capital Expenditures
- Section 4: Airport Operations

Part A, Section 1 (Questions 1 through 24) requested information to identify the airport and primary contacts, to confirm that aircraft deicing/anti-icing was performed during the three designated winter seasons (2002/2003, 2003/2004, and 2004/2005), and to characterize deicing operations. This information included the destination of deicing/anti-icing stormwater, receiving surface waters, the entity that performed aircraft and/or airfield pavement deicing, and the number of deicing/anti-icing days per winter season. This information helped EPA update the industry profile on airports deicing in the U.S., characterize deicing/anti-icing operations, and determine the proximity and types of ecosystems within and beyond airport boundaries

Part A, Section 2 (Questions 25 through 31) requested detailed information about airport deicing/anti-icing stormwater sources, flows, and destinations as well as deicing/anti-

icing chemicals, materials, and practices. EPA used this information to develop an industry profile of deicing stormwater generation and collection, to determine baseline loadings using airfield deicing chemical usage, and to develop and evaluate possible regulatory technology options and compliance cost estimates.

Part A, Section 3 (Questions 32 through 39) requested information on the collection, containment, conveyance, discharge and/or disposal methods for deicing stormwater, and pollution prevention and best management practices. EPA used this information to develop an industry profile of deicing stormwater collection/containment/conveyance methods and to evaluate pollution prevention and best management practices.

Part A, Section 4 (Questions 40 through 51) requested information on deicing stormwater treatment technologies and units operated by the airport, including deicing stormwater treatment diagrams, design and operating specifications, sources of wastewater influent, treatment chemical additions, treatment operations and maintenance costs, and discharge practices. EPA used this information to develop control technology options, regulatory options, and compliance cost estimates.

Part A, Section 5 (Questions 52 through 55) requested information concerning the availability of deicing stormwater characterization data, receiving water in-stream monitoring data, and/or data characterizing the effectiveness of treatment of deicing stormwater. EPA used this information to follow up with selected airports to request long-term monitoring data, to estimate pollutant discharge loadings, to characterize behavior of the discharge in the receiving water, to assess deicing stormwater treatment technologies, and to assess environmental impacts.

Part A, Section 6 (Questions 56 through 68) requested information to evaluate the status of pollution prevention practices at each airport and to identify pollution prevention technologies. EPA used this information to identify appropriate practices as regulatory options and to prepare an industry profile of pollution prevention practices.

Part B of the questionnaire requested airport financial and economic information. Section 1 requested information on the ownership and management structure that EPA used to develop the industry profile and to estimate economic impacts of an effluent guideline. Section 2 requested information on operation finances that EPA used to project the potential impacts of the rule. Section 3 requested information on current capital airport expenditures that EPA used to assess the capability of airports to pay for deicing-related capital improvements. Section 4 requested information on the finances for airport operations, including the airport's financial statement, which EPA used to determine the airport's cost of capital.

3.3.2.2 Airline Screener Questionnaire

The airline screener questionnaire included three questions. Question 1 requested the contact information for the airline should EPA need to verify or clarify their response. Question 2 asked who (the airline, another airline, FBO, or private contractor) performed most of the deicing/anti-icing on the respondent's aircraft at specific airports. Question 3 provided an opportunity for the respondent to provide additional information or comment on its responses. EPA used this information to identify potential airline detailed questionnaire recipients and to indicate the potential contribution of FBOs to deicing operations and to the discharge of ADF-contaminated stormwater.

3.3.2.3 Airline Detailed Questionnaire

EPA divided the airline detailed questionnaire into the following parts and sections:

PART A: TECHNICAL INFORMATION

- Section 1: General Airline Information
Section 2: Airline Deicing and Anti-Icing Operations (at each airport specified in Section 1)
Section 3: Pollution Prevention Practices (at each airport specified in Section 1)

PART B: DEICING COSTS AND OPERATIONS

- Section 1: Airline Deicing Costs and Operations
Section 2: Airport-Specific Deicing Costs and Operations

Part A, Section 1 (Questions 1 through 4) requested verification of the airline name and address and identification of the primary and secondary contacts to clarify or verify the technical questionnaire responses.

Part A, Section 2 (Questions 5 through 18) requested information on deicing/anti-icing operations performed by the airline or for the airline at each specified airport. The Agency used this information to:

- Develop an industry profile of ADF usage and deicing stormwater generation;
- Estimate pollutant loadings;
- Characterize deicing stormwater;
- Evaluate differences in airport deicing stormwater generation and characteristics;
- Identify pollutants of concern; and
- Identify opportunities for pollution prevention through chemical substitution and best management practices.

Part A, Section 3 (Questions 19 through 31) requested information on the airline's pollution prevention practices including a description of each practice and any costs and/or savings from its implementation. The Agency evaluated this information to identify appropriate practices that could become part of regulatory options and to develop an industry profile.

Part B of the questionnaire requested airline financial and economic information. Section 1 requested information on ownership, aircraft deicing costs and operations, and the airline's financial statement, that EPA used to develop the industry economic profile and to conduct the economic analysis. Section 2 requested detailed information regarding airline-specific deicing costs and operations at specific airport locations. The Agency also used this information for the industry economic profile and to determine the economic impacts of the rule.

3.3.3 Questionnaire Review, Coding, and Data Entry

EPA reviewed the screener and the two detailed questionnaires for completeness, accuracy, and consistency of the responses. In some cases, the Agency followed up with the airport or airline by email or telephone to clarify responses or to obtain missing or incomplete

information. During the review, EPA coded responses to facilitate entry of data into the airline screener and the airline and airport questionnaire databases.

The Agency developed databases containing the information provided by questionnaire respondents of each questionnaire. After detailed review and coding, EPA entered data from the questionnaires into the appropriate database using a double-key-entry and verification procedure to identify and resolve differences between the two data entry tasks.

3.4 Field Sampling

EPA conducted sampling episodes at six airports from March 2005 through August 2006 to characterize ADF and ADF-contaminated stormwater discharges and to evaluate treatment technologies for stormwater affected by aircraft and airfield deicing practices. EPA used existing industry profile information and information collected during airport site visits to determine the most appropriate locations for sampling. The Agency evaluated the following criteria for selecting sampling sites:

- Size and location of the airport;
- Deicing stormwater collection and control practices; and
- ADF-contaminated stormwater discharge practices.

EPA conducted the episodes to characterize deicing stormwater and assess the capabilities and effectiveness of several different treatment technologies such as anaerobic treatment, aerobic treatment, distillation, reverse osmosis, mechanical vapor recompression, aeration, and chemical addition. Table 3-3 lists the airports selected for EPA sampling, the reason for selection, and the points that were sampled.

3.5 Permit Review

During the regulatory development process, EPA reviewed National Pollutant Discharge Elimination System (NPDES) permits to understand what permit authorities are currently requiring of airports with respect to deicing stormwater control. Using the data gathered during the permit review assisted EPA in:

1. Assessing the current state of deicing stormwater control;
2. Evaluating the effectiveness of various deicing stormwater control measures; and
3. Identifying potential measures that EPA could use to further control deicing stormwater.

Table 3-3. Airports Selected for Sampling and the Reason for Their Selection

Airport Name	Airport Code	Dates of Sampling	Reason for Sampling	Sample Points
Detroit Metropolitan Wayne County Detroit, MI Episode 6508	DTW	3/31/05	Collects highly concentrated ADF for recycling, significant stormwater volumes, direct and indirect discharger	• Untreated deicing stormwater • Effluent from ADF-contaminated stormwater collection pond • Effluent from pavement deicer stormwater collection pond • ADF, as applied • Quality control (QC) samples ¹
Minneapolis/St. Paul International Minneapolis/St. Paul, MN Episode 6509	MSP	4/28/05	On-site collection and recycling facility, direct and indirect discharger	• High concentration ADF-contaminated stormwater storage tank • Low concentration ADF-contaminated stormwater storage tank • Influent to pavement deicer stormwater collection pond • Effluent from pavement deicer stormwater collection pond • ADF, as applied • QC samples ¹
Albany International Albany, NY Episode 6523	ALB	2/5/06-2/10/06	Reported recovery efficiency of 72% of applied ADF through collection and treatment (anaerobic and aerobic) of ADF-contaminated stormwater	• Influent to anaerobic treatment • Effluent from anaerobic treatment • Effluent from aerobic treatment • QC samples ¹
Pittsburgh International Pittsburgh, PA Episode 6528	PIT	2/26/06-3/3/06	Reported recovery efficiency of 60-66% of applied ADF through collection and treatment (ultrafiltration and reverse osmosis (RO)) of ADF-contaminated stormwater	• Influent to RO treatment • Effluent from RO treatment • QC samples ¹
Denver International Denver, CO Episode 6522	DEN	3/26/06-3/31/06	ADF-contaminated stormwater collection with glycol recovery	• Influent to mechanical vapor recompressions (MVRs) • Influent to distillation column • Distillate from MVRs • Overhead from distillation column • Effluent from treatment • QC samples ¹
Greater Rockford Rockford, IL Episode 6529 and 6530	RFD	4/20/06 and 8/29/06	On-site aerated lagoon treatment system (run in batch mode) for its deicing-contaminated stormwater	<u>Spring Sampling</u> • Influent to aerobic pond treatment • QC samples ¹ <u>Summer Sampling</u> • Effluent from aerobic pond treatment • QC samples ¹

3.5.1 *Airport Selection for Permit Review*

For this review, EPA selected the top 50 U.S. airports based on ADF usage. At the time of review, usage estimates from the airline survey were not available; therefore, EPA estimated the airports with the highest usage using a “weighting factor” based on the number of snow or freezing precipitation (SOF) days and commercial departures as a measure of ADF usage. Table 3-4 displays the results of the weighting factor analysis and lists the 50 airports for which EPA reviewed permits.

3.5.2 *Obtaining NPDES Permits*

From the list of selected airports for permit review, EPA identified those for which it already had permits. While airports were not required to submit permits as part of their questionnaire response, some airports did so. Furthermore, there were some permits already available in the airport deicing record files. Therefore, as a first step, EPA reviewed available documentation and survey responses to identify in-house permit availability.

As a next step, EPA identified NPDES permit numbers for those permits not available in-house. Some airports reported permit numbers in the airport questionnaire, so in these cases, EPA obtained the data from the questionnaire database. For the remaining airports, EPA searched its Envirofacts search tool by facility name, location, SIC code (4581), or a combination of any of the three to obtain the permit numbers.

After identifying the permit numbers, EPA obtained a copy of the permit from a state or regional permit database. If a permit was not available online, EPA contacted the appropriate regional, state, or local permitting authority to obtain a copy. If still unsuccessful in obtaining the permit, EPA contacted the airport directly to request a copy.

There were a few airports for which EPA could not identify permit numbers from either the questionnaires or Envirofacts. For these airports, EPA searched the Internet or contacted permitting authorities or the airports directly to obtain a copy of the permit.

3.5.3 *Permit Review Process*

The objectives of the permit review were to answer the following questions:

- What are the monitoring requirements for deicing area outfalls?
- What pollutants are monitored?
- Are there numeric limits listed in the permit for deicing area outfalls?
- What parameters are limited?
- What are the limits for each parameter?
- How were the limits developed?
- Are there deicing operation best management practices (BMPs) required by the permit?
- What BMPs are required?
- When does the permit expire?
- If it is a general permit, are there differences between the permit and the EPA Multi-Sector General Permit (MSGP)?

Table 3-4. Top 50 Airports in the United States with the Highest ADF Usage, Estimated Based on SOFP Days and Total Airport Departures

Rank	Airport ID	Airport Code	Airport Name	State	SOFP Days	Total Airport Departures	Weighting Factor SOFP Days × Departures ÷ 100,000
1	1006	ORD	Chicago O'Hare International	IL	26	467,721	121.6
2	1126	MSP	Minneapolis /St Paul International – Wold-Chamberlain	MN	41	246,286	101.0
3	1138	DTW	Detroit Metropolitan Wayne County	MI	31	250,629	77.7
4	1028	DEN	Denver International	CO	26	264,051	68.7
5	1012	ANC	Ted Stevens Anchorage International	AK	55	88,126	48.5
6	1053	BOS	General Edward Lawrence Logan International (Boston)	MA	26	186,253	48.4
7	1113	CVG	Cincinnati/Northern Kentucky International	KY	17	247,165	42.0
8	1069	CLE	Cleveland – Hopkins International	OH	36	116,569	42.0
9	1142	IAD	Washington Dulles International	DC	17	238,635	40.6
10	1107	PIT	Pittsburgh International	PA	31	125,143	38.8
11	1145	EWR	Newark Liberty International	NJ	16	203,082	32.5
12	1095	MDW	Chicago Midway International	IL	26	108,385	28.2
13	1139	PHL	Philadelphia International	PA	12	227,749	27.3
14	1136	MKE	General Mitchell International (Milwaukee)	WI	31	85,128	26.4
15	1029	LGA	La Guardia (New York City)	NY	12	192,127	23.1
16	1066	SLC	Salt Lake City International	UT	14	160,472	22.5
17	1010	FAI	Fairbanks International	AK	89	24,919	22.2
18	1011	STL	Lambert - St Louis International	MO	17	129,414	22.0
19	1148	MCI	Kansas City International	MO	27	76,016	20.5
20	1021	BUF	Buffalo Niagara International	NY	48	41,916	20.1
21	1089	JFK	John F Kennedy International (New York City)	NY	12	154,606	18.6
22	1024	IND	Indianapolis International	IN	21	83,769	17.6
23	1141	DCA	Ronald Reagan Washington National	DC	12	134,346	16.1
24	1129	BDL	Bradley International (Windsor Locks)	CT	31	51,389	15.9
25	1059	ROC	Greater Rochester International	NY	44	35,726	15.7

Table 3-4 (Continued)

Rank	Airport ID	Airport Code	Airport Name	State	SOFP Days	Total Airport Departures	Weighting Factor SOFP Days × Departures ÷ 100,000
26	1111	CMH	Port Columbus International	OH	26	59,938	15.6
27	1036	BWI	Baltimore - Washington International	MD	12	124,033	14.9
28	1026	DFW	Dallas/Fort Worth International	TX	4	360,933	14.4
29	1065	ALB	Albany International	NY	36	39,324	14.2
30	1080	SYR	Syracuse Hancock International	NY	44	30,840	13.6
31	1140	MEM	Memphis International	TN	8	166,910	13.4
32	1128	CLT	Charlotte/Douglas International	NC	6	214,396	12.9
33	1079	MHT	Manchester	NH	36	34,860	12.5
34	1058	GRR	Gerald R Ford International (Grand Rapids)	MI	48	25,015	12.0
35	1037	IAH	George Bush Intercontinental (Houston)	TX	4	248,339	9.9
36	1123	DAY	James M Cox Dayton International	OH	26	35,709	9.3
37	1020	ATL	Hartsfield - Jackson Atlanta International	GA	2	459,765	9.2
38	1121	PVD	Theodore Francis Green State (Providence)	RI	21	43,671	9.2
39	1147	RDU	Raleigh - Durham International	NC	10	86,302	8.6
40	1068	OMA	Eppley Airfield (Omaha)	NE	26	33,022	8.6
41	1105	GEG	Spokane International	WA	31	27,269	8.5
42	1108	SDF	Louisville International - Standiford Field	KY	12	65,586	7.9
43	1124	DSM	Des Moines International	IA	31	23,951	7.4
44	1074	SBN	South Bend Regional	IN	48	13,722	6.6
45	1153	CAK	Akron - Canton Regional	OH	41	14,911	6.1
46	1109	ILN	Airborne Airpark (Wilmington)	OH	21	25,508	5.4
47	1018	GSO	Piedmont Triad International (Greensboro)	NC	14	38,257	5.4
48	1100	TOL	Toledo Express	OH	36	14,385	5.2
49	1022	FWA	Fort Wayne International	IN	31	16,247	5.0
50	1051	HYA	Barnstable Municipal - Boardman/Polando Field (Hyannis)	MA	26	18,782	4.9

EPA also consulted Envirofacts as necessary to fill in any numeric limit data gaps from the permits and to cross-check for accuracy with the permitted limits.

To facilitate interpreting the results, EPA created a Microsoft® Access database to store the data obtained from the reviews. The database consists of two tables: a General Information table, and a Pollutant-Specific Information table. Table 3-5 and Table 3-6 detail the database table descriptions. A summary of the permit review is presented in the memorandum *Airport Deicing Operations NPDES Permit Review Summary* (ERG, 2007).

Table 3-5. Permit Review General Information Table

Data Element	Data Element Description
AirportID	The airport identification number used for the Airport Questionnaire
Permit_ID	The airport NPDES identification number
Permit_Expiration	The permit expiration date
Permit_BMPs	A checkbox that identifies the presence of BMPs in the permit
Permit_BMPs_Description	A field that allows the BMPs in the permit to be listed
General_Permit	A checkbox that identifies general permits
General_Permit_Difference from MSGP	A field that describes any differences that exist between general permits and the MSGP
Permit_Monitoring	A checkbox that indicates if the permit requires monitoring
Permit_Limits	A checkbox that indicates if the permit has numeric limits
Permit_Limit_Rationale	A field that describes what rationale was used to determine the limits in the permit

Table 3-6. Permit Review Pollutant-Specific Information Table

Data Element	Data Element Description
AirportID	The airport identification number used for the detailed airport questionnaire.
Permit_SamPoint	The outfall/sampling area identifying number.
Permit_Stream_Description	The description of the outfall/sampling area. EPA tried to determine which outfalls receive deicing stormwater and to include only information from those outfalls. If the deicing outfalls cannot be determined, EPA included all outfalls.
Permit_Pollutant	The pollutants that are monitored and/or limited at each outfall, using the following same codes that are used in the questionnaire database: • BOD • COD (chemical oxygen demand) • Fecal coliform • Metal • N (nitrogen) • OG (oil & grease) • ORG (organic pollutants) • pH • TOC (total organic carbon) • TSS • Other
OtherDesc	If a pollutant is monitored/limited that does not have a code, “Other” was selected as the Permit_Pollutant and the pollutant name was entered in this field. This method of tracking pollutants was used to be consistent with the questionnaire database.
PermitTimes	To be consistent with the questionnaire database, the frequency of monitoring for each pollutant and outfall was recorded in the PermitTimes and PermitFreq fields. These fields allow the frequency to be reported in a number/unit manner. For example, a yearly report is entered as PermitTimes = 1 and PermitFreq = Year. Frequency Codes were also used in the PermitFreq field for daily (D), monthly (M), and quarterly (Q) reports.
PermitFreq	
PermitLimitNumeric	The numeric value of the permit limit for each pollutant and outfall.
PermitLimitUnit	The unit of the permit limit for each pollutant and outfall.
LimitType	Indicates whether the limit is a minimum value, maximum value, average, or simply a reporting requirement. This also incorporates the time span of the limit using the frequency codes as above (e.g., daily maximum = DMAX; weekly average = WAVG).
Season	For deicing outfalls, the limits may vary by season for various parameters. Usually, this field is populated with Summer, Winter, or All (as in year-round).

3.6 Deicing Pad Costs

To evaluate the potential financial impacts of deicing pads for new airports, EPA reviewed deicing pad cost information received from airports. EPA collected deicing pad costs from Pittsburgh International airport and Minneapolis/St. Paul airport during the site visits, and information was provided by Akron-Canton Regional airport via email on May 3, 2007, and from Cleveland-Hopkins International airport as part of comments in its airport questionnaire response.

3.7 Industry-Submitted Data

Based on airport site visits, EPA sampling episodes, and responses to the airport questionnaire, EPA requested costing and long-term analytical data for managing deicing stormwater from specific airports. The Agency used this information to develop control technology options and compliance cost estimates, and to evaluate pollution prevention and best management practices.

Table 3-7 and Table 3-8 list those airports providing data, the type of system used to manage or treat the airport's deicing stormwater, and the costing and/or analytical data submitted by the airport.

Table 3-7. Summary of Costing Data Provided by Industry

Airport	Type of Deicing Stormwater Management	Costing Data Provided
Akron-Canton Regional	Anaerobic ADF-contaminated stormwater treatment system	Capital and operating and maintenance costs for the airport's new anaerobic fluidized bed (AFB) treatment system
Albany International	AFB/aerobic ADF-contaminated stormwater treatment system	Capital and operating and maintenance costs for the airport's AFB/aerobic treatment system
Cincinnati/Northern Kentucky International	Glycol recovery and recycling system	Capital and operating and maintenance costs for glycol collection and treatment
Denver International	Storage, recovery, and recycling; MVR and distillation system	Capital costs for storage and the recycle/recovery system
General Mitchell International	Recovery and recycling; anaerobic digester	Engineering and monitoring-related costs
Minneapolis/St. Paul International –Wold Chamberlain	ADF collection (deicing pads, plug and pump system)	Capital costs for deicing pads and operating and maintenance costs for plug and pump system
Pittsburgh International	ADF collection at deicing pads; ADF-contaminated stormwater recovery and recycling	Operating and maintenance costs for deicing pads
Seattle-Tacoma International	ADF to industrial waste treatment plant	Study costs for determining all known and reasonable technology (AKART) for handling aircraft deicing fluids

Table 3-8. Summary of Long-Term Analytical Data Provided by Industry

Airport	Type of Deicing Stormwater Management	Long-Term Analytical Data Provided
Albany International	Anaerobic/aerobic ADF-contaminated stormwater treatment	Ammonia, COD
Denver International	Storage, recovery, and recycling; MVR/distillation	COD
Detroit Metropolitan – Wayne County	Recycling; distillation and recovery	Ammonia
Pittsburgh International	Ultrafiltration/Reverse Osmosis; ADF-contaminated stormwater recovery and recycling	Ammonia, urea
Salt Lake City International	ADF recovery and recycling	COD

3.8 Literature Reviews

EPA conducted preliminary literature searches during the effluent guideline development process to supplement information acquired from site visits, sampling, and questionnaires. The purpose for the literature searches was three-fold:

- To collect information on current airport deicing practices and trends, and gather information on state-of-the-art deicing stormwater treatment and/or glycol recovery technologies;
- To collect available data from airports currently monitoring wastewater discharges; and
- To obtain studies on the toxicity and environmental impact of current deicing fluids and deicing discharges.

The following sections list the data sources used for each literature search.

3.8.1 *Current Deicing Practices and Treatment Technologies*

EPA performed keyword searches on three online search engines: 1) Cambridge Scientific Abstracts (CSA); 2) Dialog Version 5.0; and 3) Google™. CSA provides access to over 50 databases published by CSA and its publishing partners, such as Aqualine, Environmental Sciences & Pollution Management Database, and Water Resources Abstracts. Dialog provides access to over 900 databases and handles more than 700,000 searches. The databases in Dialog that contain articles pertaining to airport deicing are BIOSIS Toxicology, Life Sciences Abstracts, Institute for Science Information, ProQuest Info & Learning, Ei Compendex, Enviroline, TGG National Newspaper Index, GeoBase, National Technical Information Service (NTIS), and Wilson Applied Science & Technology Abs.

The keywords for the literature searches included: airport deicing, aircraft, airfield, runway, aircraft deicing, aircraft deicing fluid (ADF), runway deicing, anti-icing, anti-icing fluid, airport stormwater, snow melt, centralized deicing pads, environmental assessment, environmental impact study (EIS), fish mortality, fish kill, and publicly owned treatment works.

EPA also used other online journal databases, such as Science Direct, Scirus, and Infotrak, for subject-specific articles. The treatment technologies featured in the articles found included:

- AFB reactor/ biological treatment;
- Aerated storage tanks;
- Anaerobic co-digestion of ADF and municipal wastewater sludge;
- Batch-loaded AFB reactor;
- Glycol reclamation/recycling and concentration;
- Infrared technology;
- Phytoremediation;
- Plant-enhanced remediation;
- Spray irrigation;
- Subsurface-flow constructed wetlands; and
- Surface detention ponds.

3.8.2 *Current Airport Deicing Discharge Data*

In addition to sampling and airport questionnaire data, EPA procured airport deicing discharge information from its Permit Compliance System (PCS) database and online journals. EPA downloaded all data reports from PCS for SIC code 4581: Airports, flying fields, and services. Not all airports report this data to their permitting authority, so the scope of discharge data is limited. The pollutant parameters include temperature, dissolved oxygen, BOD, TSS, metals, fecal coliform, aromatic hydrocarbon, pH, and oil and grease. For online searches, EPA procured journals that discussed deicing discharge containing ADF chemicals such as benzotriazole, propylene/ethylene glycol, and alkylphenol ethoxylates. EPA also collected monitoring data during the site visit to the Minneapolis/St. Paul International Airport.

3.8.3 *Chemical Information and Environmental Impact Studies*

The methodology and databases used for chemical information and environmental impact study findings are similar to those used for the deicing practices and treatment technology search. EPA conducted searches for the following categories:

- **Chemical Properties of ADF Ingredients:** Physical appearance, structure, solubility, reactivity;
- **Human Toxicity:** Inhalation, ingestion, dermal effect, oral rat lethal dose (LD₅₀) values;
- **Aquatic Toxicity:** Aquatic life lethal concentration (LC₅₀) values; and
- **Chemical Fate and Transport:** Soil sorption, fate in river, streams, and estuaries, breakdown pathways in anaerobic and aerobic conditions, and biodegradability.

In addition to journal articles, EPA gathered chemical information from Material Safety Data Sheets (MSDSs), Chemfinder.com, the Pesticides Action Network (PAN) Pesticides Database, and the U.S. Patents Database.

The keywords for the pollutant term search included: PG, PG-based fluids, EG, EG-based fluids, urea, potassium acetate, calcium magnesium acetate (CMA), sodium acetate, sodium formate, dissolved oxygen, biodegradation, BOD, and ADF additives (e.g., tolytriazole, benzotriazole, nonylphenols, nonylphenol ethoxylate, etc.).

3.8.4 *Current Deicing Discharge Regulations*

In addition to the data sources described above, EPA searched the Internet using Google™ to review regulatory documents that contain guidelines, operation controls, management programs, laws, statutes, and certification requirements related to airport deicing from the United States, Canada, Germany, Norway, and other European countries.

3.9 Data Collected Based on Public Comments

EPA collected and received limited additional information as part of the public comment process. This section summarizes the information EPA collected as part of and in response to public comments on the proposed rule and the types of data provided as part of the public comments. Section 3.9.1 summarizes information that EPA collected to confirm deicing pad use and operations at major airports and data collected to supplement the costing effort in response to comment. Section 3.9.2 summarizes the types of data submitted as part of the public comments to the proposed rule.

3.9.1 *EPA-Collected Data*

EPA received comments on the proposed regulation that airports that had previously installed deicing pads did not use them for all flights that required deicing. EPA contacted the following airports in early August 2010 to confirm information on the airport's deicing pad use and operations:

- Minneapolis/St. Paul International Airport (MSP);
- Washington Dulles International Airport (IAD);
- Philadelphia International Airport (PHL);
- Detroit Metropolitan/Wayne County Airport (DTW);
- Denver International Airport (DEN);
- Cleveland-Hopkins International Airport (CLE);
- Salt Lake City International Airport (SLC); and
- Pittsburgh International Airport (PIT).

Table 3-9 summarizes the information collected for these airports.

EPA also collected additional post-proposal information as part of revisions to the costing analysis in response to specific public comments. Additional costing information collected by EPA included drainage cover data that it used in conjunction with existing cost data for Glycol Collection Vehicles (GCVs). The supplemental data collected to inform GCV costing is summarized in a memorandum entitled *Estimated Capital and Operation and Maintenance Costs for Glycol Collection Vehicle Operation* (ERG, 2010a). EPA also collected vendor data related to liquid application and storage of airfield deicing chemicals. These data are summarized in the memorandum entitled *Estimated Costs for Transition to Liquid Airfield Deicing Application from Solid Airfield Deicing* (ERG, 2010b). In addition, Section 10 presents the liquid application and storage of airfield deicing chemical cost data used in developing the final rule cost analysis.

Table 3-9. Selected Airport Information Related to Deicing Pad Operations

Airport	Deicing Pad Operations Data
Minneapolis/St. Paul International Airport	1. MSP encourages the use of deicing pads and requires deicing in contained locations only. ADF stormwater is contained through deicing pad use (and its collection system), block and pump, and cover and sweep (using glycol collection vehicles). There are no exceptions to the requirement for contained locations for deicing operations. 2. MSP estimates that 65-70% of ADF fluid used at the airport is sprayed at its deicing pads. The percentage of flights represented by this amount of ADF fluid use is much lower than 65-70%. The deicing pads are typically used for heavy deicing and not for defrost deicing. Delta, previously Northwest Airlines, deices at both the gate and at the deicing pads. Overall, they spray more deicing fluid at the pads than at the gates. This airline does not generally act as an FBO for other airlines but may be used as a deicing provider in a backup situation. The small airlines operating at the airport do not have personnel for deicing pad use. 3. If deicing is not done on the deicing pads, it is done at the gate. 4. Advantages of the MSP deicing pads include putting the deiced aircraft closer to the runway, which lowers the chance of missing ADF holdover times, and freeing up the gates for incoming flights.
Washington Dulles International Airport	1. Approximately 50% of the flights deiced at IAD are deiced on deicing pads. In addition, the airport requires that flights be deiced in areas of capture that may include glycol collection vehicles. 2. There are no specific requirements on where each airline has to deice their planes. The location of where each airline plans to deice is decided between the airlines at winter "snow meetings."
Philadelphia International Airport	1. All commercial aircraft except commuter aircraft (regional jets and turbo-props) must be deiced at the airport deicing pad, as specified in the airport's NPDES permit. 2. Aircraft defrosting is permitted at the gates with a usage limit of 20-40 gallons of ADF, as specified in the airport's NPDES permit. 3. Deicing of the plane is also permitted at the gate with no ADF usage limit, for required weight reduction or visibility enhancement, sufficient to safely taxi the aircraft to the deicing pad for final, pre-take-off ADF application.
Detroit Metropolitan/Wayne County Airport	1. DTW does not have a specific requirement forcing the airlines to deice aircraft at the deicing pads but does strongly encourage deicing pad use. 2. The airport estimates that approximately 90% of the airport traffic that is deiced uses the deicing pads. 3. The airport allows 747s to deice at the gates to free up the deicing pads for smaller aircraft. Airport study of this allowance shows that it achieves a higher net capture of ADF using this approach. The airport collects ADF stormwater from the 747 deicing using a glycol collection vehicle in conjunction with catch basin inserts.

Table 3-9 (Continued)

Airport	Deicing Pad Operations Data
Denver International Airport	1. DEN does not allow full-plane gate deicing, and does not track limited gate deicing operations specifically (other than to enforce the 25-gallon rule discussed in item 3. below). The airport tracks only the volume of fluid used on an airport-wide basis but estimates that 95% of deicing occurs on the dedicated deicing pads. DEN's largest carrier, United Airlines (UAL), does provide DEN (Environmental Services) with its fluid usage data, including by location. UAL's data show approximately 6% of its total fluid used was applied at the gates pursuant to DEN's 25-gallon operational allowance. UAL's data do not provide the number of flights deiced by location. On average, UAL accounts for approximately 27% of the total aircraft deicing fluid applied at DEN. 2. DEN is not aware of any specific instances of deicing outside the designated areas (pads, gates (limited), GA, South Cargo). If it did occur, it would be a very rare occurrence under special circumstances, and would require prior approval from the Manager of Aviation. 3. Limited deicing requirements are stipulated on page 6 of DEN Rule and Regulation Part 190 - Aircraft Deicing Regulations. The language does not specify for what purpose limited deicing may occur, only that "In no event may the total amount of deicing fluid used in a limited deicing exceed 25 gallons neat (undiluted) ADF per aircraft." DEN R&R Part 190 can be accessed directly at http://business.flydenver.com/info/research/rules/index.htm. 4. On a volume-only basis, for the 2008/2009 season, DEN data show approximately 5% of the total amount of deicing fluid used at DEN was applied at South Cargo and General Aviation (combined).
Cleveland-Hopkins International Airport	1. CLE estimates that 90% of deiced flights are deiced at deicing pads and the remaining 10% are deiced at the gate. Most of the air carriers are not allowed to deice at the concourse gates. 2. For those air carriers not allowed to deice at the gate, the airport does allow emergency deicing to unfreeze the wheels or other plane parts to allow the plane to move safely to the deicing pad.
Salt Lake City International Airport	1. At SLC, 95-98% of the deiced flights are deiced on pads and each major airline has its own dedicated deicing pad. 2. All deicing is to occur on the deicing pads except for specific circumstances that are typically delay related.
Pittsburgh International Airport	1. Aircraft deicing at the airport is required by consent decree to occur on deicing pads. Thus, 100% of deiced flights are deiced on the airport's pads unless doing so will result in a total loss of operations (e.g., major delays or if the deicing pad is out of ADF). The airport does allow gate deicing for both defrost and safety purposes. 2. PIT defines defrost deicing as "the removal of contamination (frost) from critical components of the airport that occurs when there is no active precipitation" and defines regular deicing as "the removal of contamination (snow/ice) that occurs when there is or has been active precipitation." 3. When an air carrier conducts gate deicing (instead of using the deicing pads), it must document why the deicing occurred at the gate.

3.9.2 *Data Submitted with Public Comments*

All comments received on the proposed airport deicing rulemaking are available in the docket. In assessing comments, EPA evaluated, and in some cases used, data or suggestions provided by specific commenters for the final rule analyses. While the data submitted by commenters were useful, in general, commenters provided very little analytical data on treatment or collection performance. Commenters, however, did provide some new data related to the costing analysis and on the feasibility of deicing pads. Section 10 summarizes the data used to develop EPA's final rule costs. As an example, EPA incorporated industry-supplied data on AFB capital costs versus COD loading in its final costing analysis (see Figure 10-1).

Comments by specific airports/port authorities on the proposed rule, including Boston-Logan International Airport and The Port of New York and New Jersey, included documentation supporting a claim that their airports are space-constrained and they would not be able to locate a deicing pad facility to comply with the proposed rule. EPA considered this data in developing the final rule and is no longer requiring collection of spent ADF at existing airports.

3.10 References

ERG. 2007. Memorandum from Jason Huckaby (ERG) to Brian D'Amico and Eric Strassler (U.S. EPA). *Airport Deicing Operations NPDES Permit Review Summary*. (April 16). DCN AD00611.

ERG. 2010a. Memorandum from Steve Strackbein and Mary Willett (ERG) to the Airport Deicing Administrative Record. *Estimated Capital and Operation and Maintenance Costs for Glycol Collection Vehicle Operation*. (October 8). DCN AD01249.

ERG. 2010b. Memorandum from Steve Strackbein and Mary Willett (ERG) to Brian D'Amico and Eric Strassler (U.S. EPA). *Estimated Costs for Transition to Liquid Airfield Deicing Application from Solid Airfield Deicing*. (October 8). DCN AD01252.

USEPA. 2000. *Preliminary Data Summary: Airport Deicing Operations*. U.S. Environmental Protection Agency. Washington, D.C. EPA-821-R-00-016. Available online at <http://www.epa.gov/guide/airport> . DCN AD00005.

USEPA. 2005. *Supporting Statement: Survey of Airport Deicing Operations*. U.S. Environmental Protection Agency. Washington, D.C. DCN AD00447.

USEPA. 2008a. *Airline Screener Questionnaire Database*. U.S. Environmental Protection Agency. Washington, D.C. DCN AD00937.

USEPA. 2008b. *Airline Detailed Questionnaire Database*. U.S. Environmental Protection Agency. Washington, D.C. DCN AD00938.

USEPA. 2008c. *Airport Questionnaire Database*. U.S. Environmental Protection Agency. Washington, D.C. DCN AD00927.

4. OVERVIEW OF THE INDUSTRY

This section provides an overview of the airport deicing/anti-icing performed by selected airports and airlines. The overview includes statistics on the number and location of airports and airlines that perform deicing/anti-icing (Section 4.1) and deicing and anti-icing practices performed on airfields and aircraft and methods used to collect and control deicing stormwater (Section 4.2).

4.1 Industry Statistics

Data sources for statistics on the number and types of airports and airlines include responses to EPA's airport and airline questionnaires, the Bureau of Transportation Statistics, FAA, and EPA's *Preliminary Data Summary: Airport Deicing Operations* (PDS) (USEPA, 2000). Data provided in responses to EPA questionnaires are based on deicing/anti-icing operations performed during the winter seasons of 2002/2003, 2003/2004, and 2004/2005, hereafter referred to as the three winter seasons.

4.1.1 *Airports*

The North American Industry Classification System (NAICS) identification number applicable to airport deicing is 488119: Other Airport Operations. The U.S. Census Bureau describes this industry as establishments primarily engaged in the following: (1) operating international, national, or civil airports or public flying fields, or (2) supporting airport operations, such as runway maintenance services, hangar rental, and/or cargo handling services.

The airport questionnaire data presented in this section are based on the 150 respondents to EPA's airport questionnaire. EPA applied weighting factors to the information provided by selected airport questionnaire recipients to scale up the questionnaire data to represent national estimates.

4.1.1.1 Number and Types of Airports

FAA's general categories of airports include commercial, general aviation, and relievers. *Commercial airports* are public airports receiving scheduled passenger service and having more than 2,500 enplaned passengers (number of passengers boarding a plane for departure) each year. *General aviation* airports have less than 2,500 enplanements per year or do not receive scheduled commercial service. *Relievers* are high-capacity general aviation airports in major metropolitan areas, and provide an alternative for small aircraft using busy commercial airports.

Airports may be further classified into several different categories, depending on the size and activity level of the airport. Often both of these factors can be determined by the number of enplanements or operations (number of arrivals and departures) at the airport in a given year. FAA classifies large commercial airports into "hubs," based on the number of annual enplanements that occur at the airport. Large Hubs are defined as airports with more than 1 percent of total U.S. passenger enplanements. Medium Hubs are defined as airports with more than 0.25 percent but less than 1 percent of total passenger enplanements. Small Hubs account for 0.05 to 0.25 percent of the total passenger enplanements. Airports with less than 0.05 percent of the total passenger enplanements but more than 10,000 annual enplanements are considered

Non-hub primary airports. Nonprimary commercial services are those airports that have 2,500 to 10,000 enplanements a year.

According to FAA 2004 data and the FAA's National Plan of Integrated Airport Systems (NPIAS) Report to Congress, about 3,344 airports operated in the United States in 2004. Table 4-1 identifies the number of airports by type as defined by number of enplanements. For all airport types, excluding general aviation airports, the totals in Table 4-1 represent counts for January through December 2004. FAA's designation of hub status depends on the percentage of total passenger boardings occurring at each airport, causing the number of airports in each hub category to vary from year to year.

Table 4-1. Number of U.S. Airports by Airport Type in 2004

Airport Type	Number of Airports
Large Hub	33
Medium Hub	36
Small Hub	67
Non-hub	231
Other Nonprimary	130
General Aviation ¹	2,573
General Aviation Relievers ¹	274
TOTAL	3,344

¹ General aviation and general aviation reliever airports (open to the public) from the NPIAS Report to Congress (USDOT, 2008a).

Note: Airport counts will differ depending on the source and year of data represented.

EPA distributed the airport questionnaire to 153 airports that included, based on 2004 information, all Large Hub, all Medium Hub, and a statistical sampling of Small Hub and Non-hub airports, as well as judgment sampling of some general aviation/cargo, and other nonprimary airports. EPA determined that one airport recipient was out of scope and removed it from the sample frame. EPA received responses from 150 of these airports. Using the airport responses and their statistical weights and including the cargo airports and Alaskan airport judgment samples, EPA estimated that the number of primary commercial airports nationally that perform deicing and/or anti-icing of airfield pavement and/or aircraft is 334.

4.1.1.2 Geographic Location of Deicing Airports

The location of the airport and its climate have a direct impact on deicing operations. Airport deicing/anti-icing operations occurred in 44 states in the three winter seasons. As shown below, the FAA divides the United States into the following nine regions:

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Region	State
Alaskan	AK
Central	IA, KS, MO
Eastern	DE, MD, NJ, NY, PA, VA, WV
Great Lakes	IL, IN, MI, MN, ND, OH, SD, WI
New England	CT, ME, MA, NH, RI, VT
Northwest Mountain	CO, ID, MT, OR, UT, WA, WY
Southern	AL, FL, GA, KY, MS, NC, PR, TN, VI
Southwest	AR, LA, NM, OK, TX
Western-Pacific	AZ, CA, HI, NV, GU, AS, MH

Source: FAA, “FAA Regional Offices,” http://www.faa.gov/about/office_org/headquarters_offices/arp/regional_offices/ (U.S. DOT, 2008b).

Table 4-2 summarizes the regions for the airports that reported deicing in the EPA airport questionnaire for the three winter seasons surveyed by EPA. (*Note: these are not national estimates.*) The Great Lakes and Eastern regions reported the highest number of deicing airports.

Table 4-2. Deicing Airports by FAA Region for the Three Winter Seasons

Region	Airports Reporting Deicing and/or Anti-Icing in EPA Airport Questionnaire
Great Lakes	31
Eastern	22
Southern	20
Northwest Mountain	17
Western-Pacific	15
Southwest	14
Alaskan	10
New England	6
Central	5

Source: EPA airport questionnaire database (USEPA, 2008c).

4.1.1.3 Weather Impacts on Airport Deicing/Anti-Icing

Airports conduct deicing/anti-icing operations when weather conditions, such as precipitation and/or temperature, have the potential to cause icing. Precipitation includes snowfall, rainfall, sleet (including freezing rain), and ice. The type of precipitation affects the volume and type of deicing/anti-icing chemicals used on aircraft and airfield pavement. For example, freezing rain requires the most deicing/anti-icing agent usage because the rain freezes on contact and coats the aircraft or airfield pavement to form a solid layer of ice. Dry-weather deicing, performed when the ambient temperature is cold enough to form ice on aircraft wings and surfaces (below 55° F), generally requires only a small volume of ADF.

The duration of the deicing/anti-icing season is also determined by the climate at an airport location. Airfield pavement deicing can begin as early as September and continue through May in colder climates and/or areas with high numbers of snow or freezing precipitation days.

The national estimate of airports performing airfield pavement deicing is 215; this is lower than the national estimate of airports performing deicing operations overall because there are airports that have some aircraft deicing (usually defrost deicing) but no airfield pavement deicing. In general, these airports are located in warm and/or dry weather climates with minimal winter storm events. For months when airfield pavement deicing occurs, December, January, and February have the most occurrences of airfield pavement deicing, and September and May have the lowest. Figure 4-1 presents the percentage of these 215 airports deicing airfield pavement for each month. The time frame during which an airport conducts deicing during a typical winter season ranges from two to nine months, and a majority of airports typically conduct deicing/anti-icing operations for five months a season. For the three winter seasons surveyed by EPA, the average reported number of airfield pavement deicing days among these 215 airports ranges from 0.3 to 240 days.

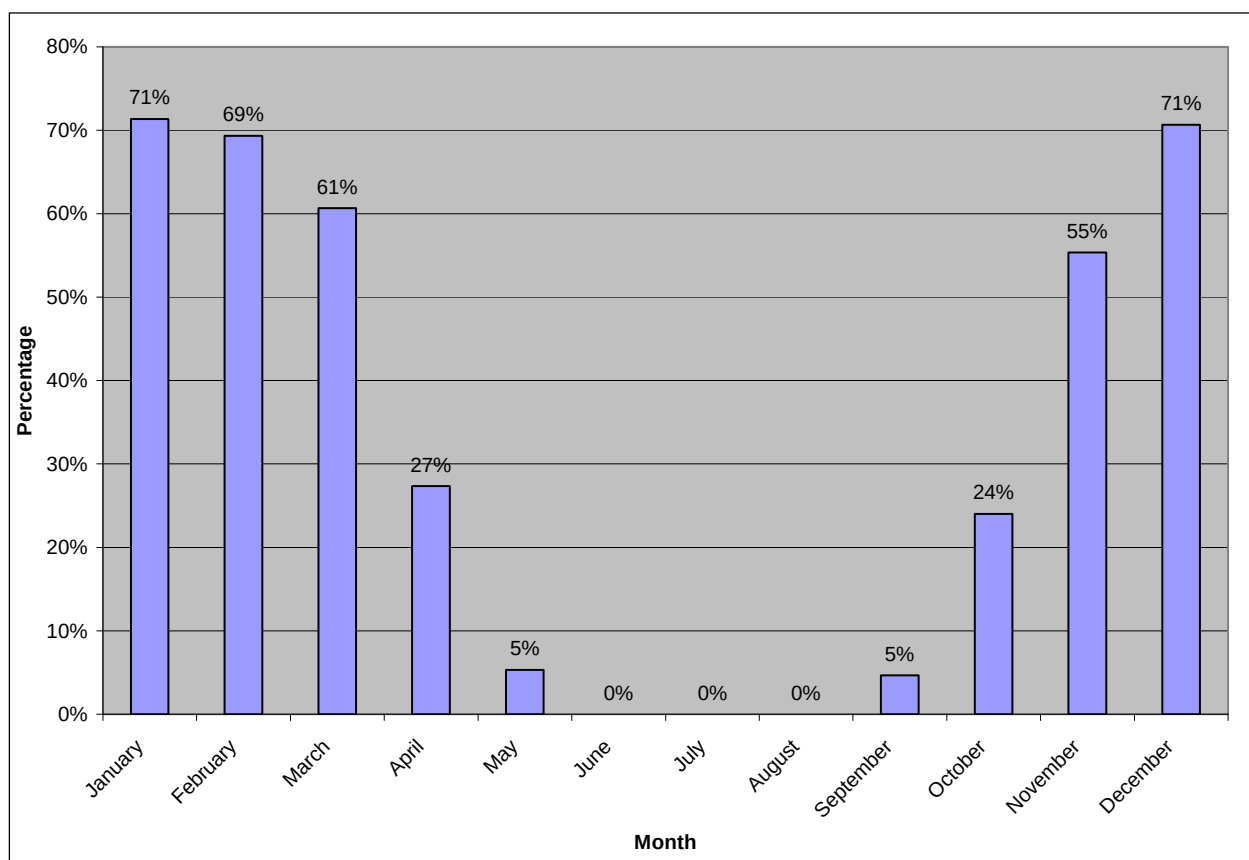


Figure 4-1. Percentage of Airports Deicing Airfield Pavement Each Month

4.1.1.4 Destination of Airport Deicing Stormwater

Airport questionnaire respondents reported direct, indirect, and zero discharge of deicing stormwater. Direct dischargers discharge deicing stormwater directly to U.S. surface waters, such as creeks, rivers, ponds, lakes, or oceans. Indirect dischargers convey deicing stormwater by pipe, conduit, or hauling to a publicly owned or other treatment works. A zero discharger disposes of deicing stormwater using methods other than direct or indirect discharge. Figure 4-2 presents the reported discharge status of airports by destination. Scaling the questionnaire data to a national estimate results in 176 airports discharging to surface water only, 52 airports

discharging both directly to surface water and indirectly to a POTW, 10 airports discharging to a POTW only, and 96 airports reporting zero discharge.

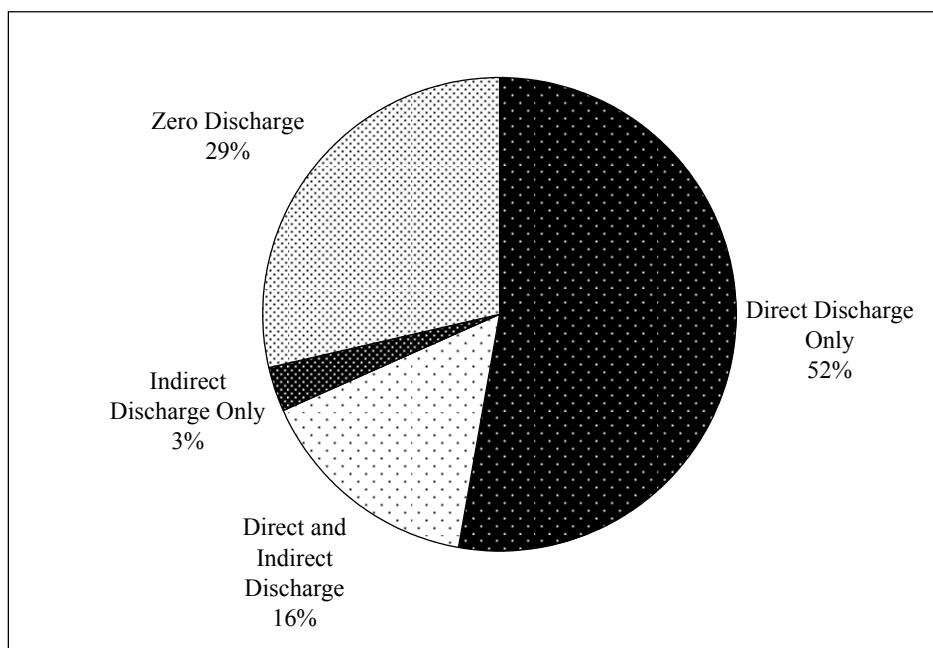


Figure 4-2. Discharge Status of Airports

A majority of the zero dischargers reported conducting aircraft deicing only (i.e., no deicing of airfield pavement). These airports generally are in warm and/or dry weather climates and have minimal dry weather (defrost) deicing. Airports reported various methods for maintaining zero discharge that included evaporation, storage in surface impoundments, contract hauling, and recycle/recovery of deicing stormwater. The most common zero discharge method reported was evaporation followed by discharge to a surface impoundment and the “other” category. The methods identified as “other” zero discharge techniques included, infiltration, discharge to tundra over permafrost, use of drain covers and sorbent material, and use of BMPs.

Even though over 100 airports indicated that they do not have any direct discharge (96 zero discharge and 10 POTW only) of ADF-contaminated stormwater, EPA believes that fugitive ADF emissions from overspray and tracking and dripping, during taxiing and takeoff, are difficult if not impossible to track and will likely result in direct discharges, albeit potentially small ones.

4.1.2 Airlines

The NAICS code for airlines is 481: Air Transportation. Specific NAICS codes for respondents to the airline deicing questionnaires are: (1) 481111: Scheduled Passenger Air Transportation, described by the U. S. Census Bureau as establishments primarily engaged in providing air transportation of passengers or passengers and freight over regular routes and on regular schedules; and (2) 481112: Scheduled Freight Air Transportation, described by the U.S. Census Bureau as establishments primarily engaged in providing air transportation of cargo without transporting passengers over regular routes and on regular schedules.

The airline data presented in this section are based on the 49 respondents to EPA's airline detailed questionnaire and additional information from the 70 respondents to EPA's airline screener questionnaire. Statistics for airlines do not have weighting factors and are based on the actual number of respondents.

4.1.2.1 Types of Airlines

The four classifications of airlines are major, national, regional, and cargo and are based on the type of service they offer and their annual revenues. Classification is based on the economic and financial aspects of each airline's aircraft fleet. Table 4-3 lists the criteria for the four classifications.

Table 4-3. Airline Classifications

Airline Type	Annual Revenues	Type of Service	Aircraft Fleet
Major	>\$100 million	Regular schedules	Large jets: >60 seats Payload >18,000 lbs
National	\$100 million to \$1 billion	Regular schedules	Medium and large jets
Regional: Large Medium Small (commuters)	\$20 million to \$100 million <\$20 million No revenue cut-off	Limited to single U.S. region Scheduled Scheduled Scheduled	>60 seats Lesser or greater than 60 seats <30 seats
Cargo	No revenue cut-off	Scheduled	Passenger aircraft with seats removed

Source: *Preliminary Data Summary: Airport Deicing Operations* (Revised) (USEPA, 2000).

There were 20 major airlines in the United States in 2006. Many national airlines typically serve multiple U.S. regions whereas regional airlines are generally limited to a single region of the country.

Small regional airlines are the largest segment of the regional airline business. Regional airlines may be private business carriers, commercial airlines, charter airlines, or provide a combination of these services. Private business carriers represent about 60 percent of regional airline flights. Regional airlines serve all airports served by major airlines as well as smaller airports that are not served by any major airline. They typically operate out of one gate area unless they are affiliates of major airlines and operate at the gates of their affiliate. Regional airlines conduct a disproportionately large number of flight operations per passenger because their aircraft are smaller and carry fewer passengers per operation.

All respondents to the airline detailed questionnaire reported conducting deicing/anti-icing operations on their aircraft at a total of 57 airport locations.

4.1.2.2 Types of Airline/Airport Relationships

The relationship between airports and airlines regarding deicing operations is one of dependency and cooperation. Airports and airlines conduct deicing using chemical and nonchemical methods in the same airfield locations and both contribute pollutants to deicing stormwater. Airlines may conduct deicing on their own aircraft, deicing for other airlines, and/or

may also use FBOs. An airline's deicing methods must be approved by the FAA for air safety. Airports provide the collection and control systems to contain and/or treat deicing stormwater generated as a result of aircraft and airfield deicing. However, both airports and airlines implement pollution prevention practices such as evaluating application rates, using alternate chemicals, pretreating pavement and aircraft, and manually removing snow and ice to reduce the quantity of pollutants discharged and the amount of deicing stormwater generated.

4.2 Industry Practices

Airport deicing and anti-icing operations involve chemical and mechanical methods and are conducted at varied locations and by different entities. This section discusses these practices and pollution prevention methods used by airports and airlines as reported by respondents to the airport and airline deicing questionnaires.

4.2.1 *Airfield Deicing Practices*

Airfield pavement deicing/anti-icing removes or prevents the accumulation of frost, snow, or ice on runways, taxiways, aprons, gates, and ramps. These methods are typically conducted by airport personnel, FBOs, or private contractors using a combination of mechanical methods and chemical deicing/anti-icing agents. To reduce the quantity of pollutants or the amount of deicing stormwater generated, airports also use various pollution prevention measures.

Responses to EPA's airport questionnaire indicated that 67 percent of airports have the primary responsibility for airfield pavement deicing/anti-icing.

4.2.1.1 Chemical Deicing/Anti-Icing

The type of precipitation and temperature affect the volume and type of deicing agents required for deicing/anti-icing. Common pavement deicing/anti-icing agents used at airports include potassium acetate, sand, airside urea, sodium acetate, glycol-based fluids, and sodium formate, as reported by respondents to EPA's airport questionnaire. Potassium acetate and PG-based fluids were reported as the top deicing/anti-icing chemicals (by weight) used on airfield pavement during the three winter seasons surveyed by EPA; some respondents also reported using a mixture of these agents as well as heated sand. Table 4-4 provides national estimates of the number of airports using these agents. Airports purchase primarily ready-to-apply rather than concentrated formulations of these chemicals. See Section 6.1 for a detailed discussion of deicing chemical usage.

Table 4-4. National Estimate of Airports Using Deicing Chemicals or Materials

Deicing/Anti-Icing Chemical or Material	Number of Airports Using Deicing Chemical/Material			Average	Percentage of Airports Using Deicing Chemical/Material
	2002/2003	2003/2004	2004/2005		
Potassium Acetate	94	104	111	103	31
Sand	103	104	98	102	30
Airside Urea	58	60	59	59	17
Sodium Acetate	39	34	33	35	10
PG-Based Fluids	16	16	16	16	5
Sodium Formate	22	1	23	15	5
EG-Based Fluids	6	6	6	6	2

Source: EPA airport questionnaire responses (scaled to national estimates) (USEPA, 2008c).

4.2.1.2 Mechanical and Nonchemical Deicing/Anti-Icing

Mechanical methods, such as plows, brushes, blowers, and shovels for snow removal, are the primary forms of airfield pavement deicing and may be used in combination with chemical methods. One facility uses heated pavement through pavement temperature sensors to prevent airfield pavement from icing. All of the 215 airports that conduct pavement deicing use some form of chemical, while an estimated 212 (99 percent) use mechanical methods as well on airfield pavement.

4.2.2 Aircraft Deicing Practices

Aircraft deicing involves removing frost, snow, or ice from aircraft. Aircraft anti-icing entails preventing frost, snow, or ice from accumulating on aircraft surfaces. Both chemical and nonchemical deicing/anti-icing methods are conducted on aircraft at varied airport locations and by different entities. The FAA also influences aircraft deicing, as it has approval authority for the deicing/anti-icing practices and procedures selected. Airlines and FBOs also perform pollution prevention practices similar to airports to reduce the quantity of pollutants discharged and/or reduce the amount of deicing stormwater generated.

Aircraft deicing may be conducted by an airline, FBO, or private contractor. Often, larger airline carriers deice their own aircraft and possibly the aircraft of other airlines. In addition, the entity conducting aircraft deicing for an airline may vary depending on the airport location. All of the airline questionnaire respondents reported deicing their own aircraft at one or more of their airport locations. Airline respondents also reported FBOs and/or another airline deiced their aircraft (84 percent and 56 percent, respectively) at some of their airport locations.

Aircraft deicing is conducted at a variety of airport locations and may be conducted at multiple types of locations at the same airport. Aircraft deicing is most commonly performed at deicing pads and terminal gates and apron areas. Airline respondents reported aircraft deicing at the following locations (the percentage of the airline respondents reporting using the specific type of location is in parentheses):

- Deicing pad (80 percent);
- Passenger terminal gates/apron areas (78 percent);
- Aircraft parking aprons (46 percent);
- Airfield ramps (42 percent);
- Taxiways (24 percent);
- Cargo apron areas (16 percent); and
- Other locations (12 percent) (e.g., hangar).

4.2.2.1 Chemical Deicing/Anti-Icing

The type of precipitation and temperature influences the volume and type of deicing chemicals required to deice/anti-ice aircraft. Two types of aircraft deicing are conducted: wet-weather and dry-weather. Wet-weather deicing is conducted when snow, sleet, or freezing rain accumulates on the aircraft. Dry-weather deicing is conducted when frost or ice forms on the aircraft due to changes in the ambient temperature or when fuel tanks become cooled during high-altitude flight, forming ice at lower altitudes and after landing. Dry-weather deicing requires significantly smaller volumes of ADFs than wet-weather deicing.

Aircraft deicing/anti-icing chemicals are categorized into four classes: Type I, Type II, Type III, and Type IV. Not all types are currently used. Airlines surveyed by EPA reported consistently using only Type I and Type IV fluids. ADFs vary by composition and allowable holdover times (i.e., the amount of time the residual fluid protects aircraft from ice formation). They generally contain either EG or PG, water, and additives to remove or prevent ice and snow. Type I ADF is used to remove ice and snow that has accumulated on aircraft, and Type IV fluids are used for anti-icing to increase holdover times for an aircraft prior to takeoff. Deicing fluids are usually heated prior to application, while anti-icing fluids are typically applied at ambient temperatures.

All fluids are usually applied under pressure using a nozzle, often from mobile deicing trucks (as reported by 31 airlines). Below are additional types of ADF application equipment used, as reported in responses to the airline questionnaire:

- Other equipment (e.g., brooms, ground sprayer and ladder, palletized equipment and fork lift, towed tower, small portable unit, self-contained mobile unit);
- Fixed booms; and
- Handheld bottle/containers.

Table 4-5 identifies the types of ADF fluids purchased by airlines that deiced their own aircraft during the three winter seasons, as well as the average across those seasons, based on the 49 airline respondents to the airline detailed questionnaire. Table 4-6 lists the ADF fluids purchased by an FBO during the three winter seasons and the average across those seasons, as reported in the airline questionnaire. As shown in the tables, Type I and Type IV PG are the most commonly purchased ADF fluids for deicing aircraft, both by airlines that deice their own aircraft and airlines that use FBOs.

Table 4-5. Deicing/Anti-Icing Chemicals Purchased by Airlines that Deiced Their Own Aircraft

Deicing/Anti-Icing Chemical	Number of Airlines Purchasing Chemicals			Average Number of Airlines Purchasing Chemicals
	2002/2003	2003/2004	2004/2005	
Type I PG	29	29	28	29
Type IV PG	22	22	23	22
Type I EG	8	8	8	8
Type IV EG	6	5	4	5
Type II PG	0	0	1	1

Source: EPA airline detailed questionnaire database (USEPA, 2008b).

Table 4-6. Deicing/Anti-Icing Chemicals Purchased for Aircraft Deiced by an FBO

Deicing/Anti-Icing Chemical	Number of Airlines for Chemicals Purchased by an FBO			Average Number of Airlines for Chemicals Purchased by an FBO
	2002/2003	2003/2004	2004/2005	
Type I PG	35	36	39	37
Type IV PG	31	35	37	34
Type I EG	17	13	13	14
Type IV EG	13	9	9	10
Type II PG	0	2	1	1
Type II EG	0	0	1	1

Source: EPA airline detailed questionnaire database (USEPA, 2008b).

4.2.2.2 Mechanical and Nonchemical Deicing/Anti-Icing

Mechanical and other nonchemical methods used to deice aircraft include brooms, ropes, hot water, infrared heating, and forced air. Brooms and ropes are not the primary method of aircraft deicing, especially wet-weather deicing, because they are so time- and labor-intensive, but rather are used in combination with chemical deicing. Forced air/hot air systems are used to blow or melt snow and ice from aircraft surfaces. Infrared heating deicing systems consist of an open hangar-type structure with infrared generators suspended from the ceiling. The infrared wavelengths are targeted to heat ice and snow and minimize heating of aircraft components. This system reduces the volume of ADF fluid required, but cannot provide anti-icing protection. Aircraft may also be stored in a hangar to prevent snow or ice from accumulating if a storm event is predicted. The most common mechanical and nonchemical methods of deicing/anti-icing used by airline questionnaire respondents are mechanical methods and hangar storage. Table 4-7 and Table 4-8 summarize the use of these methods for deicing/anti-icing aircraft by airlines and by FBOs, respectively.

Table 4-7. Summary of Mechanical and Nonchemical Aircraft Deicing Methods Used by an Airline

Mechanical/Nonchemical Method	Number of Airlines			Average Number of Airlines
	2003/2004	2003/2004	2004/2005	
Mechanical (e.g., brooms, ropes)	22	21	21	21
Hangar storage	15	16	16	16
Forced air	9	7	7	8
Hot water	5	4	4	4
Infrared heating	1	1	1	1

Source: EPA airline detailed questionnaire database (USEPA, 2008b).

Table 4-8. Summary of Mechanical and Nonchemical Aircraft Deicing Methods Used By FBOs

Mechanical/Nonchemical Method	Number of Airlines			Average Number of Airlines
	2003/2004	2003/2004	2004/2005	
Mechanical (e.g., brooms, ropes)	10	10	10	10
Hangar storage	5	5	5	5
Forced air	4	5	5	5
Hot water	3	4	4	4
Infrared heating	0	0	0	0

Source: EPA airline detailed questionnaire database (USEPA, 2008b).

4.2.3 *Airport Deicing Stormwater Collection and Control*

Deicing and anti-icing operations are conducted at multiple locations at an airport, and the fluids are widely dispersed during and after application via ramp discharge, taxiway drippage, and residual on aircraft. Deicing stormwater is contained and collected using designated deicing areas, stormwater drainage systems, glycol recovery, storage tanks, containment ponds, and plug and pump systems. Typical sources of deicing stormwater are:

- Terminal gates and aprons/areas;
- Aircraft deicing pads;
- Taxiways;
- Airfield ramps;
- Runways;
- Cargo apron areas;
- Maintenance hangar ramps;
- Aircraft parking areas;
- Military bases; and
- ADF-contaminated snow dumps.

Table 4-9 summarizes the collection and control methods used by airports. Based on responses to the airport questionnaire, an estimated 246 U.S. airports use containment, collection, and/or conveyance measures to control the discharge of deicing stormwaters to surface waters and/or POTWs. Most of the airports use stormwater drainage systems and

containment ponds and basins. See Section 9.0 for detailed discussions of deicing stormwater collection and control methods used by the Airport Deicing Category.

Table 4-9. Summary of Airport Collection, Containment, and Conveyance Methods

Collection/Containment/Conveyance Method	Estimated Number of Airports	Percentage of Airports
Stormwater drainage system	211	63
Containment pond/basin	121	36
Aboveground/underground tank	57	17
Glycol collection vehicles/sweepers	54	16
Other (vegetated swales, snow melters, absorbant)	34	10
Plug and pump	29	9

Source: EPA airport questionnaire database (scaled to national estimate) (USEPA, 2008c).

EPA estimates that approximately half (46 percent) of the U.S. airports with deicing operations also operate systems to treat or recover their deicing stormwater. The treatment and recovery technologies reported by airports include equalization (46 percent), oil/water separation (5 percent), sand or other media filtration (4 percent), membrane separation (1 percent), and biological treatment (1 percent). Eight percent of the airports report using other types of treatment technologies, including MVR, aeration, and distillation. Section 7 describes these technologies in detail.

4.2.4 Pollution Prevention Practices

To reduce the quantity of pollutants discharged and the amount of deicing stormwater generated, airports implement various pollution prevention practices that control pollution from airport deicing chemicals (e.g., glycol), thus minimizing pollutant loads by reducing chemical usage. Physical snow removal, specialized employee training, and pretreatment of airfields in advance of precipitation are the most common practices used by airports for airfield pollution prevention. The national estimate of airports implementing one or more pollution prevention practices is 244. Table 4-10 summarizes EPA's national estimates of the number and percentage of airports that used airfield pollution prevention practices. See Section 7.4 for detailed descriptions of the pollution prevention practices used by airports.

Table 4-10. Summary of Airfield Pollution Prevention Practices

Pollution Prevention Practice	Estimated Number of Airports Using Practice	Percentage of Airports Using Practice
Specialized employee training	153	46
Pretreatment of airfield in advance of precipitation	101	30
Runway ice detection system	95	28
Enhanced weather forecasting	77	23
Heated sand	74	22
Evaluation of application rates of deicing fluids	56	17
Use of alternative chemicals	40	12
Use of prewet dry chemical constituents	32	10
Other	88	26

Source: EPA airport questionnaire database (scaled to national estimates) (USEPA, 2000c).

Airlines also implement pollution prevention practices at various airports. These practices control pollution from aircraft deicing chemicals and minimize pollutant loads. Specialized training, implementation of a pollution prevention policy, and physical snow removal are the most common pollution prevention practices used by airlines. Table 4-11 summarizes airline pollution prevention practices reported in response to the airline detailed questionnaire. See Section 7.4 for detailed descriptions of the pollution prevention practices used by airlines.

Table 4-11. Summary of Aircraft Pollution Prevention Practices

Pollution Prevention Practice	Number of Airlines Reporting Practice
Specialized employee training	43
Instituting pollution prevention policy	43
Physical removal of snow or freezing precipitation	31
Overnight pretreatment/storage of aircraft	30
Custom fluid blending	27
Enhanced weather forecasting	25
Evaluation of application rates of deicing fluids	24
Pretreating aircraft with hot water	9
Use of alternative chemicals	2
Other	30

Source: EPA airline detailed questionnaire database (USEPA, 2008b).

4.3 References

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USEPA. 2008c. *Airport Deicing Questionnaire Database*. U.S. Environmental Protection Agency. Washington, D.C. DCN AD00927.

5. DEICING CHEMICAL USE AND DEICING STORMWATER CHARACTERIZATION

This section summarizes EPA’s estimate of the amount of airfield and aircraft deicing/anti-icing chemicals currently in use by U.S. primary commercial airports and provides information on deicing stormwater pollutant characteristics to the extent possible. Deicing stormwater discharges are “weather-dependent” and they are, by nature, highly variable. In addition, deicing chemical disposition after its intended use is not fully understood. These chemicals may be lost to evaporation, dispersion, or soil absorption; collected; or released into the environment and discharged from the airport, but limited information is currently available on each of these disposition methods. This section presents the information EPA has collected on the types of pollutants present in deicing stormwater and their ranges of concentrations.

5.1 Deicing Chemical Usage

As discussed in Section 4, several deicing chemicals are commonly used at U.S. commercial airports. These chemicals are used for either airfield or aircraft deicing/anti-icing and their usages are described below.

5.1.1 *Airfield Chemical Use*

Pavement deicing/anti-icing removes or prevents frost, snow, or ice from accumulating on runways, taxiways, aprons, gates, and ramps. Airports use mechanical and chemical methods for this purpose. The more often-used method is mechanical removal, but because ice, sleet, and snow may be difficult to remove by mechanical methods alone, many airports also use sand and/or chemical deicing agents such as potassium acetate, sodium acetate, sodium formate, glycol-based products, or urea. Based on the data collected by EPA in the airport questionnaire, the most common airfield deicing chemical currently used by U.S. airports is potassium acetate (approximately 63 percent of airfield chemical usage by weight). Section 9, Table 9-6 presents the average amount of pavement deicing chemical usage in pounds per year by airport and by deicing chemical.

Table 5-1 lists the total estimated national average airfield chemical usage (based on data for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons) for primary commercial airports in the United States.

Table 5-1. U.S. Commercial Airports – National Estimate of Airfield Chemical Usage

Chemical	Estimated Total Airport Usage (tons/year)	Percentage of Chemical Usage
Potassium acetate	22,538	63
Propylene glycol-based fluids	3,883	11
Airside urea	4,127	12
Sodium acetate	3,100	9
Sodium formate	1,117	3
Ethylene glycol-based fluids	774	2

Source: EPA Airport Deicing Questionnaire Database (USEPA, 2008a)

5.1.2 Aircraft Chemical Use and Purchasing Patterns

There are four types of ADFs manufactured around the world, referred to by the aviation and chemical industries as Types I through IV. Of these, Type I and Type IV are commonly used at U.S. commercial airports. Type I ADF is used to defrost and deice aircraft and Type IV ADF is used to prevent icing from recurring (anti-icing) after initial deicing with a Type I ADF. ADFs contain a primary freezing point depressant (typically PG or EG) and other additives. ADFs work by adhering to aircraft surfaces to remove and/or prevent snow and ice accumulation by virtue of their depressed freezing points. Airports conduct two types of deicing: dry-weather deicing to remove frost and wet-weather deicing and anti-icing during precipitation such as snow, sleet (ice pellets), or freezing rain. Airports may also perform dry-weather deicing on some types of aircraft whose fuel tanks become super-cooled during high-altitude flight, allowing frost/ice to form on aircraft wings at lower altitudes and after landing. Based on the data collected by EPA in the airline detailed questionnaire, the most common ADF is Type I PG-based fluids (approximately 77 percent of ADF usage). In addition, U.S. airports have been trending towards using more PG-based fluids and less EG-based fluids. Table 9-3 in Section 9 presents EPA's estimates of ADF annual usage by airport based on the airline questionnaire responses and the estimation procedure outlined in that section.

Table 5-2 presents a national estimate of the average aircraft chemical usage by U.S. commercial airports by type of fluid.

Table 5-2. U.S. Commercial Airports – National Estimate of Aircraft Chemical Usage¹

Chemical	Average Total Airport Usage (million gallons/year) ²	Percentage of Chemical Usage
Type I PG ADF	19.305	77.1
Type IV PG ADF	2.856	11.4
Type I EG ADF	2.575	10.3
Type IV EG ADF	0.306	1.2

Sources: EPA Detailed Airline Questionnaire (USEPA, 2008b); Airport Deicing Loadings Database (USEPA, 2008c).

¹ EPA used the ADF purchase information to represent usage, per airline industry recommendations.

² Total gallons normalized to 100% PG/EG.

5.2 Deicing Stormwater Characterization

EPA evaluated data from a variety of sources to better understand the components of deicing chemicals and ADFs that collect in deicing stormwater. These data include:

- Information on the additives included in ADFs;
- Data collected during sampling of concentrated and diluted ADFs used at the Detroit Metropolitan Wayne County (DTW) and Minneapolis/St. Paul International (MSP) airports during the 2003/2004 deicing season;
- Data collected during sampling of deicing stormwater at the Albany International (ALB), Pittsburgh International (PIT), Denver International (DEN), and Greater Rockford (RFD) airports during the 2004/2005 deicing season;

- Current data for airports included in the PCS database; and
- Deicing stormwater data collected by EPA during the PDS, through site visits, or through industry or permit authority submissions.

Section 6 summarizes the types of pollutants found in deicing stormwater based on these sources.

5.2.1 *Airfield Deicing Chemicals and Associated Deicing Stormwater*

Most solid airfield deicing chemical products comprise a freezing point depressant (e.g., potassium acetate, sodium acetate) and minimal additives (e.g., corrosion inhibitors). Liquid airfield deicing chemical products comprise a freezing point depressant (e.g., potassium acetate, PG), water, and minimal additives. The airfield deicing products that include salts (i.e., potassium acetate, sodium acetate, and sodium formate) will ionize in water, creating positive salt ions (K^+ , Na^+) and BOD load as the acetate or formate ion degrades into carbon dioxide (CO_2) and water.

Urea is typically applied to pavement and runway areas in granular form. Urea degrades by hydrolysis to CO_2 and ammonia, which can be toxic to aquatic organisms even at very low concentrations. Once ammonia is formed, it either remains in solution as ammonia or its ionized form (NH_4^+), biologically converts to other nitrogen forms (e.g., NO_3 or N_2), or volatilizes to the air. The formation of ammonia is dependent on the pH and temperature of the receiving water. The higher the pH and temperature, the more ammonia is formed. Another potentially toxic by-product of urea degradation is nitrous acid, which reacts with secondary amines to form nitrosamines, many of which are known carcinogens.

EPA has limited data on airfield deicing stormwater alone (i.e., stormwater that does not also contain aircraft deicing area stormwater). Most of EPA's stormwater data include both airfield and aircraft deicing components. However, during sampling at DTW, EPA collected samples from the airport's runway and open area ponds (Pond 3 East and Pond 6). These ponds are not expected to contain aircraft deicing stormwater because a separate pond collects wastewater from the gate and deicing pad areas where the stormwater is expected to contain ADF. DTW sometimes uses sand and potassium acetate for runway traction and deicing in addition to their usual mechanical snow removal equipment. It does not use urea-based deicers.

Table 5-3 presents the sampling data from the two airfield/open area runoff ponds.

5.2.2 *Aircraft Deicing Chemicals and Associated Deicing Stormwater*

ADFs primarily comprise a freezing point depressant (typically PG or EG), additives, and water. Typical additives are thickening agents, wetting agents, corrosion inhibitors, buffer, and dye, which make up 1 to 4 percent of the fluid mass. Type IV fluids have higher concentrations of the freezing point depressant and greater viscosity so that the fluid stays on the aircraft until take-off.

Table 5-3. EPA’s Analytical Results for Pond 3E Effluent and Pond 6 Effluent, DTW

Analyte	Unit	Pond 3 East Effluent	Pond 6 Effluent
BOD ₅	mg/L	146	43.0
Chloride	mg/L	855	315
COD	mg/L	273	111
Nitrate/Nitrite (NO ₂ + NO ₃ -N)	mg/L	0.0400	0.110
Sulfate	mg/L	50.1	51.0
Total Dissolved Solids (TDS)	mg/L	1,790	833
Total Kjeldahl Nitrogen (TKN)	mg/L	1.51	0.990
TOC	mg/L	813	314
Total Phosphorus	mg/L	0.340	0.280
TSS	mg/L	150	149
Aluminum	µg/L	1,660	2,110
Aluminum, Dissolved	µg/L	ND (50.0)	64.5
Barium	µg/L	92.3	81.8
Barium, Dissolved	µg/L	77.5	66.5
Calcium	µg/L	96,600	69,400
Calcium, Dissolved	µg/L	91,000	63,500
Chromium ¹	µg/L	ND (10.0)	ND (10.0)
Copper ¹	µg/L	ND (10.0)	ND (10.0)
Iron	µg/L	3,630	4,390
Iron, Dissolved	µg/L	407	600
Magnesium	µg/L	20,300	17,400
Magnesium, Dissolved	µg/L	18,200	15,700
Manganese	µg/L	508	411
Manganese, Dissolved	µg/L	462	335
Molybdenum	µg/L	ND (10.0)	ND (10.0)
Molybdenum, Dissolved	µg/L	ND (10.0)	ND (10.0)
Sodium	µg/L	547,000	191,000
Sodium, Dissolved	µg/L	522,000	189,000
Titanium	µg/L	26.2	34.8
Zinc ¹	µg/L	41.4	43.8
Acetone	µg/L	ND (50.0)	ND (50.0)
PG - 1671 ²	mg/L	ND (10.0)	ND (10.0)
PG - 8015D ²	mg/L	ND (10.0)	ND (10.0)

Source: Final Sampling Episode Report Detroit Metropolitan Wayne County International Airport (DTW) (USEPA, 2006a).

¹ Pollutant listed by EPA as a priority pollutant. See 40 CFR Part 423, Appendix A.

² Number following analyte name refers to analytical method. 1671 is a Clean Water Act method and 8015D is a hazardous waste method promulgated under the Resource Conservation and Recovery Act (RCRA).

ND – Not detected (number in parentheses is reporting limit).

The actual composition of ADFs varies and information on specific additive compounds is usually considered proprietary by ADF manufacturers. EPA believes that typical ADFs most likely include the following components:

ADF Component	Composition (%)
PG or EG	50-88
Surfactant/wetting agent	About 0.5
Corrosion inhibitor/flame retardant	About 0.5
pH buffer	About 0.25
Dyes	<1
Water	Remainder

Source: *Environmental Impact and Benefit Assessment for Proposed Effluent Limitations Guidelines and Standards for the Airport Deicing Category* (ERG, 2009).

Despite limited public information, EPA has identified two main classes of additives widely used among ADF manufacturers. Alkylphenol/alkylphenol ethoxylates (AP/APEO) are nonionic surfactants used to reduce surface tension in aircraft deicers and triethanolamine is used as a pH buffer. (ERG, 2009). At the time of proposal of the rule, EPA also identified methyl-substituted benzotriazole (MeBT) as an ADF additive, which was used as a corrosion inhibitor/flame retardant. In conversations with ADF manufacturers since proposal, EPA has been told that the use of triazole compounds in ADF is being discontinued and that triazole use in European ADFs has been phased out. EPA also has information indicating that high molecular weight, nonlinear polymers may be used as thickening agents in ADFs (see *Aircraft Deicing Fluids* (ERG, 2007b) and various classes of dyes can be used to color the ADF. The classes of dyes identified as potentially used in ADFs include azo, xanthene, triphenyl methane, and anthroquinone dyes (see *Questions Regarding Pylam Dye Use in ADF* (ERG, 2007a).

Analyses conducted by the USGS at General Mitchell International (MKE) airport in Milwaukee, WI, and EPA's sampling programs have confirmed the presence of glycols, triazole compounds, and alkylphenol compounds in deicing stormwater. EPA collected deicing stormwater samples at MSP and DTW during the 2004/2005 winter season. At MSP, EPA collected samples of deicing stormwater from segregated high concentration and low concentration storage tanks. At DTW, Northwest collected its deicing stormwater from a March 24, 2005 deicing event into a portable "frac" tank, which was then sampled by EPA. Table 5-4 lists the constituents detected in these deicing stormwaters and their concentrations. During the 2005/2006 deicing season, EPA collected five consecutive days of samples of influent to and effluent from deicing stormwater treatment at ALB, PIT, DEN, and RFD. The sampled deicing stormwater at these airports, prior to treatment, shows a wide range of constituents and constituent concentrations among the airports, as shown in Table 5-5 and Table 5-6.

Table 5-4. MSP and DTW Grab Sample Data Summary for Collected Deicing Stormwater

Analyte	Unit	MSP High Concentration Storage Tank	MSP Low Concentration Storage Tank	DTW Northwest Frac Tank
Classical Pollutants				
Ammonia as Nitrogen (NH ₃ -N)	mg/L	ND (0.05)	ND (0.05)	0.790
BOD ₅	mg/L	115,000	8,000	140,000
Chloride	mg/L	45.0	27.0	25.0
COD	mg/L	358,000	16,000	332,000
Hexane Extractable Material (HEM)	mg/L	50.0	ND (5.00)	22.0
Nitrate/Nitrite (NO ₂ + NO ₃ -N)	mg/L	0.0950	<0.0600	0.240
Silica Gel Treated HEM (SGT-HEM)	mg/L	17.0	ND (5.00)	ND (6.00)
Sulfate	mg/L	21.2	13.6	20.3
TDS	mg/L	1,370	559	1,440
TKN	mg/L	13.5	5.61	71.1
TOC	mg/L	96,100	5,660	93,100
Total Phosphorus	mg/L	6.49	< 2.10	0.320
Total Recoverable Phenolics	mg/L	0.150	0.0375	<0.007
TSS	mg/L	89.0	19.5	11.5
Total and Dissolved Metals				
Aluminum	µg/L	525	508	ND (500)
Aluminum, Dissolved	µg/L	ND (500)	136	ND (500)
Antimony, Dissolved ¹	µg/L	201	ND (20.0)	ND (200)
Barium	µg/L	114	67.1	52.4
Barium, Dissolved	µg/L	36.4	61.9	46.9
Calcium	µg/L	68,200	35,200	127,000
Calcium, Dissolved	µg/L	59,600	34,500	125,000
Copper ¹	µg/L	ND (100)	37.6	ND (100)
Copper, Dissolved ¹	µg/L	ND (100)	16.4	ND (100)
Iron	µg/L	11,000	7,470	1,410
Iron, Dissolved	µg/L	4,960	6,030	1,370
Magnesium	µg/L	9,230	4,250	12,900
Magnesium, Dissolved	µg/L	8,490	4,080	13,000
Manganese	µg/L	887	317	433
Manganese, Dissolved	µg/L	756	308	423
Mercury ¹	µg/L	ND (40)	ND (2)	45.1
Mercury, Dissolved ¹	µg/L	ND (40)	ND (2)	68.7
Molybdenum	µg/L	19,100	794	15,900
Molybdenum, Dissolved	µg/L	19,000	771	16,000
Sodium	µg/L	48,700	18,700	22,800
Sodium, Dissolved	µg/L	48,100	18,600	19,200
Tin	µg/L	611	32.1	673

Table 5-4 (Continued)

Analyte	Unit	MSP High Concentration Storage Tank	MSP Low Concentration Storage Tank	DTW Northwest Frac Tank
Tin, Dissolved	µg/L	616	32.5	646
Titanium	µg/L	ND (100)	13.5	ND (100)
Zinc ¹	µg/L	492	291	119
Zinc, Dissolved ¹	µg/L	444	277	119
Volatile and Semivolatile Organics				
Acetone	µg/L	1,440	23,700	3,340
PG – 1671 ²	mg/L	—	—	192,000
PG – 8015D ²	mg/L	193,000	8,600	170,000
Trichloroethene ¹	µg/L	ND (10)	ND (10)	14.5

Sources: Final Sampling Episode Report Minneapolis/St. Paul International Airport (MSP) (USEPA, 2006b); Final Sampling Episode Report Detroit Metropolitan Wayne County International Airport (DTW) (USEPA, 2006a).

¹ Pollutant listed by EPA as a priority pollutant. See 40 CFR Part 423, Appendix A.

² Number following analyte name refers to analytical method. 1671 is a Clean Water Act method and 8015D is a hazardous waste method promulgated under the Resource Conservation and Recovery Act (RCRA).

< – Average result includes at least one nondetect value.

ND – Not detected (number in parenthesis is reporting limit).

Table 5-5. DEN, PIT, and ALB - 5-Day Average Data Summary for Untreated Deicing Stormwater

Analyte	Units	DEN Effluent from Equalization Feed Tank 5-day Average	PIT Influent to Reverse Osmosis (RO) Unit 5-day Average	ALB Influent to Anaerobic Treatment System 5-day Average
Alkalinity	mg/L	706	481	159
NH ₃ -N)	mg/L	0.448	ND (0.05)	<0.262
BOD ₅	mg/L	149,000	16,600	3,400
COD	mg/L	247,000	28,300	5,350
Chloride	mg/L	120	11.6	90.0
Hardness	mg/L	362	542	248
HEM	mg/L	9.20	ND (6.0)	ND (5.0)
NO ₃ -N + NO ₂ -N)	mg/L	0.0266	<0.0204	<0.0284
Sulfate	mg/L	60.0	48.1	26.4
TDS	mg/L	NC	1,670	650
TKN	mg/L	6.41	9.04	1.61
TOC	mg/L	89,000	7,720	1,570
Total Orthophosphate	mg/L	<1.03	<0.0196	0.115
Total Phosphorus	mg/L	<2.76	0.0778	0.946
Total Recoverable Phenolics	mg/L	0.0608	0.0187	ND (0.005)
TSS	mg/L	<17.8	<8.40	16.6
Arsenic	µg/L	<81.8	12.7	ND (10)
Barium	µg/L	<13.2	103	42.5
Boron	µg/L	<723	532	ND (100)
Calcium	µg/L	103,000	155,000	48,300
Copper	µg/L	305	ND (10)	ND (10)
Iron	µg/L	1,210	5,870	6,270
Magnesium	µg/L	5,360	6,260	9,990
Manganese	µg/L	156	532	736
Molybdenum	µg/L	11,900	ND (10)	ND (10)
Selenium	µg/L	172	31.8	<5.38
Sodium	µg/L	254,000	54,300	89,600
Tin	µg/L	<258	41.0	ND (30)
Zinc	µg/L	<81.1	71.8	48.3
Acetone	µg/L	4,100	10,900	15,400
Benzoic Acid	µg/L	716	ND (50)	278
Methyl Ethyl Ketone	µg/L	ND (50)	ND (50)	<58.5
Phenol	µg/L	ND (100)	ND (100)	24.5
EG - 1671 ¹	mg/L	<167	<65.6	ND (10)
EG - 8015D ¹	mg/L	<172	<73.6	ND (10)

Table 5-5 (Continued)

Analyte	Units	DEN Effluent from Equalization Feed Tank 5-day Average	PIT Influent to Reverse Osmosis (RO) Unit 5-day Average	ALB Influent to Anaerobic Treatment System 5-day Average
PG - 1671 ¹	mg/L	174,000	15,700	2,570
PG - 8015D ¹	mg/L	173,000	15,900	2,630
Tolyltriazole	µg/L	10,100	7,860	325
Nonylphenol, total	µg/L	ND (5.0)	22.2	ND (12.0)
Nonylphenol-1-Ethoxylate	µg/L	ND (7.4)	130	ND (19.0)
Nonylphenol-2-Ethoxylate	µg/L	ND (21.0)	190	ND (53.0)
Nonylphenol-3-Ethoxylate	µg/L	17.8	59.9	3.90
Nonylphenol-4-Ethoxylate	µg/L	16.4	15.4	3.01
Nonylphenol-5-Ethoxylate	µg/L	21.5	213	5.70
Nonylphenol-6-Ethoxylate	µg/L	50.4	403	12.5
Nonylphenol-7-Ethoxylate	µg/L	60.7	619	15.4
Nonylphenol-8-Ethoxylate	µg/L	86.2	841	24.7
Nonylphenol-9-Ethoxylate	µg/L	79.1	942	24.7
Nonylphenol-10-Ethoxylate	µg/L	92.5	1,050	38.1
Nonylphenol-11-Ethoxylate	µg/L	100	1,040	40.4
Nonylphenol-12-Ethoxylate	µg/L	216	833	33.7
Nonylphenol-13-Ethoxylate	µg/L	167	589	25.2
Nonylphenol-14-Ethoxylate	µg/L	116	386	17.8
Nonylphenol-15-Ethoxylate	µg/L	69.9	222	8.80
Nonylphenol-16-Ethoxylate	µg/L	43.4	107	4.69
Nonylphenol-17-Ethoxylate	µg/L	23.3	53.5	2.27
Nonylphenol-18-Ethoxylate	µg/L	12.4	23.3	1.09
Octylphenol	µg/L	<8.80	ND (0.01)	ND (2.00)
Octylphenol-2-Ethoxylate	µg/L	71.8	ND (0.144)	0.159
Octylphenol-3-Ethoxylate	µg/L	1,460	4.38	2.66
Octylphenol-4-Ethoxylate	µg/L	1,260	ND (2.26)	ND (2.26)
Octylphenol-5-Ethoxylate	µg/L	891	ND (2.93)	ND (2.93)
Octylphenol-6-Ethoxylate	µg/L	441	ND (2.69)	ND (2.69)
Octylphenol-7-Ethoxylate	µg/L	198	ND (2.58)	ND (2.58)
Octylphenol-8-Ethoxylate	µg/L	116	ND (1.85)	ND (1.85)
Octylphenol-9-Ethoxylate	µg/L	44.6	ND (0.636)	ND (0.636)
Octylphenol-10-Ethoxylate	µg/L	22.5	ND (0.636)	ND (0.636)
Octylphenol-11-Ethoxylate	µg/L	12.0	ND (0.267)	ND (0.267)
Octylphenol-12-Ethoxylate	µg/L	8.08	ND (0.113)	ND (0.113)

Table 5-5 (Continued)

Analyte	Units	DEN Effluent from Equalization Feed Tank 5-day Average	PIT Influent to Reverse Osmosis (RO) Unit 5-day Average	ALB Influent to Anaerobic Treatment System 5-day Average
Total Nonylphenol-3-Ethoxylate-Nonlyphenol-18-	µg/L	1,170	7,400	260
Total Octylphenol-2-Ethoxylate-Octylphenol-12-Ethoxylate	µg/L	4,530	ND (16.0)	ND (16.0)

Sources: Draft Sampling Episode Report Denver International Airport (USEPA, 2006c); Draft Sampling Episode Report Pittsburgh International Airport (USEPA, 2006d); Draft Sampling Episode Report Albany International Airport (USEPA, 2006e).

¹ Number following analyte name refers to analytical method. 1671 is a Clean Water Act method and 8015D is a hazardous waste method promulgated under the Resource Conservation and Recovery Act (RCRA).

ND – Not detected (number in parentheses is reporting limit).

NC – Not collected.

< – Average result includes at least one nondetect value.

Table 5-6. RFD - 1-Day Data Summary for Untreated Deicing Stormwater

Analyte	Units	Influent to Aerobic Treatment System, Spring
Alkalinity	mg/L	1,030
NH ₃ -N	mg/L	59.6
BOD ₅	mg/L	603
COD	mg/L	646
Chloride	mg/L	14.0
Hardness	mg/L	112
NO ₃ -N + NO ₂ -N)	mg/L	0.0190
Sulfate	mg/L	5.65
TDS	mg/L	384
TKN	mg/L	82.8
TOC	mg/L	137
Total Phosphorus	mg/L	0.330
TSS	mg/L	85.0
Barium	µg/L	20.3
Calcium	µg/L	6,600
Iron	µg/L	108
Magnesium	µg/L	14,700
Manganese	µg/L	164
Sodium	µg/L	4,790
Acetone	µg/L	86.6
Methyl Ethyl Ketone	µg/L	136
PG - 8015D ¹	mg/L	31.0
Tolyltriazole	µg/L	45.3
Bisphenol A	ng/L	ND (12,000)
N-Nonylphenol-2-Ethoxylate	NC	50.0
N-Nonylphenoxyl-2-Carboxylic Acid	NC	41.0
Octylphenol-9-Ethoxylate	µg/L	ND (3.18)

Source: Final Sampling Episode Report Greater Rockford Airport (USEPA, 2006f)

¹ Number following analyte name refers to analytical method. 8015D is a hazardous waste method promulgated under the Resource Conservation and Recovery Act (RCRA).

ND – Not detected (number in parentheses is reporting limit).

5.3 Aircraft and Airfield Deicing Chemical Use and Associated Deicing Stormwater at Alaskan Airports

Deicing operations at Alaskan airports may be different than those commonly seen at other U.S. airports due to the nature of air travel in Alaska and weather conditions. In Alaska, small airports have a relatively high number of commercial aircraft departures (including jet aircraft) for the suite of communities they serve due to their remote locations with no access to the road system. Yet these airports utilize small amounts of ADF and runway deicers because of climate conditions (dry and cold), as well as runway maintenance scheduling. For example, in Kotzebue, a town of 3,120 people, there are about 12,000 annual departures (including passenger and freight jet planes and prop planes) and the fluid usage is only about 1,000 gallons/winter.

In addition, long periods of below-freezing temperatures affect the the timing of deicing stormwater discharges. Deicing materials are not available for collection during freezing temperatures because they are encapsulated within the snow and eventually become runoff during the spring thaw. Thus, the stormwater runoff is not linked to the time of the ADF application. For example, at locations in arctic Alaska such as Bethel Airport (BET), there is no stormwater to collect during the deicing season (October – March) as temperatures rarely, if ever, go above freezing. For these airports, collection strategies may be significantly different than airports located within the lower 48 states. One current practice reported by Ted Stevens Anchorage International Airport (ANC) is gas-and-go cargo operations, which involves anti-icing on landing during certain weather conditions. This allows the airport to avoid deicing prior to departure. This anti-icing procedure also uses less glycol and allows a quicker turnaround.

Due to the remote nature of Alaskan airports and aircraft scheduling, runways are generally prepped for individual flights each day rather than maintaining continuous operation around the clock. Because of this, Alaskan airports rely heavily on mechanical methods for runway deicing. When airfield deicing chemical use is necessary, most airports in Alaska use potassium acetate or urea.

5.4 References

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6. POLLUTANTS OF CONCERN

EPA identified pollutants in stormwater associated with deicing activities for potential control. Pollutants of concern may include pollutants directly associated with deicing chemicals, by-products from deicing activities (e.g., metals), and/or pollutant parameters that are influenced by deicing chemicals (e.g., BOD and COD).

EPA reviewed its deicing stormwater sampling data as well as the information available through NPDES permits to identify conventional, nonconventional, and priority pollutants present in airport deicing stormwater. This section presents the results of EPA's evaluation and identifies potential pollutants of concern and those chosen for regulation.

6.1 Identification of Airport Deicing/Anti-icing Stormwater Pollutants

Airport deicing stormwater is generated when airfield deicing chemicals and ADFs mix with stormwater (either directly or because of snowmelt). Because deicing stormwater is weather-dependent, it is highly variable in nature and pollutant concentrations may vary greatly. In addition, other airport-related activities, including aircraft fueling and maintenance activities, may contribute pollutants to stormwater that is also contaminated with deicing chemicals. Because of the inherent difficulties in characterizing pollutants resulting solely from deicing activities, EPA evaluated pollutants detected in deicing stormwater, pollutants present in source water, and pollutants that are present in ADFs and airfield deicers prior to use to determine the pollutants likely to be present in deicing stormwater.

EPA considered multiple sources of information to identify potential pollutants of concern associated with deicing stormwater including the following:

- EPA sampling data from the PDS;
- NPDES permits for airports to determine pollutants that are currently monitored or limited at airports;
- EPA sampling data collected during the 2004/2005 and 2005/2006 deicing seasons to identify pollutants present in untreated deicing stormwater;
- EPA sampling data collected during the 2004/2005 and 2005/2006 deicing seasons to determine pollutants present in source water;
- EPA sampling data collected during the 2004/2005 deicing season, current research, and expert sources to determine ADF constituents; and
- Responses to the airport questionnaire.

Airport Deicing Operations PDS

For the PDS, EPA sampled:

- Type I ADFs;
- Lagoon stormwater from Albany International Airport;
- Untreated deicing stormwater from Kansas City International Airport;
- Untreated deicing stormwater from Bradley International Airport;
- Untreated deicing stormwater from Greater Rockford Airport; and
- Stormwater outfalls from Bradley International Airport.

The pollutants detected in one or more of these samples were summarized in Table 8-4 of the *Preliminary Data Summary: Airport Deicing Operations* report (USEPA, 2000) and are presented in Table 6-1 of this report.

NPDES Permits

EPA reviewed NPDES individual and general stormwater permits for airports that are estimated to have significant deicing operations in the United States. The permit review is summarized in the *Airport Deicing Operations NPDES Permit Review Summary* memorandum (ERG, 2007a). Table 6-1 lists pollutants that have monitoring and limit requirements in current airport NPDES permits.

Pollutants Present in Untreated Deicing Stormwater

Under this rulemaking effort, EPA collected samples at the following six airports during the 2004/2005 and 2005/2006 deicing seasons:

- Detroit Metropolitan Wayne County (DTW) airport;
- Minneapolis/St. Paul International (MSP) airport;
- Albany International (ALB) airport;
- Greater Rockford (RFD) airport;
- Pittsburgh International (PIT) airport; and
- Denver International (DEN) airport.

Table 6-1 lists pollutants detected in untreated deicing stormwater from these locations.

Pollutants Present in Source Water

Table 6-1 also lists pollutants detected in source water samples at the airports EPA sampled at during the 2004/2005 and 2005/2006 deicing seasons.

Deicing/Anti-Icing Fluid Constituents

EPA does not have sufficient information on all of the constituents of airfield chemicals and ADFs to fully characterize them. However, EPA's airport questionnaire does identify which chemicals and brand-name products are commonly used, which can help to define the pollutants expected to be in deicing stormwater.

Table 6-1. Pollutants Under Consideration as Potential Pollutants of Concern

Analyte	Pollutants Identified in the PDS Sampling	Pollutants Monitored in NPDES Permits	Pollutants Identified in Raw ADF in Research or 2004-2006 EPA Sampling	Pollutants Identified in Untreated Stormwater in 2004-2006 EPA Sampling	Pollutants Identified in Source Water in 2004-2006 EPA Sampling
Classicals/Conventionals					
Alkalinity				X	X
NH ₃ -N	X	X		X	X
BOD ₅	X	X	X	X	
COD		X	X	X	
Chloride			X	X	X
Dissolved Oxygen		X			
Hardness				X	X
Oil & Grease		X			
SGT-HEM	X			X	
HEM	X		X	X	
NO ₃ -N + NO ₂ -N			X	X	X
Sulfate			X	X	X
TDS				X	X
TKN			X	X	X
TOC	X		X	X	X
Total Orthophosphate				X	X
Total Phosphorus			X	X	X
Total Petroleum Hydrocarbons (TPH)		X			
Total Recoverable Phenolics			X	X	
TSS		X		X	
Metals					
Aluminum	X			X	
Antimony	X		X	X	
Arsenic	X	X		X	
Barium	X			X	X
Boron	X			X	

Table 6-1 (Continued)

Analyte	Pollutants Identified in the PDS Sampling	Pollutants Monitored in NPDES Permits	Pollutants Identified in Raw ADF in Research or 2004-2006 EPA Sampling	Pollutants Identified in Untreated Stormwater in 2004-2006 EPA Sampling	Pollutants Identified in Source Water in 2004-2006 EPA Sampling
Cadmium	X				
Calcium	X		X	X	X
Chromium	X		X		
Copper	X	X	X	X	X
Iron	X		X	X	X
Lead	X	X			
Magnesium	X		X	X	X
Manganese	X			X	
Mercury	X		X		
Molybdenum			X	X	
Potassium	X				
Selenium	X			X	
Silver	X				
Sodium	X		X	X	X
Thallium	X				
Tin	X		X	X	
Titanium	X				
Vanadium	X				
Zinc	X	X	X	X	X
Organics					
Acetone			X	X	
Benzene, toluene, ethylbenzene, xylene (BTEX)	X	X			
Benzoic Acid				X	
Bis(2-Ethylhexyl) Phthalate	X				
Di-n-butyl Phthalate	X				
Diethylene Glycol	X				

Table 6-1 (Continued)

Analyte	Pollutants Identified in the PDS Sampling	Pollutants Monitored in NPDES Permits	Pollutants Identified in Raw ADF in Research or 2004-2006 EPA Sampling	Pollutants Identified in Untreated Stormwater in 2004-2006 EPA Sampling	Pollutants Identified in Source Water in 2004-2006 EPA Sampling
N-Dodecane	X				
EG	X	X		X	
N-Hexadecane	X				
Methyl Ethyl Ketone				X	
Naphthalene		X			
Phenol	X			X	
PG	X	X	X	X	
N-Tetradecane	X				
1,2,4- Trimethylbenzene		X			
Trichloroethene				X	
Tolyltriazole				X	
Benzotriazole					
5-Methyl-1H-benzotriazole	X				
Alkylphenols					
Nonylphenol, total			X	X	
Nonylphenol-1-Ethoxylate			X	X	
Nonylphenol-2-Ethoxylate			X	X	
Nonylphenol-3-Ethoxylate			X	X	
Nonylphenol-4-Ethoxylate			X	X	
Nonylphenol-5-Ethoxylate			X	X	
Nonylphenol-6-Ethoxylate			X	X	
Nonylphenol-7-Ethoxylate			X	X	
Nonylphenol-8-Ethoxylate			X	X	
Nonylphenol-9-Ethoxylate			X	X	
Nonylphenol-10-Ethoxylate			X	X	
Nonylphenol-11-Ethoxylate			X	X	
Nonylphenol-12-Ethoxylate			X	X	X

Table 6-1 (Continued)

Analyte	Pollutants Identified in the PDS Sampling	Pollutants Monitored in NPDES Permits	Pollutants Identified in Raw ADF in Research or 2004-2006 EPA Sampling	Pollutants Identified in Untreated Stormwater in 2004-2006 EPA Sampling	Pollutants Identified in Source Water in 2004-2006 EPA Sampling
Nonylphenol-13-Ethoxylate			X	X	X
Nonylphenol-14-Ethoxylate			X	X	X
Nonylphenol-15-Ethoxylate			X	X	X
Nonylphenol-16-Ethoxylate			X	X	X
Nonylphenol-17-Ethoxylate			X	X	X
Nonylphenol-18-Ethoxylate			X	X	X
Octylphenol			X	X	
Octylphenol-2-Ethoxylate			X	X	
Octylphenol-3-Ethoxylate			X	X	
Octylphenol-4-Ethoxylate			X	X	
Octylphenol-5-Ethoxylate			X	X	
Octylphenol-6-Ethoxylate			X	X	
Octylphenol-7-Ethoxylate			X	X	
Octylphenol-8-Ethoxylate			X	X	
Octylphenol-9-Ethoxylate			X	X	
Octylphenol-10-Ethoxylate			X	X	
Octylphenol-11-Ethoxylate			X	X	
Octylphenol-12-Ethoxylate			X	X	
Total Nonylphenol-3-Ethoxylate- Nonylphenol-18-Ethoxylate			X	X	X
Total Octylphenol-2-Ethoxylate- Octylphenol-12-Ethoxylate			X	X	

Note: Octylphenol and nonylphenol should have a higher toxicity than the alkylphenol ethoxylates.

The commonly used airfield deicing and anti-icing chemicals are listed below, along with the approximate percentage of total airfield deicing chemical usage they comprise:

- Potassium acetate (64 percent);
- Propylene glycol-based fluids (12 percent);
- Urea (11 percent);
- Sodium acetate (9 percent);
- Sodium formate (3 percent); and
- Ethylene glycol-based fluids (2 percent).

EPA has two sources of data on the constituents of ADF. First, EPA collected and analyzed samples of unused, or “raw,” ADF during the sampling episodes at DTW and MSP. Table 6-1 lists the chemical compounds for which EPA analyzed the raw ADF samples. Second, EPA reviewed research conducted by USGS to determine potential ADF constituents. Steven Corsi of USGS conducts research and sampling on ADF and deicing stormwater at General Mitchell International Airport in Milwaukee, WI. He has published several papers presenting his research and sampling results and has identified the following pollutants in ADF stormwater and snowmelt:

- BOD₅;
- COD;
- PG and EG;
- AP and APEO; and
- Benzotriazole (BT) and its methylated derivatives (MeBT).

6.2 Pollutants of Concern Selection Criteria

Having identified pollutants that are likely to be present in airport deicing stormwater, EPA then considered which pollutants should be pollutants of concern. EPA considered the following criteria in assessing potential pollutants of concern for the airport deicing industry:

- Whether the pollutant can be directly linked to deicing/anti-icing chemicals;
- Whether the pollutant is detected in the effluent from a small number of airports and is uniquely related to those facilities; or
- Whether the pollutant can be analyzed using an EPA-approved or other established method.

After considering the criteria listed above, EPA developed a list of those pollutants that are considered potential pollutants of concern.

6.3 Identification of Potential Pollutants of Concern

EPA compared the pollutants detected in deicing stormwater to ADF and airfield deicer constituents and determined that many pollutants present in the stormwater are not present in ADF or airfield deicers. Stormwater contains pollutants from sources other than ADF and airfield deicers; these sources may include, but are not limited to, the following:

- Source water pollutants (present in the water used at the airport facility);
- Pollutants from aircraft and vehicle fueling;

- Pollutants from maintenance-related operations; or
- Pollutants from roof runoff.

EPA also considered the other criteria listed in Section 6.2 to assess potential pollutants of concern. Below is a summary of EPA's evaluation of potential pollutants of concern by the following analytical categories: classical/conventional parameters, metals, and organic pollutants.

Classical/Conventional Parameters

The major components of both airfield deicing chemicals and ADFs are organic and degrade in the environment after their release. Because of this, COD and BOD₅ concentrations are generally high in deicing stormwater. Both of these pollutant parameters are also good indicators of the amount of acetates, urea, glycols, and formates in deicing stormwater.

EPA believes that those airports with discharge permits requiring monitoring and control of ammonia, TKN, and nitrate/nitrite are likely doing so to monitor discharges of urea. Information collected during EPA's airport site visits seemed to indicate that airports have been phasing out the use of urea for airfield deicing. However, EPA's analysis of urea use from the airport questionnaire showed an increase during the 2002/2003 through 2004/2005 deicing seasons, with approximately the same number of airports using urea in each of those seasons.

Several of the classical parameters detected in deicing stormwater are from nondeicing stormwater, dilution water, or other airport operations. Based on information on airfield deicers and analysis of raw ADF, EPA concludes these pollutants are not present in ADF or airfield deicers but are present in deicing stormwater. Pollutants from airport sources aside from ADF/airfield deicers include alkalinity, hardness, oil and grease, TDS, and TSS.

Other classical/conventional parameters (including chloride, TOC, and total phosphorus) are found in source water, which is used to dilute ADF/airfield deicers prior to application. Therefore, EPA concluded these pollutants are not present in ADF/airfield deicers.

Finally, while total recoverable phenolics are present in EPA sampling results, the phenols in ADF are widely reported as alkylphenols and octylphenols; therefore, EPA chose the analyte-specific results and not the bulk parameter as the more appropriate indicator of phenols in ADF.

Metals

Multiple metals have been detected in samples of airport deicing stormwater. Some of these metals were also detected in the ADF samples collected by EPA. Many of these metals are not original components of deicing products (e.g., aluminum and selenium); they are present as background concentrations from the stormwater or source water used for ADF dilution or they are metals picked up by stormwater runoff from aircraft maintenance/operation areas or building roofs.

Nonyl/Octyl-Phenol-Ethoxylates

EPA sampling data shows the presence of both nonylphenol and octylphenol ethoxylates. EPA decided to use the total octylphenol and total nonylphenol ethoxylates as the indicator for all ethoxylates.

Organic Pollutants

Organic pollutants present in deicing stormwater include PG, EG, triazole compounds, alkylphenols, and alkylphenol ethoxylates. Other organics may also be present from the breakdown of glycols, urea, acetates, and formates.

Pollutants of Concern

Based on this evaluation of available data, EPA identified the following as potential pollutants of concern for the Airport Deicing Category:

- COD;
- BOD5;
- EG;
- PG;
- Benzotriazole;
- 5-Methyl-1H-benzotriazole;
- Nonylphenol, total;
- Octylphenol, total;
- Total nonylphenol-3-ethoxylate-nonylphenol-18-ethoxylate;
- Total octylphenol-2-ethoxylate-octylphenol-12-ethoxylate;
- Ammonia as nitrogen;
- Nitrate/Nitrite;
- TKN;
- Aluminum;
- Antimony;
- Boron;
- Cadmium;
- Chromium;
- Iron;
- Lead;
- Magnesium;
- Mercury;
- Molybdenum;
- Potassium;
- Selenium;
- Thallium;
- Tin;
- Titanium;
- Vanadium;
- Zinc; and
- Acetone.

6.4 Selection of Regulated Pollutants

Table 6-2 lists the potential pollutants of concern identified in Section 6.3, along with an explanation of whether EPA selected the pollutants for regulation. Based on the documented environmental impacts from stormwater contaminated with airport deicing materials, EPA focused on regulating those pollutants exerting oxygen demand and contributing toxicity to receiving water bodies. EPA found that the impacts of slug loads of ADF stormwater on the dissolved oxygen of receiving streams, as well as color and odor issues associated with high ADF concentrations in stormwater discharge, are well documented. The main component of ADF is glycol, which exhibits significant oxygen demand. Research by Corsi (Corsi et al., 2006) also identified potential toxicity concerns that may be linked to ADF additives, specifically triazoles and alkylphenols. ADF manufacturers have told EPA that the use of triazole compounds in ADF is being discontinued and that triazole use in European ADFs has been phased out. Alkylphenols and their ethoxylates have also been identified as potential toxic components of ADF. EPA's sampling data have confirmed the presence of these compounds; however, EPA believes that insufficient information is currently available to fully characterize the extent to which these compounds are present in deicing stormwater and their impact. In addition, there is not currently an approved EPA method (in 40 CFR Part 136) for these compounds.

For stormwater discharges from airfield deicing operations, EPA focused on the continued use of urea. Urea breaks down into ammonia, and the resulting ammonia toxicity in receiving streams has helped to discourage urea use as an airfield deicing chemical in the past. When inadequately treated, urea-contaminated wastewater also may contribute to nitrogen enrichment and eutrophication of receiving waters. Alternative airfield deicing chemicals, predominantly comprising a salt ion (potassium or sodium) and either acetate or formate, are available that are less toxic than ammonia.

Based on the known environmental impacts from deicing stormwater discharges, EPA has selected COD and ammonia (as N) for regulation. COD is a good indicator parameter to monitor the overall oxygen demand resulting from the discharge of glycol-based ADFs and any other organic constituents present in the stormwater. Ammonia as N is selected for regulation to ensure that airports cease using urea as an airfield deicer, since other less toxic products are available.

EPA evaluated the impacts of the airport deicing collection and treatment scenarios on both BOD₅ and COD discharges. EPA selected COD for regulation and not BOD₅ for the following reasons:

- COD analyses are simple to conduct and can be measured in real time compared to a 5-day test for BOD;
- COD eliminates the need to consider receiving water temperature when evaluating water quality concerns; and
- Toxic ADF additive compounds in deicing stormwater may have a negative and variable affect on the acclimation of the active cultures used in BOD analysis, making the method less robust than COD analysis for these wastewaters.

Table 6-2. Potential Pollutants of Concern Selected for Regulation

Potential Pollutant of Concern	Selected for Regulation	Explanation of Selection or Nonselection for Final Rule
BOD ₅		COD as surrogate
COD	X	Selected for regulation
Ethylene glycol		COD as surrogate
Propylene glycol		COD as surrogate
Benzotriazole		Limited data available to support selection; potential discontinued use
5-Methyl-1H-benzotriazole		Limited data available to support selection; potential discontinued use
Nonylphenol, Total		Limited data available to support selection; no current EPA-approved method for analysis
Octylphenol, Total		Limited data available to support selection; no current EPA-approved method for analysis
Total nonylphenol-3-ethoxylate-nonylphenol-18-ethoxylate		Limited data available to support selection; no current EPA-approved method for analysis
Total octylphenol-2-ethoxylate-octylphenol-12-ethoxylate		Limited data available to support selection; no current EPA-approved method for analysis
Ammonia as nitrogen	X	Selected for regulation to monitor urea use
Nitrate/Nitrite		Ammonia as nitrogen as surrogate for urea use
TKN		Ammonia as nitrogen as surrogate for urea use
Aluminum		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Antimony		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Boron		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Cadmium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Chromium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Iron		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Lead		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Magnesium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Mercury		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Molybdenum		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Potassium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Selenium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination

Table 6-2 (Continued)

Potential Pollutant of Concern	Selected for Regulation	Explanation of Selection or Nonselection for Final Rule
Thallium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Tin		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Titanium		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Zinc		Limited impact data for metals; insufficient data to support ADF as sole source of metal contamination
Acetone		COD as surrogate

EPA is not regulating metals in the final airport deicing rule. Given the potential for background interference from airport operations, EPA does not have sufficient data to support metals as a unique pollutant from ADF alone.

6.5 References

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7. COLLECTION AND TREATMENT TECHNOLOGIES APPLICABLE TO AIRPORT DEICING OPERATIONS

The NPDES permit program, along with the emergence of problems such as fish kills and odor reports, have prompted airports and airlines to investigate a wide range of pollution prevention and treatment practices. These practices are designed to eliminate or minimize the environmental impact of ADF without compromising safety. This section summarizes the common techniques used to collect deicing stormwater and the treatment steps implemented prior to discharge. This section also discusses pollution prevention practices used by U.S. airports and airlines.

Each method of collection, treatment, or pollution prevention selected by an airport or airline often depends on a variety of airport-specific or airline-specific factors, including climate, amount of deicing and anti-icing agents applied, number of airlines operating at a particular airport, aircraft fleet mix, number of aircraft operations, costs, presence of existing infrastructure, availability of land, and effect on aircraft departures. EPA recognizes that some of the practices discussed in this section may not be practical or economically feasible for all U.S. airports.

EPA evaluated whether regulation of airfield deicing stormwater was practical or cost-effective. Because airfield deicing stormwater losses tend to occur over large areas and the volumes of dilute stormwater may be very high, at this time EPA could not identify an “economically achievable” means to regulate airfield deicing stormwater other than to encourage a complete transition away from urea use. Therefore, the technologies presented in this section are primarily used to collect and treat ADF-contaminated stormwater.

Section 7.1 discusses deicing stormwater collection, Section 7.2 describes deicing stormwater treatment, Section 7.3 discusses glycol recycling, and Section 7.4 presents pollution prevention (e.g., product substitution) practices.

7.1 Deicing Stormwater Collection

The collection of deicing stormwater from aircraft deicing/anti-icing operations helps prevent or minimize discharges at stormwater outfalls. Airports currently use a variety of collection and conveyance methods, including designated aircraft deicing pads, gate and ramp area drainage collection systems, plug and pump systems, and specially designed glycol collection vehicles (GCVs), each of which is discussed in Section 7.1.1. Individual airports often rely on a combination of these collection strategies to effectively collect ADF-contaminated stormwater.

Section 7.1.2 presents common methods for storing and discharging deicing stormwater, including detention ponds or constructed wetlands, retention ponds, permanent storage tanks or frac tanks, discharge to a POTW, trucking waste off site, or any combination of these methods. The following sections describe in detail the various wastewater collection methods used by the industry.

7.1.1 *Deicing Stormwater Collection and Conveyance*

This section describes the various wastewater collection and conveyance methods commonly used by airports. Airport stormwater collection systems are designed to collect

deicing stormwater from several different locations at which deicing operations are performed, including aircraft deicing at CDPs, at the gates, or at parking or cargo aprons. Collection systems may collect stormwater from airfield deicing locations including ramps, taxiways, and runways. Common methods of collecting and conveying deicing stormwater include deicing pad collection systems, gate and ramp area drainage collection systems, plug and pump systems, and GCVs.

Deicing Pads

A CDP is a facility on an airfield built specifically for aircraft deicing operations. It is typically a paved area adjacent to a gate area, taxiway, or runway, and constructed with a drainage system separate from the airport's main storm drain system. It is usually constructed of concrete with sealed joints to prevent the loss of sprayed ADF through the joints. The pad's collection system is typically connected to a stormwater storage facility, from which the spent ADF may be sent to an on-site or off-site treatment facility.

Deicing pads restrict aircraft deicing to a confined area, allowing the deicing stormwater to be captured at the point of generation and thereby minimizing the volume of sprayed deicing fluid discharged in an uncontrolled manner. Aircraft deicing pads also centralize deicing activities, which allows airports to more easily collect high-concentration ADF-contaminated stormwater. Transporting ADF-contaminated stormwater off site to wastewater treatment plants or POTWs is also more economical when the amount of deicing stormwater is minimized.

One benefit of deicing departing aircraft on deicing pads instead of at the gates is that it frees the gates for use by arriving aircraft. Another benefit is that pads are commonly located near the heads of runways, where planes can be deiced just prior to takeoff, potentially reducing the amount of Type IV anti-icing fluid necessary due to shorter holdover times and the amount of glycols transferred from the deicing pad or released into the air. Figure 7-1 shows an example of a CDP with fixed boom sprayers.



Figure 7-1. Deicing Pad Equipped with Fixed Deicing Booms at Pittsburgh Airport

Gate and Ramp Area Drainage Collection Systems

Other than deicing pads, the most common areas for deicing operations are passenger terminal gates and aircraft parking or cargo ramps/aprons. To collect wastewater generated at these locations, some airports have installed collection systems or modified existing stormwater drainage systems. The typical collection system consists of graded concrete pavement with trench or square drains that convey wastewater to a storage facility or discharge point through a diversion box. Gate and ramp collection systems generally generate low-concentration ADF-contaminated stormwater because more stormwater is mixed in with the ADF and because there are increased fugitive losses due to vehicle traffic around the planes. For some stormwater drainage systems, a diversion box allows uncontaminated stormwater to be diverted to stormwater outfalls.

Plug and Pump Systems

Plug and pump collection systems generally comprise devices and equipment that alter an airport's existing storm drain system to contain and collect ADF-contaminated stormwater to prevent ADF-contaminated stormwater from entering the storm drain system. These systems include, but are not limited to, temporary blocking devices at storm drain inlets and/or shutoff valves in the storm sewer system. Some airports use storm drain inserts or plugs to close the drains and allow the ADF-contaminated stormwater to collect within the existing airport stormwater drainage system. When aircraft are undergoing deicing/anti-icing, the inserts are installed to force contaminated stormwater to pool in drainage piping until it can be vacuumed or pumped out. This practice prevents manholes and stormwater piping from overflowing. Once deicing/anti-icing activity ends and the contaminated stormwater is removed, the storm drain inserts can be removed, or deactivated allowing uncontaminated stormwater to pass through the drain. Plug and pump collection systems are applicable to airports that deice at the gate and may be utilized to convert ramp areas (e.g., cargo, feeder, taxiways) into deicing areas. One benefit of deicing at the gate is that the components of the existing collection system infrastructure (i.e., existing storm sewers) can be incorporated into the plug and pump collection system, reducing the costs associated with deicing control.

Minneapolis/St. Paul International (MSP) airport is one example of an airport using a plug and pump collection system. At MSP airport, 30 percent of deicing operations takes place in the airport's 16 plug and pump containment areas. During the deicing season, the plug and pump areas are fitted with compression plugs in the storm sewers to prevent contaminated or potentially contaminated stormwater from being discharged. The stormwater plugs convert the stormwater sewer pipes and manholes into individual stormwater retention systems that can each retain between 5,000 to 42,000 gallons of stormwater. These individual stormwater retention systems are monitored during the day to determine how full they are (to prevent overflow) and to determine how to manage the ADF-contaminated stormwater based on its composition and strength. Contaminated stormwater is pumped or vacuumed from the sewer pipes and tested to determine the glycol concentration. Based on the glycol concentration of the wastewater, it is stored in either a low-concentration storage tank or a high-concentration storage tank prior to being shipped off site (USEPA, 2008a).

GCVs

GCVs are specially designed vehicles that remove stormwater contaminated with deicing materials from airport deicing pads and gate locations by vacuuming liquid from pavement surfaces. GCVs help prevent ADF losses through evaporation and/or direct discharge and allow ADF-contaminated stormwater to be collected for treatment or disposal. Drain covers that bond to surfaces to quickly seal off drains are often used in conjunction with GCVs in the area where aircraft are deiced to allow the GCVs to collect high-concentration spent deicing fluid.

Commercial GCVs have two basic designs: truck chassis or trailer mounted. The truck chassis designs are adapted from the street sweeper concept, with a vacuum unit, vacuum/sweeper head, and storage tank all mounted on a single self-propelled vehicle. Typically, a separate engine powers the vacuum system. Trailer-mounted designs have the vacuum unit, collection head, and storage tank on a towed platform with power provided by either an engine mounted on the trailer chassis or a power take-off from the tow vehicle, typically a tractor. Figure 7-2 shows an example of a GCV. GCVs help prevent ADF-contaminated stormwater from reaching unpaved areas where infiltration could occur and from contaminating surrounding waterways.

Once ADF-contaminated wastewater is vacuumed from airport surfaces, it is typically transported to an on-site storage facility (either temporary or permanent) where the airport can then treat and discharge or ship the waste off site. In addition, some airports with collection and conveyance or plug and pump systems will have a designated area where the GCV can discharge into the collection system, allowing the existing infrastructure to convey the material to final storage.



Figure 7-2. GCV

Plug and Pump with GCV

Commonly, a plug and pump system is operated in conjunction with GCVs or a tanker truck with pumps that collect the deicing stormwater that builds up behind the drainage block during the deicing event. Additionally, GCVs may be used outside of the blocked area to collect ADF-contaminated stormwater to enhance what can be collected through the plugging operation alone.

7.1.2 *Deicing Stormwater Storage*

This section describes the various stormwater storage methods commonly used by airports. Airport stormwater storage systems are designed to retain deicing stormwater from several different locations around an airport, accommodate highly variable flows and volumes, and may retain/store stormwater that contains pollutants from both airfield and aircraft deicers. Common methods of stormwater storage at airports include detention ponds, equalization ponds, retentions ponds, and storage or frac tanks.

Detention Ponds/Lagoons and Equalization Ponds

Detention ponds/lagoons are open-water ponds that collect deicing stormwater from runways and other airport property. Detention ponds and lagoons are designed to temporarily hold deicing stormwater anywhere from one day to two months and allow solids to settle while reducing oxygen demand through surface oxygenation and volatilization prior to discharge to receiving waters. Detention ponds and lagoons can be lined or gravel-filled and may contain microscopic bacteria that biodegrade deicing and anti-icing materials. Pump stations are commonly implemented to pump metered wastewater to discharge or further treatment. Detention basins often use aeration to increase dissolved oxygen levels. Lagoons may be equipped with a floating cover.

Equalization ponds are detention ponds designed to thoroughly mix ADF-contaminated stormwater so that consistent concentrations of pollutants can be pumped from the pond to treatment operations or to other disposal. Equalization ponds may contain moving parts, such as mixers, to ensure the liquid in the pond is completely mixed.

Retention Ponds

Retention ponds are designed to hold collected deicing stormwater indefinitely. Usually the pond is designed to allow overflow to drain to another location (e.g., a second retention pond or other overflow structure) when the water level gets above the pond capacity. Retention ponds can also be used to treat deicing stormwater as part of a batch process (using chemical addition and/or aeration) prior to discharge. With retention ponds, airports can collect ADF-contaminated stormwater throughout a deicing season and have the option of trucking it off site for treatment or treating it on site in the retention pond.

Advantages and Disadvantages of Ponds in Treating ADF-Contaminated Stormwater

Ponds require large areas for installation and their wastewater normally requires treatment for many months after the end of the annual deicing season before it can be discharged.

FAA discourages airports from installing new stormwater retention ponds, as they can be a lure for birds, which are a safety hazard for aircraft (FAA, 2007). For airports with existing retention ponds and adequate storage capacity, aerated pond systems may be able to provide efficient treatment. See section 7.2.1 for further discussion of aerated pond systems. Figure 7-3 shows an example of an airport pond used for deicing stormwater storage.



Figure 7-3. Pond for Deicing Stormwater Storage

Storage Tanks

Airports that treat ADF-contaminated stormwater often use tanks to store the stormwater prior to on-site treatment or transfer off site. These types of tanks can be constructed as aboveground tanks or underground tanks. Collecting and storing deicing stormwater in storage tanks allows an airport to equalize pollutant concentrations and flow the stormwater at a consistent flow rate into an on-site treatment system, which is important to ensuring consistent treatment results. Portable storage tanks, called frac tanks, can be placed on the airport property (while empty) and provide temporary storage of collected deicing stormwater. These types of tanks may also be connected by a hose or pipeline to an alternative area. Figure 7-4 shows an example of two frac tanks.



Figure 7-4. Frac Tanks

7.2 Treatment

This section describes the various means of treating stormwater contaminated with deicing chemicals. The technologies described within this section are typically used to control ADF-related pollutants; however, stormwater with pollutants from airfield deicing operations may also be routed into these systems.

7.2.1 *Biological Treatment*

This section describes the treatment of ADF-contaminated stormwater through biological processes. Biological treatment consists of two types of processes, aerobic or anaerobic, and can take place on site at an airport or off site at POTWs or other treatment facilities.

POTW Treatment of ADF-Contaminated Stormwater

Where practical, airports discharge their deicing stormwater to a POTW for biological treatment. POTW systems generally use activated sludge in an aerobic biological treatment system and may also incorporate anaerobic digestion of the sludge generated. In aerobic treatment systems, microorganisms consume the organic matter and convert it to water, carbon dioxide, and additional biomass in the presence of oxygen. To maintain the microorganism population in the treatment process, POTWs using an activated sludge process will use an aerated treatment tank followed by a sludge settling tank. Part of the settled sludge is recycled back into the aerated treatment tank and the remainder is removed for further processing or disposal.

Airports may be prevented from discharging ADF-contaminated stormwater to a local POTW for one or more of the following reasons: (1) limited hydraulic or loading capacity at the POTW, (2) high POTW wastewater treatment and/or conveyance fees, (3) inability of the local POTW to handle highly variable pollutant loadings, and/or (4) airport infrastructure constraints.

Aerated Ponds

Aerated ponds used on site at airports are effective for treating low-concentration ADF-contaminated stormwater. These are ponds that are open to the atmosphere, though open-topped tank systems may also be used. Aerated ponds are not generally used for high-concentration ADF-contaminated stormwater because the ponds do not have sufficient oxygen transfer to completely convert the ADF pollutants into water, carbon dioxide, and biomass compared to an activated sludge system. Treatment ponds may range in size and are usually operated as a batch process.

Aeration in lagoons and ponds increases the level of dissolved oxygen in the water, which is needed to decompose organic matter such as glycols. In addition, oxygen helps to oxidize certain elements that are suspended in the water, and oxidation causes some materials to become heavier so that they will settle out of the water column quicker. Without proper aeration, bacteria cannot decompose the organic matter in a pond quickly or efficiently. Aeration devices are used to agitate the lagoon or pond surface, which helps to transfer atmospheric oxygen into the wastewater to promote biological treatment processes, vent carbon dioxide and other gaseous elements from the water, and increase the amount of wastewater exposed to ambient air, allowing other volatile organics to oxygenate and evaporate.

The Greater Rockford airport is an example of an airport operating an aerated pond treatment system for deicing stormwater. Greater Rockford airport collects ADF-contaminated stormwater throughout the deicing season into a 16-million-gallon aerated detention pond. Its aerobic digestion system consists of the aerated detention pond, a settling pond, a re-circulating pump, and a chemical addition building. The biodegradation of glycol is temperature-dependant and predominantly occurs during the spring and early summer months when ambient temperatures are higher. Airport personnel monitor the process, adding nutrients, antifoaming agents, and pH adjustment chemicals as needed. When the BOD₅ concentration of the pond has been reduced to less than 30 mg/L, airport personnel discharge the treated stormwater from the settling pond to Rock River (USEPA, 1999).

Figure 7-5 shows an aerated pond installation at Portland Airport (Oregon).



Figure 7-5. Aerated Pond Installation at Portland Airport

Anaerobic Treatment

Anaerobic treatment systems can effectively treat ADF-contaminated stormwater with a range of glycol concentrations. This type of treatment usually occurs in a closed tank in which microscopic bacteria in an oxygen-deficient environment biodegrade deicing and anti-icing materials. In anaerobic treatment systems, microorganisms consume the organic matter and convert it to methane and carbon dioxide in the absence of oxygen, which creates much less sludge than an aerobic system.

AFB treatment is a demonstrated technology for addressing ADF-contaminated stormwater at both the Albany, New York (ALB) and Akron/Canton, Ohio (CAK) airports. Additionally, Portland completed construction of an AFB in 2011 and testing is slated to be complete in 2012. TF Green Airport (Providence, RI) is designing an AFB system, estimated to be operational in 2015. (Rhode Island Airport Corporation, 2011). The AFB treatment system uses a vertical, cylindrical tank in which the ADF- contaminated stormwater is pumped upwards through a bed of granular activated carbon at a velocity sufficient to fluidize, or suspend, the media. A thin film of microorganisms grows and coats each granular activated carbon particle, providing a vast surface area for biological growth. The anaerobic microorganisms that develop occur naturally in sediment, peat bogs, cattle intestines, and even brewer's yeast. Breakdown products from the AFB treatment system include methane, carbon dioxide and new biomass. Effluent from the AFB can be discharged to a local POTW or, in most cases, directly to surface water. Figure 7-6 presents a diagram showing the major components of a typical AFB treatment system (Source: US Department of Defense, 2003).

Treating wastes using an anaerobic biological system compared to an aerobic system offers several advantages. Because it does not require aeration, the anaerobic system requires

less energy and produces less than 10 percent of the sludge of an aerobic process. In addition, because the biological process is contained in a sealed reactor, odors are eliminated. EPA evaluated AFB biological treatment as it represents the best technology currently in use by airports to treat deicing stormwater prior to direct discharge.

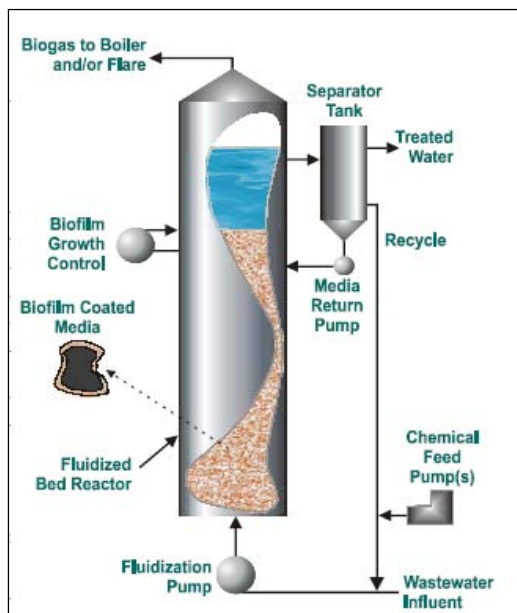


Figure 7-6. Typical Anaerobic Fluid Bed Treatment System for Treatment of ADF-Contaminated Stormwater

Land Application and Constructed Wetlands

Low-concentration deicing stormwater may also be treated on site at an airport using either land application or discharge through constructed wetlands. Land application involves spraying deicing stormwater onto a land surface for infiltration and biological degradation within the soil. As an example, Salt Lake City International (SLC) airport uses land application to dispose of batch volumes of low-concentration deicing stormwater on a periodic basis. The system sprays approximately 300,000 to 400,000 gallons of stormwater over nutrient-enriched land using agricultural wheels. The application is sprayed at a rate of about 1 gallon per square foot over a two-day period. The sprayed glycol then degrades in the soil over a week to month-long period (USEPA, 2008b). Because glycol-based ADFs readily degrade in both high clay and sandy soil systems, this type of system can be effective for low concentrations and limited volumes. Biodegradation occurs in the soil through carbon respiration of soil microbes, which consume oxygen and release carbon dioxide. Zurich International Airport, Switzerland, also uses a spray irrigation system for ADF treatment. At that airport, a heated sprinkler system applies ADF-contaminated stormwater to a 20 ha (49.4 acre) area (Jungo Engineering Ltd, 2005).

Constructed wetlands are artificial marshes or swamps placed inline with stormwater drainage at airports. The wetlands act as biofilters and help remove sediments and pollutants such as heavy metals from the wastewater. Physical, chemical, and biological processes combine in wetlands to remove contaminants from the wastewater. The discharge from constructed wetlands can also be collected and treated if it cannot meet discharge permit limits or it can be discharged to a POTW or surface water.

7.2.2 *Physical Separation*

This section describes physical separation processes that are used to treat ADF-contaminated stormwater. Physical separation consists of four types of processes: filtration, MVR, membrane separation, and distillation. The treatment can take place on site at an airport or off site at other treatment facilities.

Filtration

Primary filtration, which removes solids greater than 10 microns, is commonly the first step in glycol treatment systems because it removes suspended solids and prevents subsequent processing units from plugging. This technology is typically used in combination with other technologies. Popular primary filters used in glycol treatment are made of either polypropylene cartridges or bag filters.

MVR

MVR is an evaporation method that uses mechanically driven compressors or blowers to increase the pressure of the vapor produced. The increase in pressure causes the vapor's temperature to increase, which allows it to heat the liquid being concentrated. Benefits of using MVR in glycol treatment include:

- Low specific operating costs;
- Low specific energy consumption;
- Short residence times of the product; and
- Simplicity of the process.

EPA conducted a site visit and subsequent sampling episode at Denver International (DEN) airport, which operates MVRs in the following manner. MVRs concentrate the deicing pad storage tank influent, which ranges from 1 to 12 percent PG, to a final concentration of 50 to 55 percent glycol. Each MVR has a capacity of 3,250 gallons per day. The effluent from the MVRs goes to a storage tank where it is stockpiled prior to being sent to a distillation system (USEPA, 2007b). The evaporative process may also generate a condensate, which in most cases requires further treatment prior to indirect discharge. Typically, this is managed via an RO system, with the concentrated material returned to the treatment process and the RO permeate discharged to a POTW.

Membrane Separation

Membrane separation is an efficient one- or two-step process that incorporates ultrafiltration (UF) and/or RO to increase the ADF concentrations of ADF-contaminated stormwater. In an UF/RO process, fluid is filtered at a high temperature (75° C) using an ultrafiltration membrane as stage one. Next, the deicing fluid (ultrafiltration filtrate) can be dewatered using an RO membrane as stage two. The UF membrane is effective at removing contaminants such as turbidity, color, and odor, and RO stage two is used for dewatering and glycol separation. The combined UF/RO process produces a final glycol concentration of approximately 10 percent from an original concentration ranging between 0.5 and 4 percent. Pittsburgh International (PIT) airport uses this type of system. The PIT system first treats ADF-contaminated stormwater through an UF unit to remove suspended solids. At this point, the

stormwater is 0.5 to 4 percent PG. The stormwater is next treated through an RO unit. Following RO, the stormwater is split into two outputs: 1) concentrate that is approximately 10 percent PG, and 2) permeate that has a very low glycol concentration. The concentrated PG is transported off site for further processing and the permeate containing small amounts of glycol, CBOD, and COD is sent to the POTW for further processing (USEPA, 2006).

Distillation

Distillation can effectively treat ADF-contaminated stormwater by separating the water from the glycol. A potential drawback of distillation is that it creates a distillate that requires further treatment. Depending on whether the distillation system is operated in a batch or continuous mode, the majority of the distillate can be discharged to the local POTW without further processing. In a batch mode, there is a “mid-cut” water/glycol mixture, which marks the transition from water removal and product; this volume is redirected to the process feed. However, depending on system design and applicable limits, distillate may be able to be directly discharged. Distillation columns may be larger and more expensive than other technologies to operate, and because distillation is energy-intensive, it is generally not cost-effective to distill waste glycol solutions at low concentrations (less than 15 percent). Design variables for this technology include temperature, distillation column height, and reflux ratio. This process is commonly done in batches to ensure proper distillation and desired results.

EPA conducted site visits at SLC and DEN airports, both of which operate distillation columns.

- At DEN airport, the distillation system runs 24 hours a day for a three-week cycle and processes about 225,000 gallons of PG before the system is halted for cleaning and maintenance. The distillate from the distillation column is discharged to the airport’s storage ponds. The distillation column bottoms compile sludge that is classified as specialized nonhazardous waste. The 98 to 99 percent PG from the distillation column is pumped to a polisher (USEPA, 2007b).
- At SLC airport, 40 to 45 percent glycol-concentrated stormwater is passed through a finisher (one stage of evaporation) to increase the concentration to approximately 70 to 80 percent glycol and then discharged to a storage tank. The stored concentrate is sent to a distillation column where it is heated to 250 to 260 degrees Fahrenheit to produce a final product of 100 percent glycol. Distillate from the distillation column is discharged to a storage tank prior to RO treatment and indirect discharge. The column bottoms (residual solids) are disposed of at an off-site facility landfill (USEPA, 2008b).

7.3 Recycling

Recycling glycol from ADF-contaminated stormwater decreases the amount of ADF-contaminated stormwater that reaches and potentially impairs surface and ground waters. The process to recover glycol from ADF-contaminated stormwater may take several steps and can be conducted both on site at the airport and/or off site at a regional treatment facility. The recycle and recovery technologies currently in use by U.S. airports include filtration, MVR, membrane separation, and distillation (discussed in Section 7.2). On-site recycling typically includes some combination of these technologies, configured as an integrated treatment train to meet specific

requirements of the airport where it is located. Most commonly, an on-site facility initiates the process to increase the glycol concentration to make transport to a regional facility for final processing more cost-effective.

Recovered glycol is generally sold to help recover expenses associated with ADF application, collection, and control. On-site recycling was successful and economically viable at the airports visited by EPA that collected large enough volumes of high-concentration ADF-contaminated stormwater. However, recovery systems may also be able to handle lower concentration ADF stormwaters (with glycol concentrations in the 1-2 percent range), and small- and medium-hub airports may be able to recover and recycle glycol using off-site recycle/recovery facilities. Off-site facilities can recycle ADF-contaminated stormwater from airports not generating sufficient volumes to warrant on-site recycling and treatment. Glycol recycling vendors offer a variety of recycle/recovery related services to accommodate different airport sizes and configurations. Services commonly provided by glycol recycle/recovery vendors include supplying drain blocks, leasing portable storage tanks, on-call trucking services, and tote (fluid container) pickups. Key criteria for determining the appropriate recycle/recovery program include the type of ADF being collected, glycol concentration of the stormwater, total consumption of ADF per season, and peak ADF volume application rates. Other factors to consider are the number of deicing days per season at an airport and future air traffic plans.

7.4 Pollution Prevention and Product Substitution Practices

Pollution prevention practices reduce the generation or discharge of pollutants produced during aircraft/airfield deicing operations. Pollution prevention practices implemented throughout the aviation industry include infrared deicing, forced-air deicing, product substitution practices, and BMPs.

Infrared Deicing

Infrared heating involves transmitting energy using electromagnetic waves or rays. Infrared energy is invisible and travels at the speed of light in straight lines from the heat source (the emitter) to all surfaces and objects (the receivers) without significantly heating the space (air) through which it passes. This heating process is much faster than convection or conduction heating mechanisms used by conventional deicing, where the deicing fluid spray is cooled by ambient air.

Figure 7-7 shows a picture of the infrared hangar at John F. Kennedy (JFK) airport.



Figure 7-7. Infrared Hangar at JFK

Infrared-based aircraft deicing systems offer two advantages over traditional glycol-based deicing methods. From an environmental standpoint, they can greatly reduce the amount of glycol-based fluids used for aircraft deicing, while from an operational standpoint, they are relatively inexpensive to operate, as they use natural gas or propane as fuel.

Any infrared deicing facility must take into account the physical characteristics of all aircraft that will use the system. For example, an infrared system design factors in the maximum tail height, the shape of tails, maximum wingspans, and differences in the length and width of the fuselage. The site selected for an infrared deicing system must comply with the same FAA regulations that apply to glycol-based aircraft deicing facilities, including aircraft separation rules, airport traffic control tower line-of-sight criteria, and requirements to not interfere with radar signals, navigational aids, and airport lighting. FAA issued a new Advisory Circular in 2005 specifically for infrared deicing facilities (FAA, 2005). As with traditional aircraft deicing facilities, an infrared deicing facility must provide taxiways that allow aircraft to bypass the deicing facility.

While EPA encourages the use of this technology, industry practice has shown that it may not be applicable at all airports and it appears to be best used in conjunction with other more conventional deicing operations (ERG, 2004; Belcher-Hoppe Associates, Inc., 2004).

Forced Air Deicing

Forced air deicing uses large volumes of air at low pressure to remove loose accumulations of snow and ice from an aircraft prior to chemical deicing. Aircraft deicing trucks or fixed booms equipped with forced air nozzles help reduce the amount of glycol that is used during deicing and defrosting operations. In light snow conditions, forced air may completely replace the need for deicing fluid. For light frost and light deicing events, fluid-injected forced air can be used to reduce the amount of deicing fluid by up to 75 percent. For heavy deicing events, a fluid forced air technique is used. This technique requires the ADF application rate

sprayed from the boom to be reduced from 60 gallons per minute (gpm) to 40 gpm to achieve a 25-percent reduction in deicing fluid per aircraft. Forced air deicing can reduce operational expenses, environmental impacts, and subsequent environmental monitoring or remediation expenses (Icewolf product flyer; IDS, 2006).

Aircraft Deicing/Anti-Icing Product Substitution Practices

One solution to the environmental problems associated with glycol-based ADF is replacing such fluids with more environmentally friendly products. ADFs need to meet FAA’s Aerospace Material Specification (AMS) 1424 for Type I fluids and AMS 1428 standards for Type IV fluids. These standards require a specified level of product performance and compatibility and any alternative product must meet the same standards. To be economically viable, alternative products must also be comparably priced and be at least as effective in maintaining air safety as the glycol-based fluids they replace and less harmful to the environment.

EPA is aware of one non-glycol, plant-derived product currently being marketed by Cryotech Deicing Technology. A new Type I ADF product called “DF Sustain” uses 1,3-propanediol rather than PG, and is manufactured by a fermentation process using cornstarch. The manufacturer claims performance equal or better than PG- or EG-based deicers.

Table 7-1 lists other aircraft deicing alternatives that EPA is aware of based on literature reviews, industry meetings, and site visits. In addition, the airport and airline industry associations as well as U.S. Air Force have conducted and are continuing to conduct research into other potential substitutes for PG- and EG-based fluids.

Table 7-1. ADF Alternatives

Alternative	Comments
PG	ADF usage data indicates a trend towards greater PG use as an alternative to EG use.
Hot Air, Forced Air, and Tempered Steam Deicing	The use of hot air, forced air, or tempered steam when deicing aircraft is an alternative to typical deicing fluid application techniques using deicing trucks with conventional spray nozzles alone. These alternatives can provide more effective deicing than conventional spraying technologies and result in lower ADF usage.
Infrared Deicing	Infrared deicing is an alternative to conventional ADF usage and can greatly reduce (though not eliminate) the use of ADFs for deicing and anti-icing.
Cryotech Bio-PDO™	This bio-based product is currently being marketed as an alternative to conventional PG-based Type I fluids.
Warm Fuel for Wing Deicing	This type of deicing is an alternative to defrost deicing with ADF.

Airfield Deicing Product Substitution Practices

Environmental problems associated with past airfield deicing products like urea led to the development of the alternative airfield deicing chemicals used today. Potassium acetate has replaced urea as the primary airfield deicer at many U.S. airports. The U.S. Armed Forces no longer purchases airfield deicers that contain urea and instead use potassium acetate, sodium acetate, and sodium formate. These airfield deicers are highly effective at low temperatures, exert much lower oxygen demand than urea, and offer less environmental impact.

The aviation industry is currently evaluating the impact of common airfield deicing chemicals on the environment, runway infrastructure, and chemical corrosion of aircraft carbon brakes. Based on the results of this work, EPA anticipates that alternative airfield deicing chemicals will be identified and ultimately incorporated into practice. EPA is aware of one such product, Cryotech's Bio-PDO^{TM2}, which is currently being used as an additive for potassium acetate runway deicers. The Cryotech BX36 runway product performs similarly to its widely-used E36 product, but with reductions in electrical conductivity and potassium content (reducing carbon brake issues), and a bio-based material composition of 75 percent, allowing for easy degradation.

BMPs

BMPs are techniques used to limit the amount of ADF applied or allowed to mingle with stormwater. EPA defines a BMP as a "technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater in the most cost-effective manner." This section describes the following aircraft/airfield deicing-related BMPs:

- Application rates and deicing fluid dilution;
- Airfield prewetting;
- Ice detection systems;
- Enhanced weather forecasting;
- Heated sand;
- Separation of contaminated snow;
- Annual employee training;
- Mechanical deicing and snow removal;
- Yearly inspections of deicing equipment and infrastructure; and
- Type IV anti-icing.

Application Rates and Deicing Fluid Dilution

Deicing personnel can minimize the amount of deicing fluid used at an airport by varying deicing fluid application rates and the ADF dilution mix to best match each deicing event condition. Application rates are commonly evaluated every time deicing is required. However, ADF is usually premixed to a set 55 percent or 45 percent glycol concentration. Systems that allow for ADF dilution adjustment based on the weather conditions can use less. Ice thickness, ambient temperatures, and plane size all determine application rates and fluid dilution requirements. Small planes with small amounts of frost can require as little as 50 gallons of ADF while large planes with thick ice accumulations can take up to 2,000 gallons to deice. Application rates controlled by chemical metering systems installed to deicing trucks or booms allow the applicator to control the distribution of chemicals and maintain a consistent application rate at all times. Using a chemical metering system also allows the operator to change the application rate in mid-application based on changing weather conditions.

² Mention of Cryotech products should not be construed as an endorsement from EPA.

Airfield Prewetting

Airfield prewetting involves applying a dry chemical followed by a light coating of liquid deicer to airfield pavement. During icy conditions, a granular deicer is generally used to penetrate ice and increase surface area prior to using a liquid deicer (generally PG) to help the solid deicer stick to the pavement and prevent dry pellets from blowing off. Responses to EPA's airport questionnaire indicated that prewetting is common and helps lower the cost of materials by increasing the rate at which the liquid deicer contacts icy surfaces and by minimizing wind losses of solid deicer. Following prewetting, snow and ice are generally removed from airfield areas using mechanical equipment (such as plows and brooms).

Ice Detection Systems

Ice detection systems include sensors installed on runways and taxiways that transmit constant surface and subsurface temperature readings to deicing control personnel. These sensors indicate whether there is a potential for ice to form on the paved surfaces. Airports can then use the information provided by individual deicer manufacturers to determine whether to apply deicing/anti-icing chemicals.

Enhanced Weather Forecasting

Many of the larger U.S. airports use enhanced weather forecasting systems to help determine when they will require deicing activities. A popular weather forecasting product on the market is the Weather Support to Deicing Decision Making (WSDDM) software program. This system is a "nowcasting" system that is used to confirm National Weather Service data and forecasts. WSDDM provides forecasts, monitors storms and provides real-time storm information, and estimates and detects precipitation. WSDDM can provide the following services to the user:

1. Real-time snow gauge data (updated every minute) of the liquid equivalent snowfall rate at the airport and two to three sites 10 to 20 kilometers (km) away from the airport;
2. Real-time radar reflectivity from radars depicting current locations of precipitation and snow;
3. Meteorological data at the airport and two to three sites 10 to 20 km away from the airport updated every minute and displayed in text and time line form, with the time line going back two hours;
4. Thirty-minute nowcast of radar reflectivity based on a cross-correlation technique on the radar reflectivity data updated every six minutes; and
5. Thirty-minute nowcast of liquid equivalent snowfall rate at the airport and the off-site snow gauge locations by applying a real-time snow gauge-radar reflectivity calibration algorithm at each of the snow gauge sites, updated every six minutes.

WSDDM can improve pollution prevention by pinpointing when deicing operations are actually needed, which lowers the amount of ADFs used to keep departing aircraft free of ice and snow at takeoff and lowers the amount of anti-icing chemicals used to prevent ice and snow from bonding to aircraft and taxiways (ERG, 2005).

Heated Sand

Sand trucks can be parked in a heated garage with heat piped to the truck. Heating sand trucks accomplishes two things. First, heating the truck prevents the moisture in the sand from freezing and clumping, which would prevent the sand from being efficiently disbursed when applied. Second, applying heated sand to icy surfaces can melt ice and the sand provides needed traction when the surfaces refreeze, which minimize the need to use pavement deicers.

Separation of Contaminated Snow

Airports often segregate glycol-contaminated snow (commonly called “pink snow”) and haul it to a designated area where the snow melt can be collected. Deicing pads often contain designated areas to store contaminated snow so that the snow melt can be commingled with other deicing stormwater.

Annual Employee Training

Training and experience of personnel performing aircraft deicing/anti-icing operations affects the efficiency of aircraft deicing/anti-icing. Well-trained and experienced deicing/anti-icing personnel improve the efficiency of aircraft deicing/anti-icing operations and minimize the volume of ADF used. The training and experience of airport personnel may also affect the efficiency of airfield deicing operations. Airport personnel are typically responsible for clearing taxiways, gate areas, ramps, aprons, and deicing pads. When these areas are not adequately cleared, snow and ice accumulate on the undercarriage and the underside of aircraft during taxing and must be removed prior to takeoff.

Many airports conduct annual operations and maintenance training, with specialized winter operations training usually conducted prior to the deicing season. This specialized training can include but is not limited to proper use of equipment, application of chemicals, and location of snow melt areas. Staff may also be trained in environmental awareness detailing the requirements of airport permits and BMPs associated with airport deicing/anti-icing operations.

Mechanical Deicing and Snow Removal

The amount of ADF required to deice aircraft can be minimized by mechanically deicing the aircraft prior to chemical deicing. Mechanical deicing is generally economical only for small aircraft because mechanical deicing of large aircraft is labor-intensive and time consuming. A drawback of mechanical deicing is that aircraft (e.g., aircraft antennae and sensors) risk being damaged by incorrect mechanical deicing methods. Despite the risk of aircraft damage, many airlines use brooms, squeegees, and ropes, among other items, to remove ice and snow from aircraft surfaces. These methods are more effective at removing snow rather than ice.

Snow is commonly mechanically removed on airfield pavement, including passenger ramps, gate positions, taxiways, and runways, prior to ADF being applied, to prevent contamination of the snow. The following types of equipment are used to remove snow from airfield surfaces: self-propelled snow brooms, high speed snow blowers and snow plows, and utility trucks or tractors fitted with snow brooms or plows. Physical means are generally used to remove snow rather than ice.

Yearly Inspections of Deicing Equipment and Infrastructure

Inspections are conducted to ensure that equipment used for deicing operations is working properly and to determine where maintenance may be needed. Storage tanks are inspected to ensure there are no leaks. ADF application equipment is inspected to determine if gauges are working properly and that fluid is not being spilled. Trench or square drains are inspected to ensure there is no clogging and that water conveyed through the drain does not escape. Other equipment and airport infrastructure may require yearly inspections to make certain that deicing chemicals are applied with properly functioning equipment and collected with suitable infrastructure.

Type IV ADF Anti-icing

Type IV ADF protects aircraft from ice, snow, or slush accumulations on cleaned aircraft surfaces. Type IV fluids form a protective film on treated surfaces, protecting against ice formation and/or snow accumulation. Pretreating aircraft with Type IV fluid is sometimes used when ice is in the forecast and an aircraft is expected to remain on the ground for an extended period of time. This type of anti-icing treatment can reduce the amount of deicing fluid needed for an aircraft by reducing the amount of ice that forms on the aircraft.

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8. PERFORMANCE OF CONTROL AND TREATMENT SCENARIOS

EPA evaluated the performance of the selected control and treatment scenarios based on their ability to collect and treat ADF-contaminated stormwater and/or their ability to reduce pollutant loadings. EPA used airport-specific estimates of Type I and IV ADF to calculate the volumes of *applied* and *available* ADF at each of these airports (ERG, 2011a). EPA then evaluated the collection ranges of both the data collected by EPA and the data available in the Transportation Research Board (TRB) manual (TRB Airport Cooperative Research Program, 2009), combined with best engineering judgment to estimate the collection efficiency of each of the technologies below.

8.1 Deicing Pad Collection

EPA reviewed data on the performance of centralized deicing pads from a number of larger airports across the United States and Europe including DEN, DAY, PHL, CVG, DTW, PIT, and Oslo. These airports reported a collection range from 42 to 90 percent of their spent and/or applied ADF.

Additionally, the TRB Airport Cooperative Research Program Report No. 14, *Deicing Planning Guidelines and Practices for Stormwater Management Systems*, detailed airport collection efficiencies ranging from 44 to 86 percent of applied glycol (TRB Airport Cooperative Research Program, 2009).

EPA reviewed the airport-specific ADF usage data and determined that the collection of 42 to 90 percent of spent and/or applied ADF is equivalent to 61 to 90 percent of *available* ADF (ERG, 2011b). At proposal of this rule, EPA estimated the collection efficiency of deicing pads to be 60 percent. Based on the Agency's new analysis, this estimate represents the lower range of collection efficiency. As a result, EPA estimates deicing pads will collect at least 60 percent of the available ADF.

8.2 Plug and Pump Collection with GCV

EPA reviewed performance data from General Mitchell International (MKE) airport because its collection system matches the plug and pump with GCV collection system EPA costed for this rule. MKE reported a collection range between 22.5 and 33 percent of applied ADF.

Additionally, the TRB Airport Cooperative Research Program Report No. 14 reported collection efficiencies between 20 and 35 percent of applied ADF for plug and pump systems (TRB Airport Cooperative Research Program, 2009).

At proposal, EPA estimated a plug and pump with GCV collection system would collect 40 percent of available ADF. When adjusted for rounding, the mean of the data above is approximately 40 percent. As such, EPA has determined that a well-operated plug and pump system (in conjunction with GCVs) should be able to collect 40 percent of the available ADF. DCN AD01270 contains further details on these calculations.

8.3 GCV Collection

EPA did not identify nor did commenters provide collection efficiency data on GCVs alone. Gerald R. Ford International airport, which uses two tow-behind glycol collection units in conjunction with catch basin inserts to collect aircraft deicing contaminated stormwater around the terminal gates and apron, reported collecting 29 percent of all *applied* glycol during the 2005/2006 deicing season. Mass balance data on glycol usage and collection at Theodore Francis Green State airport between 2002 and 2006 indicate that its GCV-based system annually collects between 26 and 48 percent of all *applied* glycol. Overall, collection efficiencies of applied glycol from these airports ranged from 26 to 48 percent, although these systems also used some combination of catch basin inserts, plug and pump technology, and/or apron systems.

EPA's data points are similar to those summarized in the TRB Airport Cooperative Research Program Report No. 14. The report described collection efficiencies between 23 to 48 percent for glycol collection vehicles (TRB Airport Cooperative Research Program, 2009), although these systems, like those EPA referenced, also used some combination of catch basin inserts, plug and pump technology, and/or apron systems.

The ranges presented in the literature provide higher collection efficiencies than those associated with a plug and pump system; however, all of these data points include technologies that would have higher collection efficiencies than a GCV alone. While EPA is unable to document the efficiency of a GCV alone, it stands to reason that the collection efficiency of a GCV alone would be less than that of a plug and pump with a GCV. For the purposes of today's regulation, on a national basis, EPA assumes that a GCV is able to achieve approximately half the collection of a plug and pump with a GCV, or 20 percent of the available ADF.

8.4 AFB Treatment Performance

EPA collected data on the effectiveness of AFB treatment systems through literature review, its own sampling efforts, and industry-supplied data. These systems have demonstrated effective treatment for targeted pollutants, including COD, BOD₅, and glycol. Based on EPA's sampling data from Albany International airport, COD was reduced by greater than 97 percent, BOD₅ was reduced by greater than 98 percent, and glycol was reduced by greater than 99 percent (ERG, 2007).

Influent COD concentrations that can be efficiently treated by an AFB system range from approximately 2,000 to 128,000 mg/L and an AFB system can manage brief excursions outside of this range. (See Airport Council International – North America comments on EPA's Proposed Rule for Effluent Guidelines for the Airport Deicing Category). EPA selected AFB as the best technology for on-site treatment of ADF-contaminated stormwater because of the technology's superior ability to destroy the pollutants of concern and to handle a range of influent concentrations. An evaluation of AFB treatment for other industrial wastewaters that have high COD content, such as distillery, textile, dairy, and brewery wastewaters, shows COD removals in the 50 to 98 percent range (ERG, 2010).

8.5 References

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9. POLLUTANT LOADINGS AND POLLUTANT LOAD REDUCTION ESTIMATES

Pollutant loadings from airport deicing operations are highly variable and airport-specific. Because the use of deicing and anti-icing chemicals is weather-dependent, the pollutant loadings at each airport vary from year to year based on weather conditions and also based on each airport's climate. In addition, the amount of applied chemical that is discharged to surface water depends on the existing stormwater separation, collection, and/or containment system present at each airport.

Due to the variations of the pollutant discharges, EPA determined that it would not be appropriate to develop baseline pollutant loadings using end-of-pipe monitoring data. Monitoring data on an airport's deicing stormwater outfall(s) provides only a "snap shot" of a single point in time, during a monthly monitoring event or, in some cases, a single storm event. In addition, these data are available only for a select number of airports and are airport-specific. Although these data provide information on the types of pollutants present in airport deicing stormwater and the range of concentrations that may reach outfall points, there is insufficient basis for extrapolating or transferring the data across large time frames (e.g., an entire winter season) or to other airports.

Therefore, EPA developed a pollutant loading estimation methodology for individual airports based on the use of ADF and airfield chemicals at the airports surveyed by EPA. The methodology takes into account EPA's existing data sources and provides a better estimate of the loadings than those based on sporadic monitoring data alone. The Agency used a model-site approach to estimate loads for the Airport Deicing Category. A model airport is an operating airport whose deicing chemical usage and unit operation and treatment information were used as parameters for the loadings model. EPA selected an airport-by-airport approach to estimate baseline loadings and loading removals from the model airports, as opposed to a more generalized approach, to better characterize the current control and treatment systems in place for ADF-contaminated stormwater and to account for current site conditions and airport operations.

This section discusses the data sources available to EPA to support its pollutant loadings and loading reduction estimates (Section 9.1), provides an overview of EPA's pollutant loading methodology (Section 9.2), and describes the calculation steps that compose EPA's loading methodology (Sections 9.3 through 9.6). Section 9.7 summarizes EPA's approach for estimating loading reductions associated with the discontinued use of urea as an airfield deicing chemical.

9.1 Data Sources

EPA considered the following available data when developing the pollutant loadings estimation methodology for airport deicing operations (see Section 3 for more information about the data sources):

- Pavement deicing chemical usage information for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons, as reported by airport personnel in the airport questionnaire;
- ADF purchase information for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons, as reported by airline personnel in the airline detailed questionnaire;
- Standard airport information available from the FAA, including the number of operations and departures by airport;

- Weather information for each airport from the National Oceanic and Atmospheric Administration (NOAA), including temperature, freezing precipitation, and snowfall data;
- Existing airport stormwater collection and containment systems, as reported by airport personnel in the airport questionnaire or during EPA site visits;
- Standard chemical information about ADF and pavement deicing chemicals, including molecular formulas and densities; and
- Analytical data from EPA sampling episodes of airport deicing operations.

9.2 Aircraft Deicing Pollutant Loading

This section presents EPA's methodology for estimating ADF pollutant loads using airline questionnaire data on ADF usage and the theoretical oxygen demand associated with various deicing fluids.

9.2.1 *Estimate the Amount of Applied Deicing Chemical*

EPA requested the purchase amount, concentration, and brand name in the airline detailed questionnaire for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons for the following ADF chemicals:

- EG Type I;
- EG Type II;
- EG Type IV;
- PG Type I;
- PG Type II;
- PG Type III;
- PG Type IV; and
- Isopropyl Alcohol-Based Fluid.

Questionnaire responses provided sufficient data to estimate ADF usage at 56 model airports. In some cases, data were not available for every airline operating at a model airport. In these instances, EPA extrapolated the amount of ADF used at the reporting airlines to estimate the total amount of ADF used by the entire airport, based on the number of airport operations (departures) at the reporting airlines and the total amount of airport operations. Table 9-1 presents the ADF estimates based on airline questionnaire responses. No airports reported purchasing EG Type II, EG Type III, PG Type II, PG Type III, or isopropyl alcohol-based fluid.

In addition to the ADF data reported in the airline detailed questionnaire, 10 airports reported their estimates of total annual ADF usage to EPA in the comment section of the airport questionnaire (see Table 9-2). These ADF data were combined with the ADF data reported in the airline detailed questionnaires, resulting in 66 airports with total PG/EG (gallons) usage estimates. EPA used the airport's estimate of ADF usage from the airport questionnaires because those data came from a certified questionnaire response.

Table 9-1. ADF Estimates Based on Airline Detailed Questionnaire Responses

Airport ID	Airport Name	Estimated PG/EG Use (GPY)	PG Type I (%)	PG Type IV (%)	EG Type 1 (%)	EG Type IV (%)
1003	Ketchikan International	18,182	0	0	100	0
1006	Chicago O'Hare International	1,516,626	80	20	0	0
1010	Fairbanks International	83,335	0	0	100	0
1011	Lambert - St Louis International	325,122	23	1	70	6
1012	Ted Stevens Anchorage International	420,735	0	0	100	0
1013	Wiley Post-Will Rogers Mem	3,056	9	0	91	0
1021	Buffalo Niagara International	281,836	92	9	0	0
1022	Fort Wayne International	50,412	92	8	0	0
1024	Indianapolis International	452,155	91	9	0	0
1026	Dallas/Fort Worth International	166,790	43	12	38	7
1028	Denver International	1,043,138	87	10	4	0
1029	La Guardia	485,157	75	22	2	1
1036	Baltimore - Washington International	323,623	90	10	0	0
1037	George Bush Intercontinental Airport/Houston	10,242	82	18	0	0
1043	Ralph Wien Memorial	2,500	27	0	73	0
1047	Sacramento Mather	1,282	100	0	0	0
1053	General Edward Lawrence Logan International	995,249	82	17	0	0
1058	Gerald R Ford International	98,156	86	13	0	0
1059	Greater Rochester International	229,158	91	9	0	0
1065	Albany International	125,775	93	7	0	0
1066	Salt Lake City International	570,540	22	6	52	20
1069	Cleveland - Hopkins International	582,321	90	10	0	0
1074	South Bend Regional	29,586	75	25	0	0
1079	Manchester	177,307	87	13	0	0
1080	Syracuse Hancock International	186,351	97	3	0	0
1089	John F Kennedy International	560,031	82	18	0	0
1095	Chicago Midway International	293,834	88	12	0	0
1100	Toledo Express	46,449	64	5	29	2
1103	Juneau International	48,014	0	0	100	0
1104	Nome	3,047	15	0	85	0
1105	Spokane International	67,984	92	8	0	0
1107	Pittsburgh International	943,982	88	12	0	0
1109	Airborne Airpark	432,416	74	26	0	0
1110	Aniak	476	100	0	0	0
1111	Port Columbus International	288,374	92	8	0	0
1113	Cincinnati/Northern Kentucky International	715,836	24	5	61	11

Table 9-1 (Continued)

Airport ID	Airport Name	Estimated PG/EG Use (GPY)	PG Type I (%)	PG Type IV (%)	EG Type 1 (%)	EG Type IV (%)
1117	Cherry Capital	11,524	75	0	0	25
1118	Bethel	4,897	40	0	60	0
1123	James M Cox Dayton International	90,580	89	11	0	0
1124	Des Moines International	79,658	84	14	3	0
1126	Minneapolis/ St Paul International/Wold - Chamberlain	1,456,537	93	7	0	0
1128	Charlotte/Douglas International	143,572	81	19	0	0
1129	Bradley International	427,068	88	12	0	0
1136	General Mitchell International	152,944	90	9	0	1
1138	Detroit Metropolitan Wayne County	2,152,292	93	7	0	0
1139	Philadelphia International	979,983	88	12	0	0
1140	Memphis International	199,174	88	12	0	0
1141	Ronald Reagan Washington National	219,533	81	16	3	0
1142	Washington Dulles International	1,076,083	77	22	1	0
1145	Newark Liberty International	1,123,057	86	14	0	0
1148	Kansas City International	203,726	75	8	17	0
1149	Fort Worth Alliance	1,522	97	3	0	0
1150	Greater Rockford	146,856	79	21	0	0
1151	Kalamazoo/Battle Creek International	22,002	84	16	0	0
1152	Duluth International	68,168	96	4	0	0
1153	Akron - Canton Regional	60,246	90	10	0	0

Source: Airport Deicing Operations ADF Usage Database (USEPA, 2008).

Note: PG/EG gallons represent total usage normalized to 100 percent glycol. Values may not sum to 100 due to rounding.

GPY – Gallons per year.

Table 9-2. ADF Data Reported in the Airport Questionnaire

Airport ID	Airport Name	PG/EG Usage (GPY)
1115	Jacksonville International	1,000
1062	Birmingham International	5,000
1072	Gillette-Campbell County	880
1060	Williamson County Regional	150
1096	Santa Fe Municipal	1,108
1097	Lovell Field	4,148
1025	Tupelo Regional	820
1143	San Francisco International	105
1001	Montgomery Regional (Dannelly Field)	232
1019	Ontario International	35

Source: Airport Deicing Operations ADF Usage Database (USEPA, 2008).
GPY – Gallons per year.

Using the airline and airport questionnaire data on ADF purchases, airport departures, and climate, EPA correlated the estimate of the amount of ADF used to the climate and size of each airport. EPA created an “ADF Factor” to estimate the relative amount of deicing occurring at each airport based on the airport’s climate and number of departures. EPA calculated the ADF Factor by multiplying the 30-year annual average number of SOFP days by the average number of annual departures at each airport during 2004-2006 (USEPA, 2008a). EPA graphed the total gallons of PG/EG purchased with the ADF factor and determined the equation of the line. During this analysis, EPA noted a difference in the relationship of ADF Factor and ADF usage for Alaskan airports compared to other airports. Due to this difference, EPA developed a separate graph and equation for Alaskan airports. Figure 9-1 shows the graph for non-Alaskan airports and Figure 9-2 presents the graph for Alaskan airports.

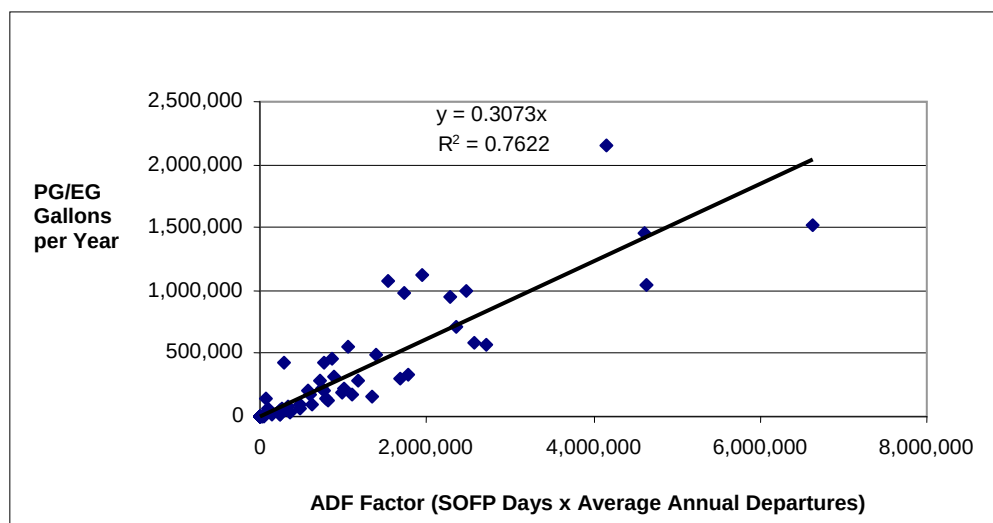


Figure 9-1. ADF Factor vs. PG/EG Gallons for U.S. Airports (excluding Alaska)

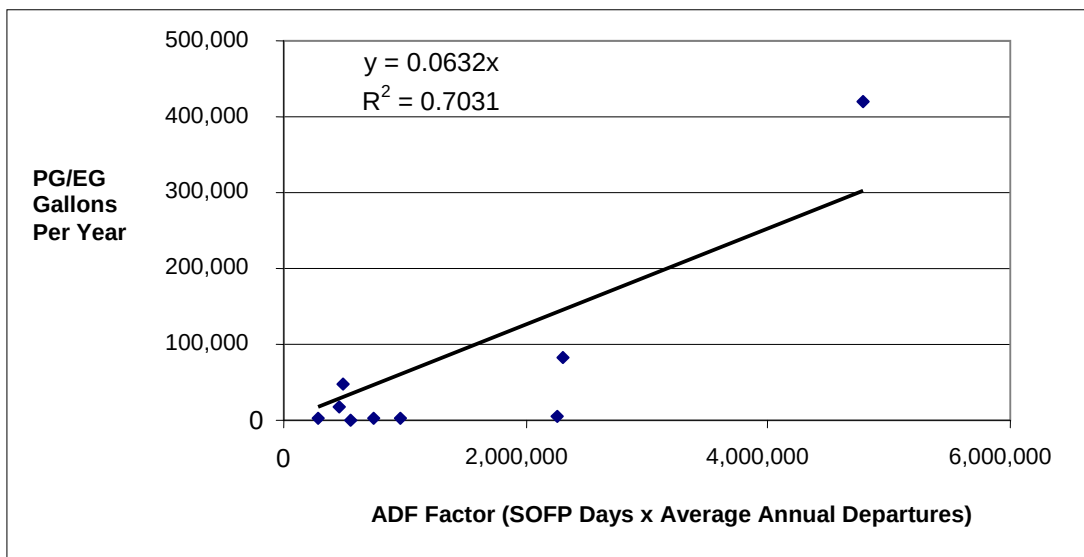


Figure 9-2. ADF Factor vs. PG/EG Gallons for Alaskan Airports

EPA used the line equations to estimate the total gallons of ADF used at model airports that did not have available ADF data in the airport or airline detailed questionnaires. Based on the estimated total gallons of ADF used at an airport, EPA calculated the distribution of different types of ADF (PG/EG, Type I/Type IV) based on the average percent distribution of the reported ADF amounts. See the *Airport Deicing Loadings Calculations* memorandum (ERG, 2008b) for more detail. Table 9-3 presents the final estimates of ADF usage for airports in the scope of the final rule.

Table 9-3. ADF Annual Usage Estimates for In-scope Airports

Airport ID	Airport Name	PG Type I (gallons)	PG Type IV (gallons)	EG Type I (gallons)	EG Type IV (gallons)
1001	Montgomery Regional (Dannelly Field)	166	22	41	3
1003	Ketchikan International	0	0	18,182	0
1004	Norfolk International	22,084	2,938	5,451	402
1006	Chicago O'Hare International	1,213,301	303,325	0	0
1007	Yeager	35,450	4,715	8,750	646
1008	Tucson International	1,675	223	413	31
1010	Fairbanks International	0	0	83,335	0
1011	Lambert-St Louis International	74,778	3,251	227,586	19,507
1012	Ted Stevens Anchorage International	0	0	420,735	0
1014	Albuquerque International Sunport	46,107	6,133	11,380	840
1015	Gulfport-Biloxi International	1,109	148	274	20
1017	Austin Straubel International	44,442	5,912	10,969	810
1018	Piedmont Triad International	49,169	6,540	12,136	896
1019	Ontario International	25	3	6	0
1020	Hartsfield - Jackson Atlanta International	259,100	34,465	63,950	4,720
1021	Buffalo Niagara International	259,289	25,365	0	0
1022	Fort Wayne International	46,379	4,033	0	0
1023	Seattle-Tacoma International	112,631	14,982	27,799	2,052
1024	Indianapolis International	411,461	40,694	0	0
1026	Dallas/Fort Worth International	71,720	20,015	63,380	11,675
1028	Denver International	907,530	104,314	41,726	0
1029	La Guardia	363,868	106,735	9,703	4,852
1031	Richmond International	42,442	5,646	10,476	773
1032	Austin-Bergstrom International	17,198	2,288	4,245	313
1033	Mc Carran International	7,613	1,013	1,879	139
1034	Metropolitan Oakland International	0	0	0	0
1035	San Diego International	0	0	0	0
1036	Baltimore-Washington International	291,261	32,362	0	0
1037	George Bush Intercontinental Airport/Houston	8,399	1,844	0	0
1040	Louis Armstrong New Orleans International	0	0	0	0
1041	Glacier Park International	27,578	3,668	6,807	502
1043	Ralph Wien Memorial	675	0	1,825	0
1044	Roanoke Regional/Woodrum Field	23,552	3,133	5,813	429
1045	Norman Y. Mineta San Jose International	10	0	0	0
1046	Long Island Mac Arthur	31,135	4,141	7,685	567
1050	Aspen-Pitkin Co/Sardy Field	10,742	1,429	2,651	196
1052	Wilmington International	1,556	207	384	28

Table 9-3 (Continued)

Airport ID	Airport Name	PG Type I (gallons)	PG Type IV (gallons)	EG Type I (gallons)	EG Type IV (gallons)
1053	General Edward Lawrence Logan International	816,104	169,192	0	0
1054	Jackson Hole	24,413	3,247	6,026	445
1057	Will Rogers World	35,409	4,710	8,740	645
1058	Gerald R. Ford International	84,414	12,760	0	0
1059	Greater Rochester International	208,534	20,624	0	0
1061	William P Hobby	10,134	1,348	2,501	185
1062	Birmingham International	3,578	476	883	65
1063	Evansville Regional	14,412	1,917	3,557	263
1065	Albany International	116,971	8,804	0	0
1066	Salt Lake City International	125,519	34,232	296,681	114,108
1067	Helena Regional	13,147	1,749	3,245	240
1068	Eppley Airfield	79,386	10,560	19,594	1,446
1069	Cleveland-Hopkins International	524,089	58,232	0	0
1070	City of Colorado Springs Municipal	54,230	7,214	13,385	988
1074	South Bend Regional	22,189	7,396	0	0
1075	Pensacola Regional	592	79	146	11
1078	Nashville International	65,479	8,710	16,161	1,193
1079	Manchester	154,257	23,050	0	0
1080	Syracuse Hancock International	180,760	5,591	0	0
1081	Bob Hope	0	0	0	0
1083	Tampa International	0	0	0	0
1084	Bismarck Municipal	15,018	1,998	3,707	274
1086	Palm Beach International	732	97	181	13
1087	El Paso International	11,608	1,544	2,865	211
1088	Outagamie County Regional	41,375	5,504	10,212	754
1089	John F Kennedy International	459,225	100,806	0	0
1090	Boise Air Terminal/Gowen Fld	51,086	6,795	12,609	931
1091	Rochester International	24,717	3,288	6,101	450
1094	Boeing Field/King County International	3,688	491	910	67
1095	Chicago Midway International	258,574	35,260	0	0
1097	Lovell Field	2,968	395	733	54
1099	Sacramento International	0	0	0	0
1100	Toledo Express	29,728	2,322	13,470	929
1101	Portland International	80,173	10,664	19,788	1,461
1102	John Wayne Airport-Orange County	0	0	0	0
1103	Juneau International	0	0	48,014	0
1104	Nome	457	0	2,590	0
1105	Spokane International	62,545	5,439	0	0

Table 9-3 (Continued)

Airport ID	Airport Name	PG Type I (gallons)	PG Type IV (gallons)	EG Type I (gallons)	EG Type IV (gallons)
1107	Pittsburgh International	830,704	113,278	0	0
1108	Louisville International-Standiford Field	91,849	12,217	22,670	1,673
1111	Port Columbus International	265,304	23,070	0	0
1113	Cincinnati/Northern Kentucky International	171,801	35,792	436,660	78,742
1114	Stewart International	23,086	3,071	5,698	421
1115	Jacksonville International	716	95	177	13
1116	Reno/Tahoe International	53,382	7,101	13,176	973
1117	Cherry Capital	8,643	0	0	2,881
1118	Bethel	1,959	0	2,938	0
1119	Rickenbacker International	7,661	1,019	1,891	140
1120	Rapid City Regional	18,185	2,419	4,488	331
1121	Theodore Francis Green State	107,383	14,284	26,504	1,956
1122	Southwest Florida International	680	90	168	12
1123	James M Cox Dayton International	80,616	9,964	0	0
1124	Des Moines International	66,913	11,152	2,390	0
1126	Minneapolis/St Paul International/Wold-Chamberlain	1,354,580	101,958	0	0
1128	Charlotte/Douglas International	116,293	27,279	0	0
1129	Bradley International	375,820	51,248	0	0
1130	San Antonio International	9,119	1,213	2,251	166
1131	Wilkes-Barre/Scranton International	30,426	4,047	7,510	554
1133	Phoenix Sky Harbor International	0	0	0	0
1135	Lafayette Regional	1,065	142	263	19
1136	General Mitchell International	137,650	13,765	0	1,529
1137	Dallas Love Field	26,622	3,541	6,571	485
1138	Detroit Metropolitan Wayne County	2,001,632	150,660	0	0
1139	Philadelphia International	862,385	117,598	0	0
1140	Memphis International	175,273	23,901	0	0
1141	Ronald Reagan Washington National	177,822	35,125	6,586	0
1142	Washington Dulles International	828,584	236,738	10,761	0
1143	San Francisco International	75	10	19	1
1144	Central Wisconsin	31,203	4,151	7,702	568
1145	Newark Liberty International	965,829	157,228	0	0
1146	Northwest Arkansas Regional	22,013	2,928	5,433	401
1147	Raleigh-Durham International	73,281	9,748	18,087	1,335
1148	Kansas City International	152,794	16,298	34,633	0

Source: Airport Deicing Operations ADF Usage Database (USEPA, 2008).

Note: Values may not sum to total usage amounts due to rounding.

9.2.2 *Calculate the Amount of Pollutant Load Associated with the Applied ADF*

As aircraft deicing chemicals break down in the environment, they increase COD and BOD. EPA calculated the amount of COD and BOD (presented as 5 day BOD, or BOD₅) associated with the degradation of the applied deicing/anti-icing chemicals.

EPA considered two approaches to estimate the amount of COD and BOD₅ associated with deicing chemicals. The first approach involved using laboratory empirical COD and BOD₅ data for deicing chemicals. The second approach involved using standard chemical information and stoichiometric equations to estimate COD and BOD₅ for each chemical.

EPA determined it would not be suitable to use empirical data to estimate loadings for three main reasons. First, empirical COD and BOD₅ data were not readily available for all deicing/anti-icing chemicals. Second, the available empirical data were outdated and brand-specific. Finally, chemical formulations vary significantly over time and by brand, so it is inappropriate to apply any given set of empirical data to all airports and chemicals.

EPA selected the second approach, calculating loadings based on standard chemical information and stoichiometric equations. The advantage of this methodology over using empirical data is that it can be used for all deicing chemicals. In addition, this methodology allows the calculations and assumptions used to be clearly presented. EPA checked the validity of the COD and BOD₅ concentrations for PG and EG calculated using this methodology against the available empirical data and found a good match.

Calculate the Total Mass of Each Pollutant

First, EPA estimated the total mass of each chemical based on the airline and airport questionnaire responses (which specified varying formulations of ADF and deicing products). To calculate the total mass of applied chemical, EPA multiplied the reported mass of each chemical by the reported percentage of the pollutant in the ADF formulation, by the density of the pollutant.

Determine the Theoretical Oxygen Demand of Each Chemical

Next, EPA determined the theoretical oxygen demand (ThOD) associated with the degradation of each of the deicing chemicals. The ThOD estimate was based on the molecular formula of the chemical and the stoichiometric equation of the breakdown of the chemical to the end products of carbon dioxide and water. Table 9-4 lists the calculated ThOD for each chemical in aircraft deicers.

Table 9-4. Theoretical Oxygen Demand Calculations for Aircraft Deicing Chemicals

Deicing Compound	Molecular Formula	Stoichiometric Formula	ThOD (Moles of O ₂ per Mole of Deicing Compound)
PG	C ₃ H ₈ O ₂	C ₃ H ₈ O ₂ + 4 O ₂ → 3 CO ₂ + 4 H ₂ O	4.0
EG	C ₂ H ₆ O ₂	2[C ₂ H ₆ O ₂] + 5 O ₂ → 4 CO ₂ + 6 H ₂ O	2.5

Determine the COD of Each Chemical

EPA next determined the COD loading associated with the chemical's degradation. EPA assumed that the chemical would completely degrade in the environment over time and therefore the calculated ThOD load would be equivalent to the COD load. EPA estimated the COD load associated with each reported chemical based on the calculated mass of the chemical purchased, the molecular weight of the chemical, the ThOD, and the molecular weight of oxygen, using the equation below:

$$\text{COD Load (pounds)} = \text{Chemical (pounds)} \times \frac{434 \text{ grams}}{\text{pound}} \times \text{Chemical Molecular Weight} \left(\frac{\text{moles of chemical}}{\text{grams of chemical}} \right) \times \text{ThOD} \left(\frac{\text{moles of O}_2}{\text{moles of chemical}} \right) \times \text{O}_2 \text{ Molecular Weight} \left(\frac{\text{grams of O}_2}{\text{moles of O}_2} \right) \times \frac{\text{pound}}{434 \text{ grams}} \quad (9-1)$$

Determine the BOD₅ of Each Chemical

EPA calculated the BOD₅ loading of ADF based on the estimated COD loading in ADF. EPA developed an industry-specific relationship between COD and BOD₅ using analytical data for untreated deicing stormwater from the EPA sampling episodes at Albany International airport, Pittsburgh International airport, and Denver International airport. The average COD/BOD₅ ratio was 1.67. This relationship was used to calculate the BOD₅ associated with the degradation of the deicing chemical. See the *Airport Deicing Loading Calculations* memorandum (ERG, 2008b) for more information.

9.2.3 *Estimate the Amount of Baseline Pollutant Load that is Discharged Directly*

The amount of applied chemical that is discharged directly is airport-specific and dependent upon the existing stormwater collection/treatment system present at each airport. Typically, ADF is applied at a number of specific locations at the airport, including gates, deicing pads, and/or aprons.

In estimating the direct discharge amount of ADF, EPA first estimated the amount of applied ADF that would be available for discharge. EPA assumed that 75 percent of applied Type I ADF falls onto the pavement at the deicing area and is available for discharge; the remaining 25 percent is lost to evaporation, wind, or tire tracking, or adheres to the plane and is later sheared off during taxiing and takeoff (Switzenbaum, et al., 1999). EPA assumed that 10 percent of Type IV ADF falls to the pavement in the deicing area and is available for discharge; the remaining 90 percent adheres to the plane. The Agency multiplied the total amount of applied ADF by the appropriate percentage available for discharge to determine the amount of ADF that is available for discharge.

Next, EPA determined the percentage of available ADF that would be directly discharged at each airport, depending on the airport's current control and treatment systems (ERG, 2011). EPA estimated collection and control percentages of available ADF for each airport based on information provided during EPA site visits and in the airport questionnaire. If the airport did not provide an ADF collection and control percentage estimate, EPA personnel reviewed the airport's questionnaire responses and the reported collection and control percentage of similar systems to determine an estimate for the airport.

The COD load associated with each ADF chemical applied at an airport was reduced by EPA's estimate of the airport's current collection and control percentage to estimate the amount of COD directly discharged. These estimates represent the baseline amount of ADF discharged to the environment. Table 9-5 in Section 9.2.5 presents EPA's estimate of the baseline COD load (in pounds) directly discharged by each airport.

9.2.4 *Estimate Pollutant Loading Discharges for Each ADF Collection/Control Scenario*

Two of EPA's regulatory options require a specific collection and treatment percentage of available ADF. For the final rule, EPA evaluated the following scenarios as discussed in Section 11:

- 20% Collection and Control Scenario: collection and treatment of 20 percent of available ADF; and
- 40% Collection and Control Scenario: collection and treatment of 40 percent of available ADF.

EPA estimated the direct discharge COD load of each collection and control scenario accounting for the following two components:

- The COD load associated with the applied ADF, minus any reductions achieved by the collection and control practices implemented; and
- The COD load that would be discharged from AFB biological treatment of the collected treatment.

EPA estimated the amount of COD load that would be discharged from treatment for each airport that had load reductions in a scenario. Using analytical data from its sampling episodes, EPA determined that AFB systems remove 97.5 percent of COD. Therefore, EPA assumed that 97.5 percent of the COD load going to treatment would be removed and 2.5 percent would be discharged.

9.2.5 *Estimate Pollutant Loading Reductions for Each ADF Collection/Control Scenario*

After estimating the loads for each scenario, EPA estimated the loading reductions as compared to baseline. Table 9-5 lists the ADF COD baseline loads and reductions for each control and treatment scenario EPA evaluated for those airports in the scope of the final rule.

Table 9-5. ADF COD Baseline Loads and Loading Reductions for Each Control and Treatment Scenario, by In-Scope Airport

Airport ID	Airport	Airport Weighting Factor	Current ADF Collection (%)	Baseline COD Load (pounds)	COD Load Reduction for 20% Collection and Control Scenario (pounds)	COD Load Reduction for 40% Collection and Control Scenario (pounds)
1001	Montgomery Regional (Dannelly Field)	6.7013	0	2,214	432	863
1003	Ketchikan International	1.0000	NA	0	0	0
1004	Norfolk International	1.0000	20	235,637	0	57,436
1006	Chicago O'Hare International	1.0000	40	8,204,552	0	0
1007	Yeager	2.1508	40	283,685	0	0
1008	Tucson International	2.9997	20	17,873	0	4,357
1010	Fairbanks International	1.0000	≥60	299,205	0	0
1011	Lambert-St Louis International	1.0000	≥60	1,154,584	0	0
1012	Ted Stevens Anchorage International	1.0000	40	2,265,902	0	0
1014	Albuquerque International Sunport	1.0000	20	491,959	0	119,915
1015	Gulfport-Biloxi International	5.8413	≥60	0	0	0
1017	Austin Straubel International	2.3269	40	355,646	0	0
1018	Piedmont Triad International	1.0000	0	655,787	127,879	255,757
1019	Ontario International	1.0000	0	334	200	200
1020	Hartsfield - Jackson Atlanta International	1.0000	≥60	1,382,287	0	0
1021	Buffalo Niagara International	1.0000	40	1,718,928	0	0
1022	Fort Wayne International	1.9682	0	511,705	102,341	204,682
1023*	Seattle-Tacoma International	1.0000	0	1,502,208	292,931	585,861
1024	Indianapolis International	1.0000	40	2,728,125	0	0
1026	Dallas/Fort Worth International	1.0000	≥60	557,682	0	0
1028	Denver International	1.0000	≥60	104,244	0	0
1029	La Guardia	1.0000	0	4,216,728	822,262	1,644,524
1031	Richmond International	1.0000	40	339,643	0	0
1032	Austin-Bergstrom International	1.0000	40	137,629	0	0
1033	Mc Carran International	1.0000	40	60,923	0	0
1034	Metropolitan Oakland International	1.0000	≥60	0	0	0
1035	San Diego International	1.0000	≥60	0	0	0
1036	Baltimore-Washington International	1.0000	≥60	1,289,506	0	0
1037	George Bush Intercontinental Airport/Houston	1.0000	40	56,571	0	0
1040	Louis Armstrong New Orleans International	1.0000	≥60	0	0	0

Table 9-5 (Continued)

Airport ID	Airport	Airport Weighting Factor	Current ADF Collection (%)	Baseline COD Load (pounds)	COD Load Reduction for 20% Collection and Control Scenario (pounds)	COD Load Reduction for 40% Collection and Control Scenario (pounds)
1041	Glacier Park International	3.1409	0	367,815	71,724	143,448
1043	Ralph Wien Memorial	1.0000	0	23,743	4,630	9,260
1044	Roanoke Regional/Woodrum Field	2.1921	0	314,124	61,254	122,508
1045	Norman Y. Mineta San Jose International	1.0000	10	0	0	0
1046	Long Island Mac Arthur	1.9985	≥60	166,102	0	0
1050	Aspen-Pitkin Co/Sardy Field	4.7500	40	85,963	0	0
1052	Wilmington International	6.0388	0	20,756	4,047	8,095
1053	General Edward Lawrence Logan International	1.0000	0	9,147,072	1,783,679	3,567,358
1054	Jackson Hole	4.3500	≥60	0	0	0
1057	Will Rogers World	1.0000	0	472,260	92,091	184,181
1058	Gerald R. Ford International	1.5862	40	563,544	0	0
1059	Greater Rochester International	1.0000	50	1,152,208	0	0
1061	William P Hobby	1.0000	≥60	0	0	0
1062	Birmingham International	2.8410	0	47,717	9,305	18,610
1063	Evansville Regional	5.1042	0	192,217	37,482	74,965
1065	Albany International	1.0000	≥60	25,771	0	0
1066	Salt Lake City International	1.0000	≥60	1,687,338	0	0
1067	Helena Regional	4.2000	≥60	0	0	0
1068	Eppley Airfield	1.0000	0	1,058,801	206,466	412,933
1069	Cleveland-Hopkins International	1.0000	40	3,480,467	0	0
1070	City of Colorado Springs Municipal	1.7414	40	433,971	0	0
1074	South Bend Regional	2.1417	≥60	0	0	0
1075	Pensacola Regional	3.9341	≥60	0	0	0
1078	Nashville International	1.0000	≥60	349,329	0	0
1079	Manchester	1.0000	0	1,715,962	334,613	669,225
1080	Syracuse Hancock International	1.0000	≥60	791,854	0	0
1081	Bob Hope	1.0000	≥60	0	0	0
1083	Tampa International	1.0000	≥60	0	0	0
1084	Bismarck Municipal	3.8679	0	200,305	39,059	78,119
1086	Palm Beach International	1.0000	≥60	0	0	0
1087	El Paso International	3.0457	≥60	0	0	0
1088	Outagamie County Regional	2.4841	0	551,842	107,609	215,218

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Table 9-5 (Continued)

Airport ID	Airport	Airport Weighting Factor	Current ADF Collection (%)	Baseline COD Load (pounds)	COD Load Reduction for 20% Collection and Control Scenario (pounds)	COD Load Reduction for 40% Collection and Control Scenario (pounds)
1089	John F Kennedy International	1.0000	0	5,155,239	1,005,272	2,010,543
1090	Boise Air Terminal/Gowen Fld	1.5043	≥60	272,543	0	0
1091	Rochester International	3.1749	40	197,799	0	0
1094	Boeing Field/King County International	5.8985	40	29,510	0	0
1095	Chicago Midway International	1.0000	≥60	0	0	0
1097	Lovell Field	4.9996	0	39,586	23,752	23,752
1099	Sacramento International	1.0000	20	0	0	0
1100	Toledo Express	2.0917	20	359,704	0	87,678
1101	Portland International	1.0000	20	855,437	0	208,513
1102	John Wayne Airport-Orange County	1.0000	≥60	0	0	0
1103	Juneau International	1.0000	0	430,969	84,039	168,078
1104	Nome	1.0000	0	28,231	5,505	11,010
1105	Spokane International	1.5192	≥60	0	0	0
1107	Pittsburgh International	1.0000	≥60	3,689,998	0	0
1108	Louisville International- Standiford Field	1.0000	≥60	490,009	0	0
1111	Port Columbus International	1.0000	0	2,927,149	570,794	1,141,588
1113	Cincinnati/Northern Kentucky International	1.0000	≥60	415,766	0	0
1114	Stewart International	2.8661	40	184,745	0	0
1115	Jacksonville International	1.0000	≥60	0	0	0
1116	Reno/Tahoe International	1.0000	20	569,580	0	138,835
1117	Cherry Capital	3.5400	≥60	0	0	0
1118	Bethel	1.0000	0	47,733	9,308	18,616
1119	Rickenbacker International	4.3659	0	102,180	19,925	39,850
1120	Rapid City Regional	3.1082	0	242,540	47,295	94,591
1121	Theodore Francis Green State	1.0000	≥60	572,884	0	0
1122	Southwest Florida International	1.0000	≥60	0	0	0
1123	James M Cox Dayton International	1.0000	≥60	357,499	0	0
1124	Des Moines International	1.6211	40	460,483	0	0
1126	Minneapolis/St Paul International/Wold-Chamberlain	1.0000	≥60	5,968,923	0	0
1128	Charlotte/Douglas International	1.0000	0	1,308,047	255,069	510,138
1129	Bradley International	1.0000	≥60	1,669,398	0	0

Table 9-5 (Continued)

Airport ID	Airport	Airport Weighting Factor	Current ADF Collection (%)	Baseline COD Load (pounds)	COD Load Reduction for 20% Collection and Control Scenario (pounds)	COD Load Reduction for 40% Collection and Control Scenario (pounds)
1130	San Antonio International	1.0000	0	121,626	23,717	47,434
1131	Wilkes-Barre/Scranton International	2.6815	0	405,801	79,131	158,262
1133	Phoenix Sky Harbor International	1.0000	20	0	0	0
1135	Lafayette Regional	6.6425	0	14,201	8,521	8,521
1136	General Mitchell International	1.0000	44	852,970	0	0
1137	Dallas Love Field	1.0000	40	213,039	0	0
1138	Detroit Metropolitan Wayne County	1.0000	≥60	0	0	0
1139	Philadelphia International	1.0000	≥60	1,436,522	0	0
1140	Memphis International	1.0000	0	1,946,410	379,550	759,100
1141	Ronald Reagan Washington National	1.0000	40	1,229,789	0	0
1142	Washington Dulles International	1.0000	40	5,686,802	0	0
1143	San Francisco International	1.0000	≥60	0	0	0
1144	Central Wisconsin	3.0156	0	416,170	81,153	162,306
1145	Newark Liberty Intl	1.0000	0	10,762,687	2,098,724	4,197,448
1146	Northwest Arkansas Regional	1.8782	0	293,595	57,251	114,502
1147	Raleigh-Durham Intl	1.0000	0	977,382	190,589	381,179
1148	Kansas City Intl	1.0000	40	1,200,632	0	0

NA – Ketchikan was sent an airport questionnaire but did not respond.

Sources: Airport Deicing Loadings Database. (USEPA, 2010); ADF Capture and Control Efficiency Review Memorandum. (ERG, 2011)

* The airport post-questionnaire has installed deicing pads; high BOD stormwater is sent to a POTW.

For each scenario, EPA estimated no load reductions for the airport if it collects and controls more than the required percentage of available ADF (e.g., for the 20 percent efficiency scenario, if an airport currently collects and controls 20 percent or more of available ADF, no load reductions were estimated for the airport). Model airports that currently collect the required percentage of available ADF either treat it to the required discharge levels, discharge the collected ADF to a POTW, or send it off-site and are assumed to be in compliance with any numeric effluent limitation.

EPA assumed that airports that used small quantities of ADF (less than 5,000 gallons of normalized ADF), as described below in Section 10.1, would collect and haul away the required percentage of ADF instead of collecting it for on-site treatment. For more information, refer to the *Airport Deicing Loadings Calculations* memorandum (ERG, 2008b).

9.3 Airfield Deicing Pollutant Loading

This section presents EPA's methodology for estimating airfield deicing pollutant loads using airport questionnaire data on airfield chemical use.

9.3.1 *Estimate the Amount of Applied Deicing Chemical*

In the airport questionnaire, EPA requested that airport personnel report the usage amount, concentration, and brand name of the following pavement deicing materials for the 2002/2003, 2003/2004, and 2004/2005 deicing seasons:

- Urea;
- Potassium Acetate;
- CMA;
- Sodium Acetate;
- Sand;
- Sodium Formate;
- EG-Based Fluids;
- PG-Based Fluids; and
- Other: (Specify).

EPA evaluated the data provided for each reported chemical to determine the most appropriate way to estimate the average amount used over the three winter seasons reported. In addition, EPA read the comments provided by the airport personnel to determine any extenuating circumstances that affect chemical use. For example, airport personnel may have reported that urea was replaced with potassium acetate at the airport during the three years reported. In this case, EPA used the potassium acetate average in the loadings estimate and did not use any of the urea data to better represent the airport's current practices. Ninety airports reported pavement deicing chemical usage values to EPA in their questionnaire responses.

Table 9-6 shows the three-year average pavement deicing chemical usage EPA calculated from the reported data (normalized to pure chemical) by airport and chemical. In the questionnaire, airports reported pounds or gallons of pavement deicing chemical used along with the concentration of the chemical. If airport personnel reported a volume of chemical in the airport or airline detailed questionnaire, EPA multiplied the reported volume by the reported deicing chemical strength and the chemical density.

No airports reported using CMA. Multiple airports reported using sand, but these data are not included in Table 9-6, because sand was not included in the loads analysis. Only one airport reported using granular potassium acetate. Potassium acetate (in the liquid form) is the most commonly used pavement deicing chemical.

Table 9-6. Three-Year Average Amount of Pavement Deicing Chemical Usage, in Pounds

Airport ID	Airport Name	EG-Based Fluids	Granular Potassium Acetate	Potassium Acetate	Sodium Acetate	Sodium Formate	PG-Based Fluids	Urea
1006	Chicago O'Hare Intl	0	0	655,284	0	0	4,681,462	0
1007	Yeager	0	0	0	2,560	0	11,540	27,517
1010	Fairbanks Intl	0	0	197,024	0	0	0	332,000
1011	Lambert - St Louis Intl	0	0	5,119,502	0	0	0	0
1012	Ted Stevens Anchorage Intl	0	0	1,266,417	0	0	0	2,514,900
1013	Wiley Post-Will Rogers Mem	0	0	0	0	0	0	20,000
1014	Albuquerque Intl Sunport	0	0	4,586	0	0	0	0
1016	Tri - State/Milton J Ferguson Field	0	0	27,089	0	0	0	56,000
1017	Austin Straubel Intl	0	0	38,121	0	0	0	44,860
1018	Piedmont Triad Intl	0	0	53,938	0	0	0	92,667
1020	Hartsfield - Jackson Atlanta Intl	0	0	314,456	0	0	0	0
1021	Buffalo Niagara Intl	0	0	0	0	7,760	0	0
1022	Fort Wayne Intl	0	0	268,772	0	0	0	285,544
1023	Seattle - Tacoma Intl	0	0	97,914	696	0	0	0
1024	Indianapolis Intl	0	0	783,038	470,667	0	0	0
1026	Dallas/Fort Worth Intl	0	0	18,179	0	0	0	0
1028	Denver Intl	0	0	3,526,704	0	0	0	0
1029	La Guardia	0	0	1,118,145	1,676	0	442,700	0
1031	Richmond Intl	0	0	284,770	17,000	0	0	0
1032	Austin - Bergstrom Intl	0	0	17,483	0	0	0	0
1036	Baltimore - Washington Intl	0	0	1,178,861	257,280	156,800	0	0
1041	Glacier Park Intl	0	0	0	0	0	0	333
1043	Ralph Wien Memorial	0	0	38,870	0	0	0	10,000
1044	Roanoke Regional/Woodrum Field	0	0	109,044	0	0	0	0
1050	Aspen - Pitkin County/Sardy Field	0	17,000	46,732	0	0	0	0
1052	Wilmington Intl	0	0	0	0	0	0	0
1053	General Edward Lawrence Logan Intl	1,217,300	0	0	0	0	0	10,217

Table 9-6 (Continued)

Airport ID	Airport Name	EG-Based Fluids	Granular Potassium Acetate	Potassium Acetate	Sodium Acetate	Sodium Formate	PG-Based Fluids	Urea
1057	Will Rogers World	0	0	49,603	2,910	0	0	0
1058	Gerald R Ford Intl	0	0	66,341	0	8,568	0	0
1059	Greater Rochester Intl	0	0	294,634	0	0	0	0
1063	Evansville Regional	0	0	29,065	0	0	0	0
1065	Albany Intl	0	0	196,535	148,500	0	0	0
1066	Salt Lake City Intl	0	0	173,169	0	0	0	1,121,232
1068	Eppley Airfield	0	0	289,288	9,474	0	0	0
1069	Cleveland – Hopkins Intl	0	0	2,456,657	190,055	6,117	0	0
1070	City of Colorado Springs Municipal	0	0	224,598	0	0	0	0
1071	Tweed - New Haven	0	0	0	291	0	0	0
1074	South Bend Regional	0	0	0	0	0	0	32,440
1078	Nashville Intl	0	0	163,779	0	0	0	0
1079	Manchester	0	0	398,780	0	0	0	36,833
1080	Syracuse Hancock Intl	0	0	11,792	0	0	0	0
1082	Trenton Mercer	0	0	12,393	0	4,704	0	0
1084	Bismarck Municipal	0	0	16,114	0	0	0	0
1085	Waterloo Municipal	0	0	0	0	0	0	6,000
1088	Outagamie County Regional	0	0	229,290	0	0	0	0
1089	John F Kennedy Intl	0	0	170,330	3,460,831	0	224,792	0
1090	Boise Air Terminal/Gowen Field	0	0	98,582	0	0	0	269,901
1094	Boeing Field/King County Intl	0	0	10,255	0	0	0	0
1095	Chicago Midway Intl	0	0	1,397,274	0	0	0	0
1098	Aberdeen Regional	0	0	17,489	0	0	0	0
1100	Toledo Express	0	0	240,209	0	0	0	0
1101	Portland Intl	0	0	256,478	10,292	211,183	0	0
1103	Juneau Intl	0	0	0	0	0	0	478,000

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Table 9-6 (Continued)

Airport ID	Airport Name	EG-Based Fluids	Granular Potassium Acetate	Potassium Acetate	Sodium Acetate	Sodium Formate	PG-Based Fluids	Urea
1104	Nome	0	0	39,307	0	0	0	0
1105	Spokane Intl	0	0	240	0	0	951	498,000
1107	Pittsburgh Intl	0	0	1,198,425	13,333	89,507	0	0
1108	Louisville Intl - Standiford Field	0	0	762,020	0	109,760	0	0
1109	Airborne Airpark	0	0	1,916,877	0	1,809,373	0	0
1110	Aniak	0	0	0	0	0	0	2,400
1111	Port Columbus Intl	0	0	623,773	0	7,161	0	0
1112	Deadhorse	0	0	12,229	0	0	0	20,000
1113	Cincinnati/Northern Kentucky Intl	0	0	3,050,218	0	4,000	0	0
1114	Stewart Intl	0	0	78,614	2,520	0	0	151,800
1116	Reno/Tahoe Intl	0	0	42,583	0	0	0	11,186
1117	Cherry Capital	0	0	63,909	0	0	0	0
1118	Bethel	0	0	0	0	0	0	67,333
1119	Rickenbacker Intl	0	0	71,919	0	37,782	0	0
1120	Rapid City Regional	0	0	0	0	0	6,484	0
1121	Theodore Francis Green State	0	0	160,532	0	0	0	0
1123	James M Cox Dayton Intl	0	0	174,912	0	0	0	0
1124	Des Moines Intl	0	0	340,660	139,033	0	0	0
1126	Minneapolis /St Paul Intl/Wold - Chamberlain	0	0	1,273,019	82,667	0	0	0
1128	Charlotte/Douglas Intl	0	0	109,356	0	0	0	149,883
1129	Bradley Intl	0	0	443,282	223,150	0	0	16,748
1136	General Mitchell Intl	0	0	1,275,038	0	127,400	0	0
1137	Dallas Love Field	0	0	218	0	0	0	0
1138	Detroit Metropolitan Wayne County	0	0	1,851,138	0	0	0	0
1139	Philadelphia Intl	0	0	0	0	0	809,829	0

Table 9-6 (Continued)

Airport ID	Airport Name	EG-Based Fluids	Granular Potassium Acetate	Potassium Acetate	Sodium Acetate	Sodium Formate	PG-Based Fluids	Urea
1140	Memphis Intl	0	0	496,699	74,325	0	0	0
1141	Ronald Reagan Washington National	0	0	319,347	34,000	0	0	78,000
1142	Washington Dulles Intl	0	0	2,430,542	619,868	0	0	0
1144	Central Wisconsin	1,858	0	59,419	0	0	0	123,440
1145	Newark Liberty Intl	0	0	2,657,040	6,143	0	0	0
1146	Northwest Arkansas Regional	243,723	0	0	0	0	0	18,000
1147	Raleigh - Durham Intl	0	0	0	0	0	0	63,333
1148	Kansas City Intl	0	0	597,465	4,573	0	0	0
1149	Fort Worth Alliance	0	0	5,241	0	0	0	0
1150	Greater Rockford	0	0	311,914	0	0	0	680,267
1151	Kalamazoo/Battle Creek Intl	0	0	0	4,000	0	0	0
1153	Akron - Canton Regional	0	0	20,073	162	0	0	21,333

Source: Airport Deicing Loadings Database (USEPA, 2010).

9.3.2 Calculate the Amount of Pollutant Load Associated with the Applied Chemical

As airfield deicing chemicals break down in the environment, they (like aircraft deicers) result in increased COD and BOD discharges. EPA calculated the amount of COD associated with the degradation of the applied pavement deicing chemicals. Because pavement deicers containing urea will also break down into ammonia, EPA also calculated the amount of ammonia associated with the degradation of these deicers.

As with the aircraft deicers, EPA determined it would not be suitable to use empirical data to estimate loadings and decided to calculate loadings based on standard chemical information and stoichiometric equations.

Determine the ThOD of Each Chemical

As with aircraft deicers, the ThOD estimate was based on the molecular formula of the chemical and the stoichiometric equation of the breakdown of the chemical to the end products of carbon dioxide and water. Table 9-7 lists the calculated ThOD for each chemical in airfield deicer.

Table 9-7. ThOD Calculations for Airfield Deicing Chemicals

Deicing Compound	Molecular Formula	Stoichiometric Formula	ThOD (Moles of O ₂ per Mole of Deicing Compound)
EG	C ₂ H ₆ O ₂	2[C ₂ H ₆ O ₂] + 5 O ₂ → 4 CO ₂ + 6 H ₂ O	2.5
Urea	N ₂ H ₄ CO	N ₂ H ₄ CO + 4 O ₂ → 2 HNO ₃ + CO ₂ + H ₂ O	4.0
Potassium acetate	KC ₂ H ₃ O ₂	[C ₂ H ₃ O ₂] ⁻ + 1.75 O ₂ → 2 CO ₂ + 1.5 H ₂ O	1.75
Sodium acetate	NaC ₂ H ₃ O ₂	[C ₂ H ₃ O ₂] ⁻ + 1.75 O ₂ → 2 CO ₂ + 1.5 H ₂ O	1.75
Calcium magnesium acetate	C ₈ H ₁₂ CaMgO ₈	[C ₈ H ₁₂ O ₈] ⁴⁻ + 7 O ₂ → 8 CO ₂ + 6 H ₂ O	7.0
Sodium formate	NaHCO ₂	2[HCO ₂] ⁻ + 0.5 O ₂ → 2 CO ₂ + H ₂ O	0.25

Determine the COD of Each Chemical

EPA next determined the COD loading associated with the chemical's degradation. EPA assumed that the chemical would completely degrade in the environment over time and therefore the calculated ThOD load would be equivalent to the COD load. EPA estimated the COD load associated with each reported chemical based on the calculated mass of the chemical purchased, the molecular weight of the chemical, the ThOD, and the molecular weight of oxygen, using the equation below:

$$\begin{aligned} \text{COD Load (pounds)} = & \text{Chemical (pounds)} \times \frac{434 \text{ grams}}{\text{pound}} \times \text{Chemical Molecular Weight} \left(\frac{\text{moles of chemical}}{\text{grams of chemical}} \right) \\ & \times \text{ThOD} \left(\frac{\text{moles of O}_2}{\text{moles of chemical}} \right) \times \text{O}_2 \text{ Molecular Weight} \left(\frac{\text{grams of O}_2}{\text{moles of O}_2} \right) \times \frac{\text{pound}}{434 \text{ grams}} \end{aligned} \quad (9-1)$$

9.3.3 *Estimate the Amount of Baseline Pollutant Load that is Discharged Directly*

As pavement deicing chemicals are applied at a large variety of areas at an airport, the amount of pavement deicers being directly discharged could range from close to 100 percent on pavement areas near outfall drains, to nearly 0 percent for chemicals that may fall onto grassy areas and infiltrate into the ground during a thaw. Estimating a percentage of direct discharge release of pavement deicers at a particular airport is difficult without performing a detailed study of each airport. Therefore, EPA assumed 100 percent direct discharge of pavement deicers to represent the maximum possible amount of discharge.

9.3.4 *Estimate Pollutant Reductions for Each EPA Collection/Control Scenario*

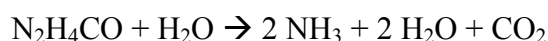
Urea COD Load Reduction

As described in section 9.3.2, EPA calculated the COD load associated with urea use at the surveyed airports. EPA then evaluated the amount of potassium acetate that would be required to replace the current average urea use using a comparison of application rates under varying winter conditions (see EPA's Urea/Potassium Acetate memorandum (ERG, 2010) for the details of this analysis). Based on the COD load associated with the equivalent potassium acetate use, EPA determined the potential reductions in COD load. Table 9-8 presents by airport the COD load associated with urea use, the COD load associated with a switch to potassium acetate use, and the potential COD load reduction that would result from airfield product substitution.

Urea Ammonia Load Reduction

Because ammonia is not associated with potassium acetate use, the amount of ammonia reduction from a urea product substitution is equal to the amount of ammonia associated with urea usage.

The following equation expresses the breakdown of urea to ammonia:



EPA estimated the ammonia load associated with urea based on the equation above, the mass of urea use, and the molecular weights of urea and ammonia, using the equation below:

$$\begin{aligned} \text{Ammonia Load (pounds)} = & \text{Urea (pounds)} \times \frac{434 \text{ grams}}{\text{pound}} \times \text{Urea Molecular Weight} \left(\frac{\text{mole of urea}}{\text{grams of urea}} \right) \\ & \times \left(\frac{2 \text{ moles of ammonia}}{\text{mole of urea}} \right) \times \text{Ammonia Molecular Weight} \left(\frac{\text{grams ammonia}}{\text{mole of ammonia}} \right) \times \frac{\text{pound}}{434 \text{ grams}} \end{aligned} \quad (9-2)$$

Table 9-8 presents by airport the potential ammonia load reduction that would result from airfield product substitution.

Table 9-8. Baseline Ammonia and COD Load and Potential Load Reduction Associated with the Discontinued Use of Urea as an Airfield Deicing Chemical for In-Scope Airports

Airport ID	Airport	Airport Weighting Factor	Urea Load (lbs of COD)	Equivalent Potassium Acetate Load (lbs of COD)	Potential Load Reduction (lbs of COD)	Potential Load Reduction (lbs of Ammonia)
1007	Yeager	2.1508	58,644	16,172	42,471	15,572
1010	Fairbanks Intl	1.0000	707,559	195,127	512,432	187,883
1012	Ted Stevens Anchorage Intl	1.0000	5,359,760	1,478,087	3,881,674	1,423,212
1017	Austin Straubel Intl	2.3269	95,606	26,366	69,240	25,387
1018	Piedmont Triad Intl	1.0000	197,491	54,463	143,028	52,441
1022	Fort Wayne Intl	1.9682	608,551	167,823	440,728	161,593
1041	Glacier Park Intl	3.1409	710	196	514	189
1043	Ralph Wien Memorial	1.0000	21,312	5,877	15,435	5,659
1053	General Edward Lawrence Logan Intl	1.0000	21,774	6,005	15,769	5,782
1066	Salt Lake City Intl	1.0000	2,389,572	658,984	1,730,588	634,519
1074	South Bend Regional	2.1417	69,136	19,066	50,070	18,358
1079	Manchester	1.0000	78,499	21,648	56,851	20,844
1090	Boise Air Terminal/Gowen Field	1.5043	575,214	158,629	416,584	152,740
1103	Juneau Intl	1.0000	1,018,715	280,936	737,779	270,506
1105	Spokane Intl	1.5192	1,061,339	292,690	768,648	281,824
1114	Stewart Intl	2.8661	323,516	89,218	234,299	85,905
1116	Reno/Tahoe Intl	1.0000	23,840	6,574	17,265	6,330
1118	Bethel	1.0000	143,501	39,574	103,927	38,105
1128	Charlotte/Douglas Intl	1.0000	319,432	88,091	231,340	84,821
1129	Bradley Intl	1.0000	35,692	9,843	25,849	9,478
1141	Ronald Reagan Washington National	1.0000	166,234	45,843	120,391	44,141
1144	Central Wisconsin	3.0156	263,076	72,550	190,526	69,856
1146	Northwest Arkansas Regional	1.8782	38,362	10,579	27,782	10,186
1147	Raleigh - Durham Intl	1.0000	134,976	37,223	97,753	35,841

Source: Airport Deicing Loadings Database. (USEPA, 2010).

9.4 References

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10. TECHNOLOGY COSTS

This section presents EPA's estimates of costs for the Airport Deicing Category to implement the control and treatment technologies EPA considered as technology bases for existing airports in the final rule. EPA estimated the compliance costs for each control and treatment technology to determine potential economic impacts on the industry. EPA also weighed these costs against the pollutant load reduction benefits resulting from the control and treatment technologies.

This section discusses the following information:

- Section 10.1 – EPA's costing approach using airport-specific data as model airports;
- Section 10.2 – EPA's methodology for estimating aircraft deicing costs associated with the collection and treatment of ADF-contaminated stormwater, including an overview of EPA's cost model and example calculations showing how the model estimates costs;
- Section 10.3 – EPA's methodology for estimating airfield deicing costs associated with urea substitution;
- Section 10.4 – Other compliance-related costs; and
- Section 10.5 – A summary of EPA's annualized costs evaluated for the final rule.

10.1 Costing Approach

The Agency used a model-site approach to estimate costs for the Airport Deicing Category. A model airport is an operating airport for which EPA estimated site-specific compliance costs. In general, these include sites for which EPA has questionnaire responses. EPA selected an airport-by-airport approach to estimate compliance costs based on a comparison of information from the model airports, as opposed to a more generalized approach, to better characterize the current control and treatment systems in place for ADF contaminated stormwater and to account for current site conditions and airport operations.

For each model airport, EPA developed both capital and operating and maintenance costs to reduce pollutant discharges from aircraft deicing and from airfield deicing. EPA combined these costs for each model airport to estimate total costs of each regulatory option evaluated. EPA then applied a weighting factor to the costs for each airport to estimate national costs for each option. A description of the weighting factors for the Airport Deicing Category is in DCN AD01234.

EPA estimated compliance costs for the model airports using information provided in the airport questionnaire, the detailed airline questionnaire, and from individual airports and vendors. For any given model airport, the estimated costs may deviate from those that the airport would actually incur. However, EPA considers the compliance costs to be accurate when aggregated on an industry-wide basis. These compliance costs are generally broken down into three categories, costs associated with aircraft deicing, costs associated with airfield deicing, and costs with documenting compliance with today's regulation.

10.2 Aircraft Deicing Costs

This section describes the general methodology for estimating costs for ADF collection and treatment, including the Airport Deicing Cost Model design and the development of cost equations that use model-airport-specific inputs. Components of the aircraft deicing costs include collection, containment and storage, and treatment costs. EPA estimated capital and annual operating costs for each of these costing components, which were then amortized to generate model-airport-specific annualized costs.

10.2.1 *Overview of the ADF Collection and Treatment Airport Deicing Cost Model*

Managing ADF-contaminated stormwater is a multistep process. EPA developed an Airport Deicing Cost Model to estimate deicing stormwater control costs for each of these steps and the various alternatives within each step. Costs for each selected alternative are combined for each airport included in the costing effort to develop cost estimates for the different EPA control and treatment technology options considered for the final rule. For example, regulatory costs at an airport may include a combination of alternatives from the collection, containment and storage, and treatment categories.

The EPA regulatory options were based on requiring an airport to collect and control deicing stormwater through a variety of mechanisms. Based on information provided in the airport questionnaire and data gathered during EPA's engineering site visits to various airports, EPA decided to estimate costs for three collection technologies. Those collection technologies included GCVs alone, a combination of plug and pump system with GCVs, and use of CDPs. Each collection alternative is expected to provide a different level of collection efficiency for ADF-contaminated stormwater. In the final rule, EPA decided to estimate costs for only two of these technologies, GCVs and plug and pump with GCV, in part due to concerns that space-constrained airports may not be able to incorporate CDP because of FAA requirements on their design and siting. EPA estimates that using only GCVs to collect ADF-contaminated stormwater from areas within the airport where aircraft are deiced will collect 20 percent of the available ADF. Adding a plug and pump system in combination with GCVs to the existing stormwater drainage system is expected to collect 40 percent of the available ADF.

Once ADF-contaminated stormwater has been collected, the airport has a variety of alternatives for control, including disposal at a POTW, off-site recycle and recovery, on-site recycle and recovery, or on-site treatment and disposal. Each of these alternatives should be considered by an airport when selecting the appropriate method to manage collected ADF. For the airport deicing rulemaking option analysis, EPA selected the AFB reactor treatment system as the basis of costs because of its demonstrated capability to destroy glycols and generate an effluent suitable for direct discharge. Although AFB treatment systems may be more expensive to install and operate when compared to other treatment alternatives, EPA's basis of all treatment conducted via AFB should provide a conservative cost estimate for individual airports to treat spent ADF. For costing purposes, EPA assumed that all model airports requiring improvement to meet the collection requirements, except for low ADF usage airports, would install an AFB system. For airports that occasionally deice aircraft primarily to remove frost, installing permanent collection and treatment equipment for ADF would not be practical. Instead, EPA assumes these airports would use contractors to provide deicing stormwater collection and removal services.

EPA assumed that all airports that are required to collect additional ADF will need on-site containment or storage for the collected deicing stormwater prior to treatment in an AFB system. The final rule does not require nor is it based on collecting the full volume of wastewater generated in a deicing season. Rather, storage is included as part of the technology basis for flow and/or pollutant equalization to support the AFB treatment system. In these cases, containment and storage selections can include ponds, underground storage tanks, aboveground storage tanks, or temporary storage tanks (e.g., frac tanks). EPA decided to estimate costs for aboveground storage tanks in the final rule because they will have less of an impact on subsurface utilities for which EPA does not have site-specific information. In addition, FAA discourages airports from installing new stormwater retention ponds, as they can be a lure for birds, which are a safety hazard for aircraft. Airports may also require additional stormwater piping to transfer collected ADF-contaminated stormwater from aircraft application areas to storage tanks.

The airport deicing cost model considers each of these alternatives to develop a costing scheme for collecting and containing ADF-contaminated stormwater at each model airport. The Airport Deicing Cost Model also takes into account the effectiveness of each model airport's current control and treatment program for ADF-contaminated stormwater to determine if additional costing is required to comply with the regulatory options considered for the final rule.

In general, EPA's approach to develop costs for the model airports consists of the following steps:

- **Step 1:** Develop cost equations for each collection, storage, and treatment alternative evaluated for the final rule;
- **Step 2:** Estimate an airport's current level of ADF-contaminated stormwater collection based on information provided in the airport questionnaire;
- **Step 3:** Apply the collection and treatment cost equations for the various components to those airports that currently collect and manage less than the control and treatment scenario percentage being evaluated to determine airport-specific capital and annual costs for that scenario and each component; and
- **Step 4:** Estimate total airport-specific annualized costs for each component of the airport scenario for each control and treatment scenario.

10.2.2 *Airport Deicing Cost Model Equation Development*

Based on the available data, EPA developed cost equations for the collection, storage, and treatment technologies that could be applied to those model airports not currently achieving the required collection percentage. In general, the Agency developed cost equations using cost data from the BAT model airports representing their entire system rather than attempting to estimate costs for individual components. EPA believes using system wide costs is a better way to estimate costs for this regulatory effort because all installed capital and annual operating costs are rolled under a single value, eliminating the concern that specific components may not have been included and allowing for more robust estimates. For example, EPA did not prepare costs for individual components within the AFB treatment system such as reaction vessels, piping, pumps, flow meters, and buildings, but instead estimated costs for the entire treatment system.

EPA used the cost data from the model airports and information supplied by equipment vendors along with airport-specific information to develop normalized cost equations that could then be projected to other airports based on common variables. The sections below describe the development of the normalized cost equations for the collection, transfer and storage, and treatment system alternatives evaluated by EPA.

10.2.2.1 ADF Collection

Airports use ADF-contaminated stormwater collection alternatives to achieve the targeted ADF collection percentage. Collection alternatives that EPA selected for costing include developing a winter operations plan to help manage ADF use and maximize recovery of available ADF, using glycol collection vehicles to collect ADF from surfaces following aircraft deicing, and using a plug and pump system to collect ADF. EPA estimates that airports using GCVs can collect 20 percent of the available ADF, and airports using plug and pump in combination with GCVs can collect 40 percent of the available ADF. Airports with deicing pads are expected to collect more than 40 percent of the available ADF and would therefore comply with the control alternatives evaluated for this final rule.

Winter Operations Plan

A large number of airports currently have a Stormwater Pollution Prevention Plan (SWPPP) that includes deicing operations during the winter months. However, these SWPPPs may not provide specific guidance for achieving the regulatory requirements considered for the final deicing rule. Therefore, EPA envisions that airports will supplement their SWPPP with a specific winter operations plan that includes information such as methods to verify the percentage of ADF collection, standard operating procedures for ADF collection technology systems, and training information for system operators. Once airports have assessed specific winter operations to collect and control deicing stormwater, they can implement a control and treatment strategy to decrease the amount of ADF leaving the airport through stormwater outfalls.

Costs to develop a winter operations plan will likely vary depending on the type of ADF collection system. EPA assumed that airports targeting 20 percent collection using GCVs would require 120 hours of engineering labor to prepare the plan and those airports targeting 40 percent ADF collection using a combination of GCVs with plug and pump would require approximately 240 hours of engineering labor. Based on an engineering rate of \$100/hour obtained from the airport questionnaire, the one-time costs to prepare a winter operations plan for 20 percent and 40 percent ADF capture would be \$12,000 and \$24,000, respectively.

GCVs

Airports use GCVs to collect ADF-contaminated stormwater from various locations including gate and apron areas, taxi areas, and centralized deicing areas. GCVs can be either truck-mounted systems or tow-behind units. Drain covers that bond to surfaces to quickly seal off drains are often used in conjunction with GCVs in the area where aircraft are deiced to allow the GCVs to collect high-concentration spent deicing fluid.

To estimate total capital costs for purchasing GCVs and annual operating and maintenance (O&M) costs for operating GCVs, EPA used information provided by airports in the airport questionnaire.

All airports that provided costing information, regardless of hub size, maintained three or less GCVs. EPA used the information presented in Table 10-1 to estimate the number of GCVs by airport hub size. The Agency assumes that Non-hub, Small Hub, and Medium Hub airports can operate effectively and efficiently with two GCVs and that Large Hub airports can operate effectively and efficiently with three GCVs. Additional details regarding costs for GCVs is provided in a memorandum entitled *Estimated Capital and O&M Costs for Glycol Collection Vehicle Operation* (ERG, 2010).

Control of drainage while operating GCVs will vary by airport. For purposes of estimating GCV costs, EPA assumed that airports use drain covers in combination with the GCV operation. Variables that could impact drainage control costs include the size of drain covers and number of drains to be covered. Because these variables are airport-specific and details are not available, EPA was unable to develop a specific approach to estimate the cost of drain covers and the labor needed to install them. EPA has instead incorporated a cost increase factor of 20 percent to the annual O&M cost for using GCVs. EPA assumes that a 20 percent increase in O&M costs for GCVs will cover costs to purchase and replace drain covers and labor to install and remove the drain covers as needed.

Table 10-1. GCV Capital and O&M Costs

Site ID	Hub Size	Estimated ADF Usage (gal/yr)	Number of GCVs	Total GCV Capital Costs	Capital Cost Base Year	2007 GCV Capital Cost	Total GCV Annual Cost	Annual Cost Base Year	2007 GCV Annual Cost (\$/yr)	Unit Capital Cost (\$/GCV)	Annual O&M Cost (\$/yr)
1136	Medium	152,944	1	\$361,355	2001	\$415,558	\$15,268	2004	\$16,184	\$415,558	\$16,184
1012	Medium	420,735	1	\$273,840	2001	\$314,916	\$80,000	2005	\$82,400	\$314,916	\$82,400
1113	Large	722,995	1	\$250,000	1997	\$317,500	\$5,000	2005	\$5,150	\$317,500	\$5,150
1066	Large	570,540	1	\$353,000	2004	\$374,180				\$374,180	
1101	Medium	112,086	2	\$700,000	1996	\$910,000	\$43,236	2004	\$45,831	\$455,000	\$45,831
1021	Medium	284,654	2	\$530,000	2001	\$609,500			\$0	\$304,750	
1036	Large	323,623	1	\$283,463	2006	\$283,463	\$214,516	2004	\$227,387	\$283,463	\$227,387
1065	Small	125,775	1	\$325,000	2005	\$334,750	\$45,000	2005	\$46,350	\$334,750	\$46,350
1031	Small	59,337	2	\$518,300	2001	\$596,045	\$35,000	2005	\$36,050	\$298,023	\$36,050
AVERAGE										\$344,238	\$59,773

Plug and pump with GCVs

Two airports provided sufficient information to estimate costs for a plug and pump type collection system. During the 2005 deicing season, the first airport used sewer balloons at eight locations, storm sewer shutoff valves at four locations, and two catch basin inserts. In addition, this airport utilized two GCVs for ancillary glycol collection; one is a traditional truck-based GCV and the other is a GCV unit (a V-Quip Ramp Ranger) that is towed behind a tractor. The estimated capital cost for this airport's plug and pump system (including the GCVs) is approximately \$790,000. The plug-and-pump system operated at this airport prevents ADF-contaminated stormwater from discharging through three deicing stormwater outfalls (USEPA, 2006a).

The second airport operates 16 plug and pump locations that prevent ADF-contaminated stormwater from leaving the airport through a maximum of five outfalls. These plug and pump operations include plugging the associated drainage pipes and pumping out these drains with dedicated pumping trucks. According to the airport, the annual budget to operate the plug and pump system is approximately \$1,300,000. This cost includes permit monitoring, glycol management, the pumping contractor, plus other miscellaneous costs (ERG personnel communication, May 3, 2007). Because the glycol collection system at this airport is contracted to a third party, all costs to the airport are reoccurring annual costs. Therefore, these O&M costs are likely over estimates compared to airports that do not contract out their glycol collection system operation.

To estimate both capital and annual O&M costs for other airports where plug and pump collection may be applicable, EPA normalized the costs based on the number of deicing outfalls. EPA assumed that the number of deicing outfalls is related to the number of areas where aircraft deicing occurs, so that in general an airport that has a greater number of discontinuous deicing areas will have a greater number of deicing outfalls. EPA estimated that more deicing areas would indicate the need for additional costs associated with removing ADF from those areas. Table 10-2 presents the normalized capital and annual O&M costs for the plug and pump collection system at the airports for which EPA had costing data.

Table 10-2. Normalized Capital and O&M Costs for the Plug and Pump Collection System

Airport	Deicing Outfalls	Total Capital Cost (2006 \$) ¹	Annual O&M Cost (2006 \$)	Normalized Capital Cost (\$/outfall)	Normalized Annual O&M Cost (\$/outfall)
Airport 1	3	\$790,000	NA	\$263,400	NA
Airport 2	5	NA	\$1,300,000	NA	\$260,000

NA – Data not available.

Contract Hauling of ADF-Contaminated Stormwater

For airports that occasionally deice aircraft primarily to remove frost, installing permanent collection and treatment equipment for ADF-contaminated stormwater would not be practical. Instead, EPA assumes these airports would contract out deicing stormwater collection

and removal and their costs would not vary between the 20 percent and 40 percent collection/control scenarios. This costing approach impacts the following airports:

- Ontario International airport in California;
- Birmingham International Airport in Alabama;
- Montgomery Regional airport in Alabama;
- Sacramento Mather airport in California;
- Lovell Field airport in Tennessee; and
- Lafayette Regional airport in Louisiana.

These airports reported that they do some deicing, but all reported or are estimated to use 5,000 gallons/year or less normalized ADF, had less than 100 percent capture of ADF-contaminated stormwater, indicated that they discharged ADF-contaminated stormwater to surface waters, but reported no typical deicing months. Specific details regarding the costs for occasional removal of ADF-contaminated stormwater by a local contractor is included in a memorandum entitled *Estimated Annual Costs for Airports with Limited ADF Use* (ERG, 2008).

10.2.2.2 AFB Treatment System

EPA based the proposed COD discharge limitation on AFB treatment. As such, when applicable, EPA determined costs for in-scope facilities to treat collected ADF through an AFB system. EPA also included costs for associated storage and transfer piping.

Transfer Piping

Piping costs to transfer collected stormwater to holding tanks prior to either on-site or off-site ADF management will vary for each airport. Variables that could impact transfer piping costs include existing subsurface utilities, soil types, elevation changes, and anticipated peak precipitation events. Because each of these variables is airport-specific and the details are not available, EPA estimated costs for each airport to construct 10,000 linear feet of new subsurface stormwater conveyance piping from various areas around the airport. EPA modified this estimate from the proposal's 1,000 linear feet after considering public comment.

Elements of a stormwater piping system include subsurface concrete piping, manholes and catch basins throughout the system to control the direction of flow. EPA obtained costs for individual elements within the system from RSMeans (RS Means, 2010) and adjusted the costs to 2006 dollars. The Agency added cost factors for plumbing and site work to the direct costs to obtain total installed direct costs. Indirect costs for engineering, permits, scheduling, performance bonds, and contractor markups were added to the total installed direct costs. Table 10-3 shows the estimated installed capital cost for 10,000 linear feet of a new stormwater conveyance piping system at an airport is approximately \$1,140,000. Details regarding capital costs plus indirect cost factors are provided in a memorandum entitled *Estimated Capital and O&M Costs for Additional Stormwater Piping* (ERG, 2010c).

Table 10-3. Estimated Cost for 10,000 Linear Feet of Stormwater Piping

Description	Total Cost
Trenching for stormwater piping	\$59,000
Backfill and compact trench after piping	\$38,000
Concrete stormwater piping (18-inch diameter)	\$310,200
Manholes/catch basins	\$137,400
Manhole frames and covers	28,800
Plumbing (connectors, extra labor, etc.)	\$187,500
Site work (clearing, grading, surveying)	\$80,300
Engineering	\$67,300
Permits	\$16,800
Scheduling	\$6,700
Performance bonds	\$21,000
Insurance (risk, equipment floater, public liability)	\$19,300
Contractor markup (handling, procuring, subcontracting, change orders, etc.)	\$84,000
Overhead and profit	\$84,000
Total Installed Capital Cost for 10,000' of Stormwater Piping	\$1,140,000

Source: RS Means Heavy Construction Cost Data, 64th Edition, 2010.

Annual O&M costs for the piping and conveyance system include periodic inspections to verify integrity of the piping system. To estimate labor costs for TV inspection of the 18" sewer, EPA made a conservative assumption that an airport would inspect 20 percent of the storm sewer system annually (2,000 linear feet), at a rate of \$1,400 per day (2006 basis). Based on engineering experience, a sewer TV crew of two to three persons can inspect approximately 500 feet of piping per day. At a rate of \$1,400/day, the annual airport inspection cost would be approximately \$5,600.

Storage Tanks for ADF-Contaminated Stormwater

The AFB system that forms the basis for today's COD limitation include storage to provide both flow and concentration equalization. Storage tanks are used at airports to equalize either flow and/or concentration of ADF-contaminated stormwater prior to treatment in the AFB system. The actual size of the storage tank depends primarily on the amount of ADF-impacted stormwater generated during precipitation events, the area from which deicing stormwater is collected, and the rate the stormwater can be discharged to the AFB. For costing purposes, EPA selected aboveground rather than underground storage tanks due to constraints such as existing underground utilities or high ground water levels at individual airports.

EPA obtained storage tank volumes and capital costs when available from five airports in the airport questionnaire (USEPA, 2006b). Using normalized ADF usage data for each of these airports, EPA normalized tank volumes and costs to the annual ADF use per year to provide an equation that could be used to estimate storage tank sizes and costs at other airports. EPA's normalized ADF usage amounts represent ADF amounts without any water dilution. EPA chose ADF usage as the costing basis for tank storage because the amount of tank storage needed is directly related to the amount of ADF applied for aircraft deicing, which is a function of the

frequency, duration, and intensity of precipitation events at a particular airport during a deicing season. In addition, the storage tanks at each of these airports are used to contain ADF-contaminated stormwater prior to treatment, and therefore the hydraulic capacity has likely been designed with equalization requirements (e.g., maximum flow and equalized pollutant concentrations) in mind.

The data in Table 10-4 indicate the volume of storage tanks at the five airports ranges between 1.5 million gallons and 8 million gallons, with the average being approximately 4.6 million gallons. The average unit cost for storage tanks calculated from the data in Table 10-4 is \$1.67/gallon. The normalized storage tank volume, calculated from the data provided in Table 10-4, is 11.4 gal/gal ADF use/yr. The basis of the 11.4 gal/gal ADF use/yr factor includes storage of ADF-contaminated stormwaters from a variety of collection technologies (including GCVs, diversion systems, and deicing pads) that were identified as having glycol concentrations greater than 1 percent or in one case greater than 1,000 mg/l BOD. EPA believes that this factor will provide sufficient storage volume for those airports required to meet either a 20 or 40 percent available ADF collection requirement because the airports forming the basis of the factor have an ADF collection percentage greater than the considered requirement.

Table 10-4. Storage Tank Volumes and Installed Capital Cost for Various Airports

Airport	ADF Use (gal/yr)	Total Storage Tank Volume (gal)	Storage Tank Volume per ADF Use (gal/gal/yr)	Installed Capital Cost (2006 \$)	Storage Tank Capital Cost (\$/gal)
1	1,043,138	6,520,000	0.4	\$795,000 ¹	\$1.89
2	943,982	5,140,000	2.6	NA	NA
3	715,836	8,000,000	11.2	\$9,440,000	\$1.18
4	112,086	2,000,000	17.8	NA	NA
5	60,246	1,500,000	24.9	\$2,890,000	\$1.93
AVERAGE			11.4		\$1.67

NA – Not available.

¹ Cost provided for one 420,000-gallon storage tank.

To determine if the unit cost for aboveground storage tanks was reasonable, EPA compared the \$1.67/gallon unit cost to the cost for permanent storage tanks reported in the ACRP Fact Sheets (ARCP Fact Sheets). According to Fact Sheet 30, aboveground permanent storage tank costs range from \$1.25 to \$1.75/gallon for tanks ranging in size from 500,000 gallons to 1 million gallons. Unit costs for storage tanks between 1 million and 2 million gallons range from \$1.00 to \$1.50/gallon. Based on the data in the fact sheets, EPA believes the \$1.67/gallon unit cost factor should provide a conservative estimate of tank costs.

The airport questionnaire responses provided limited data to determine the annual O&M cost for storage tanks. One airport reported annual O&M costs for its storage tanks ranged between \$50,000 and \$100,000. Using ADF usage information for this airport (281,836 gal/yr) and the reported annual O&M cost for the airport (\$75,000/yr), EPA calculated the normalized annual O&M cost for storage tanks to be \$0.27 per gallon of ADF used per year (\$75,000/281,836).

AFB Treatment Systems

In the proposed rule, EPA used a linear relationship between ADF use and ADF percent collection to predict AFB costs. Public comments raised the issue that such a relationship does not consider minimum capital costs for small systems or the economy of scale for larger systems. All AFB treatment systems, regardless of size, will require basic components such as chemical dosing systems, gas handling systems, sludge handling systems, storage tanks, in-line monitoring equipment, and process control systems. For many of these components, cost is independent of treatment system size.

To assist EPA with developing costs for AFB treatment, industry developed a cost curve that shows a general relationship between cost and COD load for systems designed to treat between 500 and 7,000 lbs/day of COD. As shown in Figure 10-1, the cost per pound of COD removal decreases rapidly for larger load removal systems because of the economy of scale with the reactor and separator system, and the cost for support buildings and facilities is relatively constant and not tied to COD loading.

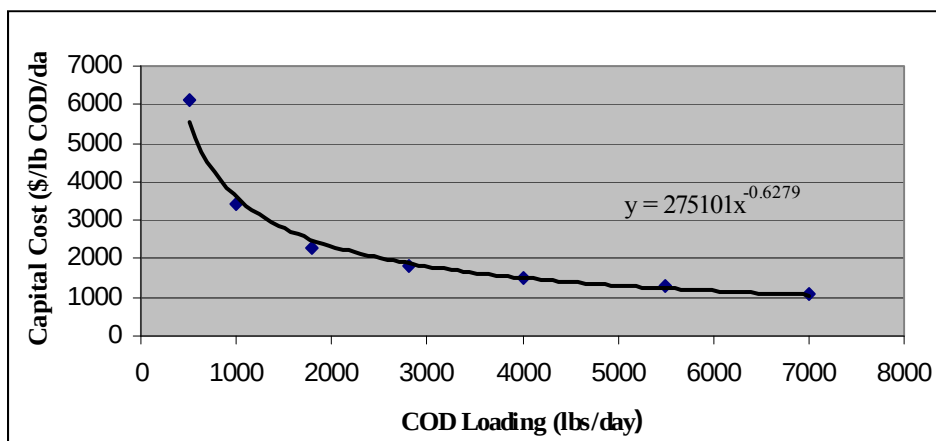


Figure 10-1. AFB Reactor Capital Cost for Treating ADF-Contaminated Stormwater

Using the equation in Figure 10-1 developed from industry comments (See Airport Council International – North America comments on EPA’s Proposed Rule for Effluent Guidelines for the Airport Deicing Category), EPA can estimate the installed capital cost for an AFB reactor (excluding storage, transfer piping, and possible land costs) if the COD loading is known. To test the accuracy of this equation, EPA compared calculated costs to those provided by Albany International Airport (Albany) for their AFB treatment units. According to Albany airport staff, the installed cost for their AFB treatment system is approximately \$8.1 million dollars (2006 \$). This cost does not include equalization tanks or ponds prior to the AFB, additional stormwater piping to transfer ADF-contaminated stormwater from areas of generation to storage, or purchase of additional land to accommodate the AFB treatment reactors or storage. Based on Albany’s design COD loading of 5,200 lbs/day, the equation in Figure 10-1 would predict an AFB installed cost of \$6.6 million dollars (2006 \$). Because the estimated cost for the Albany AFBs, using industry’s equation, is within ± 20 percent of the actual cost provided by Albany, EPA concludes the equation shown in Figure 10-1 can be used to predict AFB costs for all airports.

Both the Albany and Akron-Canton (Akron) airports provided annual O&M costs for their treatment reactors. According to Albany, its annual O&M cost is approximately \$510,000/year. Akron has recently constructed its AFB and did not have actual operating data at the time of EPA's costing analysis but did provide estimated annual O&M costs of \$195,000/year (McQueen, R. and Arendt, T.). Because annual operating costs for an AFB system are directly related to the annual amount of ADF use and the collection percentage, EPA normalized annual AFB reactor annual operating costs to these two factors. Table 10-5 shows the AFB reactor annual O&M costs normalized to annual ADF usage for Albany and Akron.

Table 10-5. Normalized Annual O&M Costs for the AFB Reactors

	Annual ADF Use (gal/yr)	Estimated Percent Capture ¹	Annual ADF Captured	Annual O&M Cost (2006 \$/yr) ¹	Normalized Annual O&M Cost (\$/gal ADF recovered)
Albany	125,775	92	115,713	\$510,000	\$4.40
Akron	60,264	60	36,200	\$195,000	\$5.39
AVERAGE					\$4.90

¹ Airport deicing loadings database.

Land Costs

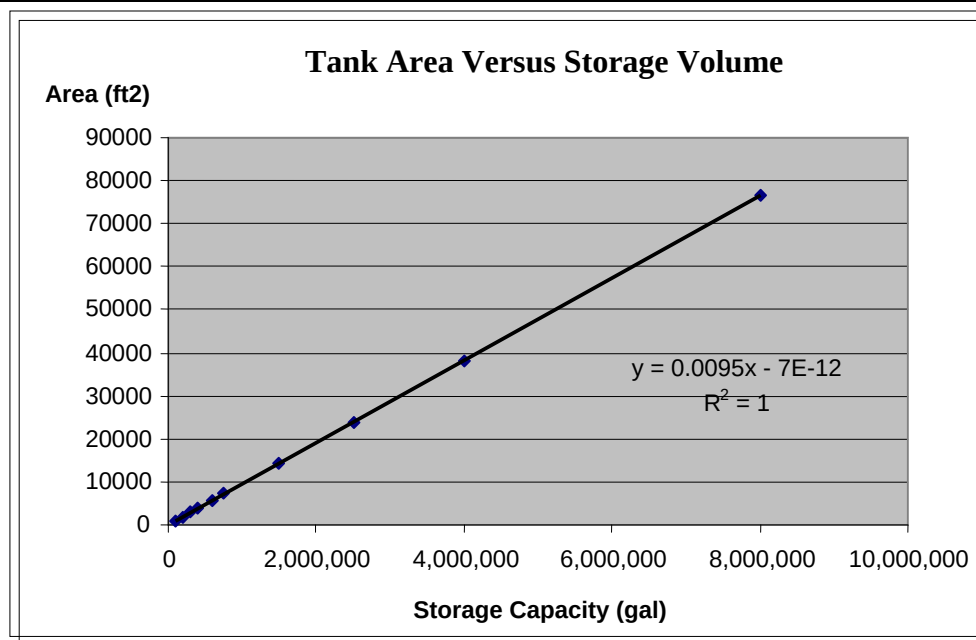
EPA has included the opportunity cost of land use for both storage and treatment of ADF-contaminated stormwater. EPA's approach to estimating this cost is to first estimate the amount of land needed for storage tanks and the AFB treatment system and then apply an opportunity cost per square foot. The opportunity cost assumes the land could potentially be leased for some other use by an airport tenant if not being used for the treatment and storage system.

To estimate the area of land associated with the AFB treatment system, EPA obtained information on the footprint of the AFB systems at Albany using Google Earth (Google Earth, 2007). Based on a review of the Google Earth images, EPA estimates the footprint for the AFB treatment system is approximately 2.4 acres or 104,544 sq.ft. This area would include the reactors, associated buildings, pump houses, roadways and parking areas, etc.

To predict the amount of land needed for storage tanks, EPA used the following equation developed for predicting storage tank costs:

$$\text{Volume of Required Storage Capacity (gal)} = \text{ADF Use gal/yr} \times 13.1 \text{ gal/gal/yr}$$

Combining this equation with the one developed from the figure below allows EPA to estimate the minimum footprint for storage tanks at individual airports based on ADF use. The equation shown in the figure below is based on storage tanks with a 14-foot sidewall depth.



Because storage tanks require a barrier-free area of approximately 20 feet around the entire tank for maintenance as well as access roads to the tanks, EPA decided to increase the minimum tank footprint by 20 percent.

EPA believes that siting of AFB and deicing stormwater storage systems will require that they be placed away from the terminal and main runway area. To estimate the value of this land if leased by an airport, EPA obtained leasing information from a number of airports. Based on the leasing cost data obtained from these airports, EPA selected an estimated \$1.00/sq.ft. cost for purposes of the costing model. Additional information on land costs is included in a memorandum entitled *Estimated Land Requirements and Opportunity Costs for the Anaerobic Fluid Bed Treatment System and ADF Stormwater Storage Tanks* (ERG, 2010d).

10.2.3 Development of Airport Deicing Cost Model Inputs

The key inputs to EPA's Airport Deicing Cost Model include airport operations data and site-specific precipitation and physical feature data for the model airports.

10.2.3.1 Airport Operations Data

The primary source of airport operations data used in the calculation of collection and treatment costs were responses to the Agency's 2006 airport questionnaire (U.S. EPA, 2006b). EPA entered data from all questionnaire responses into an electronic database that it used to determine if any ADF-contaminated stormwater collection and treatment technologies were currently utilized and to access reported operations data needed to estimate costs for additional collection and treatment. EPA used the following specific data from the questionnaire responses: geographical location, aircraft deicing chemical usage, manner/frequency of deicing discharges, deicing, and ADF collection operations.

EPA required the following additional airport operating data not requested in the airport questionnaire to estimate costs: annual ADF use and the number of annual nonpropeller aircraft

departures. EPA collected data on annual ADF usage in its airline detailed questionnaire (U.S. EPA 2006). EPA evaluated annual nonpropeller aircraft departures using data from the Bureau of Transportation Statistics (BTS).

10.2.3.2 Precipitation Data and Site Characteristics

Estimating costs to collect and treat ADF-contaminated stormwater partially depends upon the volume of the stormwater. To predict the annual volume of ADF-impacted stormwater generated at an airport, EPA used precipitation data along with airport site characteristics and assumed ADF-impacted stormwater would be collected from areas where ADF is applied and possibly from areas where ADF may drip from the aircraft during taxi and takeoff. EPA obtained precipitation data from 1976 to 2006 (30 years) from NOAA for each airport questionnaire respondent and then averaged the data by airport to estimate an airport-specific monthly average. EPA uses these data, combined with the number of deicing months taken from the questionnaire responses, to estimate the average annual amount of precipitation that may be contaminated by ADF.

10.2.4 Airport Deicing Cost Model Design

This section describes how the Airport Deicing Cost Model uses the capital and annual cost equations, in combination with the model input data, to predict costs for each model airport.

10.2.4.1 Airport Deicing Cost Model Description

EPA developed the Airport Deicing Cost Model using Microsoft® Access. The model uses various tables structured from the airport questionnaire responses to provide input to the design equations. EPA designed the model to use a series of “Yes – No” statements and its assessment of the current collection efficiency achieved by an airport to build costs, as appropriate, based on the appropriate types of collection alternatives needed to achieve the target collection efficiency.

The Airport Deicing Cost Model provides output costs in Microsoft® Excel for each selected collection alternative, and the treatment system (piping, storage tanks, and AFB treatment system). The outputs include both installed capital cost and annual O&M costs. Airport Deicing Cost Model outputs for each airport that is currently not achieving the analyzed percent control and treatment of ADF-contaminated stormwater are then used to calculate annualized costs by airport. Section 10.2.5 provides more detail regarding cost annualization. The Airport Deicing Cost Model collection and control cost output is \$0 for those airports which EPA estimates are achieving the analyzed option for collection and control of available ADF. EPA’s assessment of each airport’s current collection and control percentage is provided in the memorandum entitled *ADF Capture and Control Efficiency Review* (ERG, 2011).

10.2.4.2 Summary of Airport Deicing Cost Model Equations

The Airport Deicing Cost Model uses capital and annual cost equations in combination with various input parameters to estimate costs for each option’s collection and treatment technology at each airport. Table 10-6 summarizes the cost equations used by the model, the input variables, and any assumptions used by the model to estimate costs. The equations in Table

10-6 are based on an airport collecting ADF-contaminated stormwater with glycol concentrations greater than 0.5 percent.

10.2.4.1 Example Cost Calculation

The following example shows how the Airport Deicing Cost Model uses the equations in Section 10.2.2 along with an airport's questionnaire response to estimate costs. The example below is designed to more clearly illustrate the Airport Deicing Cost Model.

Example Airport Capital and Annual Costs

Airport A has six deicing outfalls and currently has no collection or control equipment in place for ADF-contaminated stormwater. The estimate of airport normalized ADF usage is approximately 490,000 gallons per year of Type 1 and Type IV ADF. The airport has 23 deicing days per year spanning a five-month period (150 days). The airport does not discharge to a POTW or contract haul ADF to an off-site recovery/recycle facility. Based on the final rule, the airport will collect 40 percent of the available ADF using a plug and pump system with GCVs. Collected ADF contaminated stormwater will be treated by an AFB treatment system.

Winter Operations Plan Development

Engineering Labor: $240 \text{ hours} \times \$100/\text{hr} = \$24,000$

Plug and pump Collection System

Plug and Pump Capital Cost: $= 6 \times \$263,400 = \$1,580,400$

Plug and Pump Annual O&M Cost (\$/yr) $= 6 \times \$260,000 = \$1,560,000/\text{yr}$

Table 10-6. Airport Deicing Cost Model Equations, Input Variables, and Assumptions

Calculation Description	Equation	Input Variables	Assumptions
Estimates costs for airports to prepare a one-time winter operations plan as a supplement to the current SWPPP.	Winter Operations Plan (\$) 20% ADF collection: 120 hours × \$100/hr 40% ADF collection: 240 hours × \$100/hr	Target ADF collection percentage	Labor costs assume airport will contract with an outside consultant to prepare the winter operations plan.
Estimates costs to purchase and operate GCVs to collect 20% of available ADF. Includes a 20% factor on the O&M costs for drainage control.	GCV Capital Cost (\$) = \$344,238 × number of GCVs GCV Annual Cost(\$/yr) = \$59,773 × number of GCVs × 1.2	Airport hub status	Small, medium and Non-hub airports require 2 GCVs. Large Hub airports require 3 GCVs
Estimates costs to install and operate a block-and pump collection system with GCVs to collect 40% of available ADF.	Plug and Pump Capital Cost (\$) = \$263,400 × outfall number Plug and Pump Annual Cost (\$/yr) = \$260,000 × outfall number	Number of stormwater deicing outfalls from the airport questionnaire	The number of deicing outfalls relates to the number and size of deicing areas requiring controls.
Estimates costs to install and operate an AFB bioreactor treatment system.	AFB COD Load (lbs/day) = ADF Use × 14.28 × Collect % / 100 × 1/operating days AFB Unit Capital Cost (\$/lb/day): $275,101 \times (\text{COD Load})^{-0.6279}$ AFB Capital Cost (\$): AFB Unit Capital Cost × COD Load AFB Annual Cost (\$/yr) = ADF Use × Collect % / 100 × \$4.90	ADF use from airline detailed questionnaire Treatment system operating period based on deicing months from airline detailed questionnaire Collection % from selected collection technology	Ultimate COD is 14.28 lbs COD/gal Type I ADF.
Estimated costs to install storage tanks to equalize collected ADF - contaminated stormwater.	Storage Tank Capital Cost (\$) = ADF Use × 11.4 × \$1.67 Storage Tank Annual Cost (\$/yr) = ADF Use × \$0.27	ADF use from airline detailed questionnaire	Storage tank volume requirement is 11.4 gal per gal of ADF used per year.

Table 10-6 (Continued)

Calculation Description	Equation	Input Variables	Assumptions
Estimated costs to install an additional 10,000 linear feet of stormwater piping to convey ADF-contaminated water from collection to treatment.	Piping Capital Cost (\$) = \$1,140,000 Piping Annual Cost (\$/yr) = \$5,600	None	Based on 10,000 linear feet of 18” diameter subsurface piping.
Estimated cost for land to install storage tanks and an AFB treatment system.	AFB Treatment System Annual Land Cost (\$/yr) = \$104,544 Storage Tank Annual Land Cost (\$/yr) = $1.2 \times (\text{ADF Use gal/yr} \times 13.1 \text{ gal/gal/yr} \times 0.0095 \text{ ft}^2/\text{gal}) \times \$1/\text{ft}^2$	None ADF use from airline detailed questionnaire	AFB treatment system can be installed on 2.4 acres and the lease cost for land is \$1/ft ² . Lease cost for land is \$1/ft ² .

AFB Biological Treatment System

AFB COD Loading = $490,000 \text{ gal/yr} \times 14.38 \text{ lbs COD/gal ADF} \times 0.4 \times 1/150 \text{ days/yr} = 18,789 \text{ lbs/day}$

AFB Unit Capital Cost (\$/lb/day): $275,101 \times (18,789)^{-0.6279} = \$570/\text{lb COD/day}$

AFB Capital Cost (\$): $18,789 \text{ lbs/day COD} \times \$570/\text{lb COD/day} = \$10,711,000$

AFB Annual O&M Cost (\$/yr): $490,000 \times 0.4 \times \$4.90 = \$960,000/\text{yr}$

Piping System

Piping system capital cost: \$1,140,000

Piping system annual O&M cost: \$5,600/yr

Storage Tank(s)

Storage Tank Capital Cost (\$) = $490,000 \times 11.4 \times \$1.67 = \$9,329,000$

Storage Tank Annual O&M Cost (\$/yr) = $490,000 \times \$0.27 = \$132,300$

Land

AFB Cost (\$/yr) = \$104,544

Storage Tanks (\$/yr) = $\$1.2 \times 490,000 \text{ gal/yr} \times 13.1 \text{ gal/gal/yr} \times 0.0095 \text{ ft}^2/\text{gal} \times \$1/\text{ft}^2 = \$60,980$

The total capital and O&M costs are therefore:

Cost Category	Capital Costs (\$)	O&M Costs (\$/year)
Winter Operations Plan	24,000	
Plug and Pump Collection System	1,580,400	1,560,000
AFB Treatment System	10,711,000	960,000
Piping	1,140,000	5,600
Storage	9,329,000	132,300
Land Opportunity Costs – For AFB Treatment System	–	104,544
Land Opportunity Costs – For Storage	–	60,980
Total	22,784,400	2,823,424

The capital costs are then amortized and added to the annual O&M costs to assess an overall annualized cost for the facility.

10.2.5 Annualized Costs for ADF Collection and Treatment Alternatives

Table 10-7 presents the annualized costs by airport developed for the two control and treatment scenarios evaluated by EPA for the final rule. See the Economic Development document (USEPA, 2012; DCN AD01280) for a more detailed analysis of annualized costs.

Table 10-7. Annualized Costs by Model Facility for Control and Treatment ¹

Airport ID	Airport	Current ADF Collection	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)
1001 ²	Montgomery Regional (Dannelly Field)	0	\$1,168	\$1,168
1003 ³	Ketchikan International	NA	\$0	\$0
1004	Norfolk International	20	\$0	\$2,235,548
1006	Chicago O'Hare International	40	\$0	\$0
1007	Yeager	40	\$0	\$0
1008	Tucson International	20	\$0	\$1,069,305
1010	Fairbanks International	≥60	\$0	\$0
1011	Lambert-St Louis International	≥60	\$0	\$0
1012	Ted Stevens Anchorage International	40	\$0	\$0
1014	Albuquerque International Sunport	20	\$0	\$6,269,926
1015	Gulfport-Biloxi International	≥60	\$0	\$0
1017	Austin Straubel International	40	\$0	\$0
1018	Piedmont Triad International	0	\$1,090,753	\$8,121,534
1019 ²	Ontario International	0	\$1,110	\$1,110
1020	Hartsfield - Jackson Atlanta International	≥60	\$0	\$0
1021	Buffalo Niagara International	40	\$0	\$0
1022	Fort Wayne International	0	\$991,516	\$3,272,310
1023*	Seattle-Tacoma International	0	\$1,560,687	\$3,863,913
1024	Indianapolis International	40	\$0	\$0
1026	Dallas/Fort Worth International	≥60	\$0	\$0
1028	Denver International	≥60	\$0	\$0
1029	La Guardia	0	\$2,976,443	\$6,286,465
1031	Richmond International	40	\$0	\$0
1032	Austin-Bergstrom International	40	\$0	\$0
1033	Mc Carran International	40	\$4,216	\$4,216
1034	Metropolitan Oakland International	≥60	\$0	\$0
1035	San Diego International	≥60	\$0	\$0
1036	Baltimore-Washington International	≥60	\$0	\$0
1037	George Bush Intercontinental Airport/Houston	40	\$4,099	\$4,099
1040	Louis Armstrong New Orleans International	≥60	\$0	\$0
1041	Glacier Park International	0	\$1,037,252	\$1,266,155
1043	Ralph Wien Memorial	0	\$605,365	\$707,178
1044	Roanoke Regional/Woodrum Field	0	\$943,332	\$4,095,087
1045 ²	Norman Y. Mineta San Jose International	10	\$0	\$0

Table 10-7 (Continued)

Airport ID	Airport	Current ADF Collection	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)
1046	Long Island Mac Arthur	≥60	\$0	\$0
1050	Aspen-Pitkin Co/Sardy Field	40	\$0	\$0
1052	Wilmington International	0	\$654,946	\$3,131,737
1053	General Edward Lawrence Logan International	0	\$4,860,377	\$6,659,582
1054	Jackson Hole	≥60	\$0	\$0
1057	Will Rogers World	0	\$986,385	\$2,675,571
1058	Gerald R. Ford International	40	\$0	\$0
1059	Greater Rochester International	50	\$0	\$0
1061	William P Hobby	≥60	\$0	\$0
1062 ²	Birmingham International	0	\$2,675	\$2,675
1063	Evansville Regional	0	\$846,931	\$1,609,927
1065	Albany International	≥60	\$0	\$0
1066	Salt Lake City International	≥60	\$0	\$0
1067	Helena Regional	≥60	\$0	\$0
1068	Eppley Airfield	0	\$1,250,502	\$2,132,279
1069	Cleveland-Hopkins International	40	\$0	\$0
1070	City of Colorado Springs Municipal	40	\$0	\$0
1074	South Bend Regional	≥60	\$0	\$0
1075	Pensacola Regional	≥60	\$0	\$0
1078	Nashville International	≥60	\$0	\$0
1079	Manchester	0	\$1,600,420	\$1,995,084
1080	Syracuse Hancock International	≥60	\$0	\$0
1081	Bob Hope	≥60	\$0	\$0
1083	Tampa International	≥60	\$0	\$0
1084	Bismarck Municipal	0	\$770,509	\$1,215,970
1086	Palm Beach International	≥60	\$0	\$0
1087	El Paso International	≥60	\$0	\$0
1088	Outagamie County Regional	0	\$1,011,102	\$2,412,516
1089	John F Kennedy International	0	\$3,215,317	\$10,136,241
1090	Boise Air Terminal/Gowen Fld	≥60	\$0	\$0
1091	Rochester International	40	\$0	\$0
1094	Boeing Field/King County International	40	\$0	\$0
1095	Chicago Midway International	≥60	\$0	\$0
1097 ²	Lovell Field	0	\$3,745	\$3,745
1099 ²	Sacramento International	20	\$0	\$0
1100	Toledo Express	20	\$0	\$1,767,861
1101	Portland International	20	\$0	\$2,792,934

Table 10-7 (Continued)

Airport ID	Airport	Current ADF Collection	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)
1102	John Wayne Airport-Orange County	≥60	\$0	\$0
1103	Juneau International	0	\$957,795	\$2,343,519
1104	Nome	0	\$618,441	\$1,904,296
1105	Spokane International	≥60	\$0	\$0
1107	Pittsburgh International	≥60	\$0	\$0
1108	Louisville International-Standiford Field	≥60	\$0	\$0
1111	Port Columbus International	0	\$2,029,946	\$4,321,331
1113	Cincinnati/Northern Kentucky International	≥60	\$0	\$0
1114	Stewart International	40	\$0	\$0
1115	Jacksonville International	≥60	\$0	\$0
1116	Reno/Tahoe International	20	\$0	\$1,614,875
1117	Cherry Capital	≥60	\$0	\$0
1118	Bethel	0	\$643,331	\$1,936,511
1119	Rickenbacker International	0	\$710,969	\$1,433,955
1120	Rapid City Regional	0	\$838,073	\$4,548,952
1121	Theodore Francis Green State	≥60	\$0	\$0
1122	Southwest Florida International	≥60	\$0	\$0
1123	James M Cox Dayton International	≥60	\$0	\$0
1124	Des Moines International	40	\$0	\$0
1126	Minneapolis/St Paul International/Wold-Chamberlain	≥60	\$0	\$0
1128	Charlotte/Douglas International	0	\$1,574,890	\$2,111,996
1129	Bradley International	≥60	\$0	\$0
1130	San Antonio International	0	\$780,240	\$5,064,195
1131	Wilkes-Barre/Scranton International	0	\$971,556	\$1,476,180
1133 ²	Phoenix Sky Harbor International	20	\$0	\$0
1135 ²	Lafayette Regional	0	\$1,536	\$1,536
1136	General Mitchell International	44	\$0	\$0
1137	Dallas Love Field	40	\$0	\$0
1138	Detroit Metropolitan Wayne County	≥60	\$0	\$0
1139	Philadelphia International	≥60	\$0	\$0
1140	Memphis International	0	\$1,740,377	\$3,651,474
1141	Ronald Reagan Washington National	40	\$0	\$0
1142	Washington Dulles International	40	\$0	\$0
1143	San Francisco International	≥60	\$0	\$0

Table 10-7 (Continued)

Airport ID	Airport	Current ADF Collection	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)
1144	Central Wisconsin	0	\$952,550	\$1,451,583
1145	Newark Liberty Intl	0	\$5,366,144	\$9,674,611
1146	Northwest Arkansas Regional	0	\$873,730	\$1,644,615
1147	Raleigh-Durham Intl	0	\$1,294,323	\$4,254,332
1148	Kansas City Intl	40	\$0	\$0

¹ Treatment includes installation and operation of an AFB biological treatment system.

² Airport is in a warm climate and uses either no ADF or less than 5,000 gal/yr.; EPA assumes the airport will contract out all ADF removal and disposal operations.

³ Airport was sent an airport questionnaire but did not respond.

*The airport post-questionnaire has installed deicing pads. High BOD stormwater is sent to a POTW.

10.3 Airfield Deicing Costs

This section describes EPA's cost evaluation for model airports to discontinue using urea as an airfield deicing chemical. Information collected by EPA during the rulemaking effort indicated that use of urea as an airfield deicing chemical is being phased out due to concerns with its environmental impacts and the availability of less harmful alternatives. Responses to EPA's airport questionnaire indicated that potassium acetate was by far the predominant airfield deicing chemical in use from 2002 to 2005, representing about 80 percent of all airfield deicing chemical use; therefore, EPA assumed that airports would switch to this chemical to deice their pavement. However, approximately 35 of the surveyed airports continued to use urea for airfield deicing during the 2002/2003, 2003/2004, and 2004/2005 deicing seasons. EPA did not estimate capital or operating costs associated with airfield deicing control for model airports that did not report urea usage.

10.3.1 *Urea and Potassium Acetate Chemical Costs and Application Rates*

EPA evaluated the chemical cost of using urea compared to the chemical cost to use potassium acetate in evaluating costs for controlling discharges associated with pavement deicing. This section presents information on the chemical, mechanical, and storage costs to replace urea with potassium acetate. Additional details on urea and potassium acetate use is included in a memorandum entitled *Estimated Costs for Transition to Liquid Airfield Deicing Application from Solid Airfield Deicing* (ERG, 2010a).

Based on responses to the airport questionnaire (USEPA, 2006b), 19 of the airports that used urea also used potassium acetate. EPA attempted to contact these airports to obtain their unit costs for both chemicals and were able to get unit cost data from eight of these airports. Table 10-8 presents the average cost for urea and potassium acetate during the 2002-2005 time frame for these eight airports.

Table 10-8. Average Cost for Urea and Potassium Acetate, 2002-2005

Year	Average Urea Cost	Average Liquid Potassium Acetate Cost
2002	\$268.17/ton	\$2.81/gallon
2003	\$280.57/ton	\$2.86/gallon
2004	\$297.90/ton	\$2.86/gallon
2005	\$300.21/ton	\$2.92/gallon

Potassium acetate is applied at different rates depending on the weather conditions and the thickness of the ice layer at the time of application. Table 10-9 shows the typical deicing, anti-icing, and prewetting application rates for four commercial potassium acetate runway deicers.

Table 10-9. Typical Application Rates for Potassium Acetate

Brand Name	Deicing Application Rates	Anti-Icing Application Rates	Prewetting Application Rates
Safeway® KA Runway Deicing Fluid	1 gal/1000 ft ²	0.4gal/1000ft ²	70% solid and 30% liquid
Cryotech E-36® LRD	1 gal/1000 ft ² (thin ice) and 3 gal/1000 ft ² (2.5cm thick ice)	0.5 gal/1000ft ²	85-95% solid and 5-15% liquid, or 130g/kg of solid deicer, 1.25gal/100lbs. solid deicer
IceClear RDF	1 gal/1000 ft ² (thin ice) and 3 gal/1000 ft ² (1in. thick ice)	0.5 gal/1000ft ²	
PEAK® PA	1 gal/1000 ft ²	0.4 gal/1000ft ²	70% solid and 30% liquid

Although it could not obtain actual application rates for urea at individual airports, EPA did obtain airfield application rates for sodium acetate; therefore, the Agency used sodium acetate rates as a surrogate to estimate urea application rates. The amount of sodium acetate required to provide the same protection as urea is between 66 and 70 percent (Transport Canada, 1998). EPA used this relationship to calculate the corresponding urea application rates. Table 10-10 lists typical application rates for Cryotech NAAC®, a commercial sodium acetate deicer and the corresponding urea application rate based on the relationship between sodium acetate and urea.

Table 10-10. Application Rates for Sodium Acetate and Urea

Sodium Acetate, Cryotech NAAC®, Application Rate	Urea Application Rate
Near 32°F on thin ice = 3-5 lbs/1000 ft ²	Near 32°F on thin ice = 4.3-7.1 lbs/1000 ft ²
Less than 10°F on 1 inch ice = 10-25 lbs/1000 ft ²	Less than 10°F on 1 inch ice = 14.3-35.7 lbs/1000 ft ²

Using the information in Table 10-10, EPA estimated the application costs for urea and potassium acetate based on the 2005 average unit costs (\$/1,000 ft²), as shown in Table 10-11.

Table 10-11. Cost for Application of Urea and Potassium Acetate, per 1000 Square Feet

Chemical	Deicing Application Cost (per 1000 ft ²)	Anti-Icing Application Cost (per 1000 ft ²)
Urea	\$0.65-\$1.07, Near 32°F on thin ice	
Potassium Acetate	\$2.92 (thin ice) and \$8.76 (thick ice)	\$1.17-\$1.46

10.3.2 Mechanical Application Equipment and Storage of Potassium Acetate

Airports that change from urea to potassium acetate for airfield deicing will need new application equipment to apply a liquid rather than a solid as well as liquid storage tanks to contain potassium acetate during the deicing season. The following sections discuss the costs for mechanical application equipment and storage tanks for liquid potassium acetate.

10.3.2.1 Mechanical Application Equipment

Airports require application equipment to spread chemical deicers on the airside pavement. A change from solid to liquid chemicals will require an airport to purchase or retrofit equipment to properly apply liquid chemical deicers. EPA requested liquid chemical application equipment costs from vendors across the country that offer a variety of different application equipment options and obtained costs from three vendors. EPA requested information on equipment of various sizes to assess costs by a large vs. small/medium coverage area.

Based on information provided by the vendors, EPA assumed that new trucks with a large coverage area operated with 100-foot spraying booms and at least 2,500 gallons of tank space. For truck retrofits or trailers, EPA assumed a large coverage area for units that operated with at least 75-foot booms and at least 2,000 gallons of tank space. EPA assumed that new trucks with a small/medium coverage area operated with 50-foot spraying booms and at least 1,100 gallons of tank space. For truck retrofits or trailers, EPA assumed a small/medium coverage area for units that operated with booms of 50 feet or a different type of spreading mechanism. EPA used this information to estimate liquid application equipment costs for those airports that currently use solid urea.

Table 10-12 provides costing information for small/medium and large liquid deicer application equipment. Equipment is presented for two types of installations: new sprayer trucks and truck retrofits/towed sprayers. Costs are presented as a total capital cost and are averaged by equipment type and size.

EPA assumed that small, medium, and Non-hub airports would be required to purchase a medium-size spreader truck and a medium-size truck retrofitted with a tow unit for application of potassium acetate. EPA assumed Large Hub airports would purchase a large-size spreader truck and a large-size truck retrofitted with a towed unit. Based on these equipment assumptions and the relationship between urea and potassium acetate amounts, EPA estimated small, medium and Non-hub airports would be required to spend approximately \$203,000 for a potassium acetate application system and large airports would be required to spend approximately \$348,000. EPA assumed that airports using both urea and potassium acetate have sufficient application

equipment available to apply only potassium acetate and those airports were not assigned application equipment costs.

10.3.2.1 Potassium Acetate Storage Tanks

Users of liquid pavement deicers can purchase the chemicals in various size carboys or in bulk. The actual size of bulk liquid storage tanks needed will depend primarily on the amount of deicing chemical purchased each deicing season. EPA used tank cost data from fact sheets contained in ARCP Report 14 (ARCP Fact Sheets) to estimate liquid pavement deicer storage costs for airports that currently use solid urea for airfield deicing and would need to convert to a non-urea-containing deicing chemical.

Table 10-12. Application Equipment Costs for Liquid Pavement Deicer

Installation Type	Large Coverage	Deicing Unit	Medium/Small Coverage	Deicing Unit
Full Truck	\$160,000	Tyler Ice AD Series – 4,000 Gallons with 100' Booms (Eagle)	\$130,000	Tyler Ice AD Series – 2,000 Gallons with 75' Booms (Eagle)
	\$280,000	4,000-5,000-gallon units (Tyler ICE)	\$197,500	2,000-3,000-gallon unit (Tyler ICE)
	\$245,000	ASP nozzle sprayer spraying width 45 Meter. Tank content 10,000 liter (Schmidt)		
Average Cost ¹	\$228,000		\$163,000	
Installation Type	Large Coverage	Deicing Unit	Medium/Small Coverage	Deicing Unit
Truck Retrofit/ Spreader	\$110,000	3,500 2T 5M Towed Spreader (Eagle)	\$35,000	Smart Tote 125, 8-25' spray width (Eagle)
			\$35,000	Epoke PC Compact , Drop behind spreader (Eagle)
	\$130,000	Tyler Ice TAD Series, 2,000 gallons with 75' booms (Eagle)	\$60,000	Tyler Ice TAD Series, 500 gallons with 12-36' boomless spray (Eagle)
			\$20,500	Small Tote Sprayer, 8-50' booms (Tyler ICE)
			\$50,000	ASPT nozzle sprayer spraying width of 15 meters. Tank content 3,000 liters (Schmidt)
Average Cost ¹	\$120,000		\$40,000	

¹ – Yearly cost was calculated assuming a 6% interest rate and a 20 year loan term.

Sources:

Eagle – Mr. Trevor Winn, CA, CFO at Eagle Airfield (a division of Team Eagle Ltd). <http://www.team-eagle.ca/>.

Tyler ICE Div. of Wausau Equipment – Mr. Mark Kreutzfeldt. <http://www.wausau-everest.com/>

Schmidt – Mr. Rene Wender - Product Manager Airport equipment. <http://www.aebi-schmidt.com>.

Table 10-13 provides capital costs for potassium acetate storage tanks. Costs for three types of storage tanks are presented: portable (frac), modular, and permanent. For smaller storage needs, EPA assumed that an airport could use the chemical tote provided with the liquid deicer purchase. EPA assumed that O&M costs for liquid storage are about the same as those for solid storage. EPA assumes that a modular tank with a 50,000-gallon storage capacity will be the best option for airports that use between 1,000 and 50,000 gallons of liquid airfield deicing chemical each deicing season. A modular tank with a 100,000-gallon storage capacity will be the best option for airports that use greater than 50,000 gallons of deicing chemical each season. EPA assumed that airports using both urea and potassium acetate have sufficient liquid storage available and therefore no costs for tanks are assigned to these airports.

Table 10-13. Storage Tank Capital Costs for Liquid Pavement Deicer

Tank Type	Size (gallon)	Transaction Type	Cost	Cost for 2/3 of a year rental
Portable (Frac)	21,000	Rental	\$45/day	\$10,980
Portable (Frac)	21,000	Rental	\$1,350/month	\$10,800
Average Portable (Frac) Tank Cost				\$10,890/yr
Tank Type	Size (gallon)	Transaction Type	Cost	Cost per gallon
Modular	50,000	Purchase	\$40,000	\$0.80
Modular	100,000	Purchase	\$50,000	\$0.50
Modular	245,000	Purchase	\$80,000	\$0.33
Modular	500,000	Purchase	\$130,000	\$0.26
Modular	1,000,000	Purchase	\$225,000	\$0.23
Modular	2,000,000	Purchase	\$375,000	\$0.19
Average Modular Tank Cost				\$0.38
Tank Type	Size (gallon)	Transaction Type	Average Cost	Cost per gallon
Permanent	2,000,000	Purchase	2,000,000	\$0.90
Permanent	4,000,000	Purchase	4,000,000	\$0.70
Average Permanent Tank Cost				\$0.80

The national average use of urea, based on EPA's airport questionnaire (U.S. EPA, 2006b) data for the three deicing seasons between 2002 and 2005, was 7,075,900 pounds per year. Using the available range of application rates (small coverage area and large coverage area for the same amount of urea) and statistical airport weighting values as determined by EPA, the Agency estimated both capital costs for equipment (application equipment and storage tanks) and chemical costs for a national switch from urea to potassium acetate. Table 10-14 lists the annualized capital costs for application equipment and storage plus the annual cost for potassium acetate for those airports in the scope of the final rule that indicated they use urea. Note that airports that currently use potassium acetate for a portion of airfield deicing are assumed to have both application equipment and storage available and therefore no capital costs are required.

Table 10-14. Annualized Costs for In-Scope Airports to Change from Urea to Potassium Acetate for Airfield Deicing

Airport ID	Annualized Capital Equipment Cost ¹ (\$/yr 2006)	Predicted Potassium Acetate Annual Cost (\$/yr 2006)	Total Annualized Cost (\$/yr 2006)
1007	\$30,654	\$10,487	\$41,141
1010	\$0	\$150,844	\$150,844
1012	\$0	\$657,442	\$657,442
1017	\$0	\$16,346	\$16,346
1018	\$0	\$38,826	\$38,826
1022	\$0	\$105,445	\$105,445
1041	\$27,125	\$131	\$27,256
1043	\$0	\$3,935	\$3,935
1053	\$49,879	\$2,243	\$52,122
1066	\$0	\$577,406	\$577,406
1074	\$30,654	\$12,765	\$43,419
1079	\$0	\$8,854	\$8,854
1090	\$0	\$159,636	\$159,636
1103	\$31,536	\$199,901	\$231,436
1105	\$31,536	\$251,319	\$282,855
1114	\$0	\$59,734	\$59,734
1116	\$0	\$2,848	\$2,848
1118	\$30,654	\$25,971	\$56,625
1128	\$0	\$91,667	\$91,667
1129	\$0	\$6,590	\$6,590
1141	\$0	\$24,660	\$24,660
1144	\$0	\$33,209	\$33,209
1146	\$30,654	\$10,625	\$41,278
1147	\$30,654	\$35,153	\$65,807

¹ Cost includes both application equipment and storage tanks.

10.4 Other ADF-Compliance-Related Costs

In addition to the costs associated with ADF stormwater collection and control and airfield deicing chemical substitution, EPA also analyzed potential monitoring and reporting costs for airports to comply with the various options. Specifically, EPA costed the model airports to:

- Assess ADF usage (in some instances, EPA assumed that the airport would not need to assess usage);
- Perform an engineering review of airport operations to determine and document compliance with the percent ADF collection standard (for those that are in scope of the analyzed collection requirements);

- Perform annual ADF collection equipment/system inspections (for those who are in scope of the analyzed collection requirements); and
- Perform COD monitoring from an on-site treatment system (such as AFB treatment) to demonstrate compliance with the COD standards (for those facilities that are in scope of the analyzed option).

EPA's assumptions and methodology for estimating these costs are described below along with a summary of the in-scope airports which EPA projected would incur these costs. Table 10-15 presents these other compliance-related costs for each of the model airports determined to be in the scope of the final rule.

10.4.1 *Assessing ADF Usage from Airport Tenants*

EPA assumed that many airports using ADF during typical winter seasons will need to collect and compile ADF usage information from the airlines operating at the airport. EPA is assuming that airport personnel will collect ADF usage data monthly from airport tenants and will collate that data into a spreadsheet, which can be totaled each season to assess an annual ADF usage for the entire airport. EPA is assuming that this activity will require 8 hours per month and that ADF usage data is collected for 6 months of the year on average (based on airports' reported deicing months). Costs associated with assessing ADF usage will therefore be:

$$8 \text{ hours/month} \times 6 \text{ deicing months/year} \times \$35/\text{hour labor rate} = \$1,680/\text{year}$$

The labor rate shown in the equation above is based on an average reported labor rate of \$33/hour obtained from responses to the airport questionnaire and an escalation rate of 7 percent to adjust costs to a 2006 basis³. EPA adjusted the labor rate so that the labor costs for the compliance activity will be on a similar-year basis as the other costs assessed by EPA.

EPA is assuming that only those airports that use less than 80,000 gallons of normalized ADF per year would need to collect and assess total airport annual ADF. Rather than collect and tabulate ADF usage, airports that use more than 80,000 gallons would likely certify that their usage is above the cutoff specified in the analyzed option.

10.4.2 *Determination of ADF Stormwater Collection Percentage*

As part of the options evaluated by EPA in the final rule, airports with normalized ADF use of $\geq 60,000$ gallons/year would need to demonstrate that they achieve the analyzed collection requirement. Airports would meet the collection requirement using the technologies costed by EPA or through other means. EPA is assuming that airports would hire an engineering consultant or firm to evaluate the airport's ADF usage data to calculate its available normalized ADF. The engineering consultant would also evaluate information on the airport's pollution prevention, deicing stormwater collection, and on-site treatment or alternative disposal.

³ From Bureau of Labor Statistics, Producer Price Index industry data for the airport industry. Increase from 2004 to 2006.

Table 10-15. Other Compliance-Related Costs by Airport

Airport ID	Airport	Total Annualized Compliance-Related Costs (\$/yr 2006)
1001	Montgomery Rgnl (Dannelly Field)	\$1,680
1003	Ketchikan Intl	\$1,680
1004	Norfolk Intl	\$1,680
1006	Chicago O'Hare Intl	\$9,279
1007	Yeager	\$1,680
1008	Tucson Intl	\$1,680
1010	Fairbanks Intl	\$9,279
1011	Lambert-St Louis Intl	\$9,279
1012	Ted Stevens Anchorage Intl	\$9,279
1014	Albuquerque Intl Sunport	\$21,333
1015	Gulfport-Biloxi Intl	\$1,680
1017	Austin Straubel International	\$10,959
1018	Piedmont Triad International	\$21,333
1019	Ontario Intl	\$1,680
1020	Hartsfield - Jackson Atlanta Intl	\$9,279
1021	Buffalo Niagara Intl	\$9,279
1022	Fort Wayne International	\$1,680
1023	Seattle-Tacoma Intl	\$19,653
1024	Indianapolis Intl	\$9,279
1026	Dallas/Fort Worth International	\$9,279
1028	Denver Intl	\$19,653
1029	La Guardia	\$19,653
1031	Richmond Intl	\$1,680
1032	Austin-Bergstrom Intl	\$1,680
1033	Mc Carran Intl	\$1,680
1034	Metropolitan Oakland Intl	\$1,680
1035	San Diego Intl	\$1,680
1036	Baltimore-Washington Intl	\$9,279
1037	George Bush Intercontinental Arpt/Houston	\$1,680
1040	Louis Armstrong New Orleans Intl	\$1,680
1041	Glacier Park Intl	\$1,680
1043	Ralph Wien Memorial	\$1,680
1044	Roanoke Regional/Woodrum Field	\$1,680
1045	Norman Y. Mineta San Jose International	\$1,680
1046	Long Island Mac Arthur	\$1,680
1050	Aspen-Pitkin Co/Sardy Field	\$1,680
1052	Wilmington Intl	\$1,680
1053	General Edward Lawrence Logan Intl	\$19,653
1054	Jackson Hole	\$1,680
1057	Will Rogers World	\$1,680
1058	Gerald R. Ford International	\$9,279
1059	Greater Rochester International	\$9,279
1061	William P Hobby	\$1,680
1062	Birmingham Intl	\$1,680
1063	Evansville Regional	\$1,680
1065	Albany Intl	\$19,653
1066	Salt Lake City Intl	\$9,279
1067	Helena Regional	\$1,680
1068	Eppley Airfield	\$19,653

Table 10-15 (Continued)

Airport ID	Airport	Total Annualized Compliance-Related Costs (\$/yr 2006)
1069	Cleveland-Hopkins Intl	\$9,279
1070	City of Colorado Springs Municipal	10,959
1074	South Bend Regional	\$1,680
1075	Pensacola Regional	\$1,680
1078	Nashville Intl	\$19,653
1079	Manchester	\$19,653
1080	Syracuse Hancock Intl	\$9,279
1081	Bob Hope	\$1,680
1083	Tampa Intl	\$1,680
1084	Bismarck Municipal	\$1,680
1086	Palm Beach Intl	\$1,680
1087	El Paso Intl	\$1,680
1088	Outagamie County Regional	\$1,680
1089	John F Kennedy Intl	\$19,653
1090	Boise Air Terminal/Gowen Fld	\$10,959
1091	Rochester International	\$1,680
1094	Boeing Field/King County Intl	\$1,680
1095	Chicago Midway Intl	\$9,279
1097	Lovell Field	\$1,680
1099	Sacramento International	\$1,680
1100	Toledo Express	\$1,680
1101	Portland Intl	\$19,653
1102	John Wayne Airport-Orange County	\$1,680
1103	Juneau Intl	\$1,680
1104	Nome	\$1,680
1105	Spokane Intl	\$10,959
1107	Pittsburgh International	\$9,279
1108	Louisville Intl-Standiford Field	\$9,279
1111	Port Columbus Intl	\$19,653
1113	Cincinnati/Northern Kentucky International	\$9,279
1114	Stewart Intl	\$1,680
1115	Jacksonville Intl	\$1,680
1116	Reno/Tahoe International	\$21,333
1117	Cherry Capital	\$1,680
1118	Bethel	\$1,680
1119	Rickenbacker International	\$1,680
1120	Rapid City Regional	\$1,680
1121	Theodore Francis Green State	\$9,279
1122	Southwest Florida Intl	\$1,680
1123	James M Cox Dayton Intl	\$9,279
1124	Des Moines Intl	\$9,279
1126	Minneapolis/St Paul Intl/Wold-Chamberlain	\$9,279
1128	Charlotte/Douglas Intl	\$19,653
1129	Bradley Intl	\$9,279
1130	San Antonio Intl	\$1,680
1131	Wilkes-Barre/Scranton Intl	\$1,680
1133	Phoenix Sky Harbor Intl	\$1,680
1135	Lafayette Regional	\$1,680

Table 10-15 (Continued)

Airport ID	Airport	Total Annualized Compliance-Related Costs (\$/yr 2006)
1136	General Mitchell International	\$9,279
1137	Dallas Love Field	\$1,680
1138	Detroit Metropolitan Wayne County	\$9,279
1139	Philadelphia Intl	\$9,279
1140	Memphis Intl	\$19,653
1141	Ronald Reagan Washington National	\$9,279
1142	Washington Dulles International	\$19,653
1143	San Francisco International	\$1,680
1144	Central Wisconsin	\$1,680
1145	Newark Liberty Intl	\$19,653
1146	Northwest Arkansas Regional	\$1,680
1147	Raleigh-Durham Intl	\$19,653
1148	Kansas City Intl	\$9,279

EPA has estimated 264 hours and \$28,424 total costs for a consulting firm to develop and document an engineering assessment using airport-specific data. These costs include time for project management, data analysis and evaluation of airport drawings, calculation of airport-specific ADF collection, and preparation of a report. EPA developed the project elements and estimated the average hourly rate for consulting engineers at \$85/hour based on best professional judgment. This cost is assumed to occur once each permit cycle (i.e., once every five years). EPA assumed that all airports with $\geq 60,000$ gallons/year normalized ADF usage would be required to perform this analysis of the airport's ADF collection percent.

10.4.3 Annual ADF Collection Equipment/System Inspections

As part of the options evaluated by EPA for the final rule, airports could document annual compliance with the collection standard by demonstrating that their selected BAT system was properly maintained and operated. Airports could demonstrate that they were using those technologies properly by annually inspecting the collection equipment and documenting that the equipment was being maintained and used per the manufacturer's specifications.

EPA assumed that an annual inspection of ADF stormwater collection equipment/systems would occur prior to the airport's deicing season and would include the following types of activities as applicable:

- Inspection of GCVs to ensure that they are maintained and ready for use as well as any inspection of the vehicle vacuum system recommended by the manufacturer (e.g., inspection of the vacuum pressure and/or nozzles); and
- Inspection of the plug and pump or drainage diversion system to ensure that system components are in good condition and working order (e.g., inspection and exercising of shut-off valves, inspection of balloon inserts).

EPA assumed that 2 weeks of labor (80 hours total) would be required to perform these activities on an annual basis:

$$80 \text{ hours/season} \times \$35/\text{hour labor rate} = \$2,800/\text{year}$$

EPA included these costs for all airports with $\geq 60,000$ gallons/year normalized ADF usage when evaluating the options with a collection standard in the final rule.

10.4.4 COD Monitoring of On-Site Treatment Systems

For this costing effort, EPA assumed that airports requiring additional ADF stormwater collection and control to comply with the analyzed options, would treat the stormwater through an on-site AFB treatment system. In addition, airports that were already achieving compliance with the collection standard that use on-site treatment prior to direct discharge would need to monitor compliance with the COD limitation. Most of the airports that currently collect ADF-contaminated stormwater send it to a POTW or to off-site glycol recovery. However, for the costing effort, EPA did not assume either POTW discharge or transfer to an off-site glycol recovery facility would be a viable option for those airports requiring additional collection and control. In assessing national costs, EPA assumed that airports requiring additional collection and control would need to conduct ongoing monitoring of the effluent discharge point of the on-site treatment system to ensure permit compliance.

To estimate AFB discharge monitoring costs, EPA assumed the following:

- Airports would collect a daily 24-hour composite sample of treatment system effluent for analysis of COD for each day the treatment system is operating;
- Treatment systems would be operated continuously for 26 weeks per year (6 months);
- Approximately 1 hour of labor is associated with sample collection and delivery of the sample to the laboratory;
- Labor costs for sample collection are \$35/hr;⁴ and
- Cost for COD analysis by the laboratory is \$22/sample⁵ and includes the cost of the sample container.

Using the assumptions above, EPA calculated the annual cost for monitoring the effluent from an airport treatment system to be \$10,374/year as follows:

- Sample Analysis Cost (\$/yr): $1 \text{ sample/day} \times 7 \text{ days/wk} \times 26 \text{ wks/yr} \times \$22/\text{sample} = \$4,004$;
- Labor Cost (\$/yr): $1 \text{ hr/day} \times 7 \text{ days/wk} \times 26 \text{ wks/yr} \times \$35/\text{hr} = \$6,370$; and
- Total Cost (\$/yr): $\$4,004 + \$6,370 = \$10,374$

EPA assumed that all model airports with normalized ADF use $\geq 60,000$ gallons/year, costed for additional collection and on-site treatment of ADF stormwater would monitor for COD at the effluent discharge point from the on-site treatment system. In addition, EPA

⁴ Average labor costs from the airport questionnaire escalated to 2006 year basis.

⁵ Sample analysis costs obtained from EPA for analysis of COD samples by contract laboratory.

evaluated all of the other model airports estimated as having $\geq 60,000$ gallons/year normalized ADF usage to determine which of those airports treat ADF stormwater on site and discharge the effluent directly to U.S. surface waters. As a result, EPA also evaluated monitoring costs for the following airports:

- Washington Dulles International Airport;
- Denver International Airport;
- Albany International Airport; and
- Nashville International Airport.

EPA assumed that all of the other model airports that would be required to meet the collection standard do not directly discharge the available ADF required for collection.

10.5 Summary of Annualized Costs

Table 10-16 summarizes EPA's annualized costs for ADF collection and treatment, other compliance-related costs, and urea substitution costs.

Table 10-16. Summary of EPA’s Annualized Costs for ADF Collection and Treatment, Airfield Deicing Urea Substitution, and Other Compliance-Related Costs

Airport ID	Airport	Airport Weighting Factor	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)	Total Annualized ADF-Compliance-Related Costs (\$/yr 2006)	Urea Substitution Total Annualized Cost (\$/yr 2006)
1001 ¹	Montgomery Regional (Dannelly Field)	6.7013	\$1,168	\$1,168	\$1,680	\$0
1003 ²	Ketchikan International	1.0000	NC	NC	\$1,680	\$0
1004	Norfolk International	1.0000	\$0	\$2,235,548	\$1,680	\$0
1006	Chicago O'Hare International	1.0000	\$0	\$0	\$9,279	\$0
1007	Yeager	2.1508	\$0	\$0	\$1,680	\$41,141
1008	Tucson International	2.9997	\$0	\$1,069,305	\$1,680	\$0
1010	Fairbanks International	1.0000	\$0	\$0	\$9,279	\$150,844
1011	Lambert-St Louis International	1.0000	\$0	\$0	\$9,279	\$0
1012	Ted Stevens Anchorage International	1.0000	\$0	\$0	\$9,279	\$657,442
1014	Albuquerque International Sunport	1.0000	\$0	\$6,269,926	\$21,333	\$0
1015	Gulfport-Biloxi International	5.8413	\$0	\$0	\$1,680	\$0
1017	Austin Straubel International	2.3269	\$0	\$0	\$10,959	\$16,346
1018	Piedmont Triad International	1.0000	\$1,090,753	\$8,121,534	\$21,333	\$38,826
1019 ¹	Ontario International	1.0000	\$1,110	\$1,110	\$1,680	\$0
1020	Hartsfield - Jackson Atlanta International	1.0000	\$0	\$0	\$9,279	\$0
1021	Buffalo Niagara International	1.0000	\$0	\$0	\$9,279	\$0
1022	Fort Wayne International	1.9682	\$991,516	\$3,272,310	\$1,680	\$105,445
1023	Seattle-Tacoma International	1.0000	\$1,560,687	\$3,863,913	\$19,653	\$0
1024	Indianapolis International	1.0000	\$0	\$0	\$9,279	\$0
1026	Dallas/Fort Worth International	1.0000	\$0	\$0	\$9,279	\$0
1028	Denver International	1.0000	\$0	\$0	\$19,653	\$0
1029	La Guardia	1.0000	\$2,976,443	\$6,286,465	\$19,653	\$0
1031	Richmond International	1.0000	\$0	\$0	\$1,680	\$0
1032	Austin-Bergstrom International	1.0000	\$0	\$0	\$1,680	\$0
1033	Mc Carran International	1.0000	\$4,216	\$4,216	\$1,680	\$0
1034	Metropolitan Oakland International	1.0000	NC	NC	\$1,680	\$0
1035	San Diego International	1.0000	NC	NC	\$1,680	\$0
1036	Baltimore-Washington International	1.0000	\$0	\$0	\$9,279	\$0

Table 10-16 (Continued)

Airport ID	Airport	Airport Weighting Factor	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)	Total Annualized ADF-Compliance-Related Costs (\$/yr 2006)	Urea Substitution Total Annualized Cost (\$/yr 2006)
1037	George Bush Intercontinental Airport/Houston	1.0000	\$4,099	\$4,099	\$1,680	\$0
1040	Louis Armstrong New Orleans International	1.0000	NC	NC	\$1,680	\$0
1041	Glacier Park International	3.1409	\$1,037,252	\$1,266,155	\$1,680	\$27,256
1043	Ralph Wien Memorial	1.0000	\$605,365	\$707,178	\$1,680	\$3,935
1044	Roanoke Regional/Woodrum Field	2.1921	\$943,332	\$4,095,087	\$1,680	\$0
1045 ¹	Norman Y. Mineta San Jose International	1.0000	NC	NC	\$1,680	\$0
1046	Long Island Mac Arthur	1.9985	\$0	\$0	\$1,680	\$0
1050	Aspen-Pitkin Co/Sardy Field	4.7500	\$0	\$0	\$1,680	\$0
1052	Wilmington International	6.0388	\$654,946	\$3,131,737	\$1,680	\$0
1053	General Edward Lawrence Logan International	1.0000	\$4,860,377	\$6,659,582	\$19,653	\$52,122
1054	Jackson Hole	4.3500	\$0	\$0	\$1,680	\$0
1057	Will Rogers World	1.0000	\$986,385	\$2,675,571	\$1,680	\$0
1058	Gerald R. Ford International	1.5862	\$0	\$0	\$9,279	\$0
1059	Greater Rochester International	1.0000	\$0	\$0	\$9,279	\$0
1061	William P Hobby	1.0000	\$0	\$0	\$1,680	\$0
1062 ¹	Birmingham International	2.8410	\$2,675	\$2,675	\$1,680	\$0
1063	Evansville Regional	5.1042	\$846,931	\$1,609,927	\$1,680	\$0
1065	Albany International	1.0000	\$0	\$0	\$19,653	\$0
1066	Salt Lake City International	1.0000	\$0	\$0	\$9,279	\$577,406
1067	Helena Regional	4.2000	\$0	\$0	\$1,680	\$0
1068	Eppley Airfield	1.0000	\$1,250,502	\$2,132,279	\$19,653	\$0
1069	Cleveland-Hopkins International	1.0000	\$0	\$0	\$9,279	\$0
1070	City of Colorado Springs Municipal	1.7414	\$0	\$0	10,959	\$0
1074	South Bend Regional	2.1417	\$0	\$0	\$1,680	\$43,419
1075	Pensacola Regional	3.9341	\$0	\$0	\$1,680	\$0
1078	Nashville International	1.0000	\$0	\$0	\$19,653	\$0
1079	Manchester	1.0000	\$1,600,420	\$1,995,084	\$19,653	\$8,854
1080	Syracuse Hancock International	1.0000	\$0	\$0	\$9,279	\$0
1081	Bob Hope	1.0000	NC	NC	\$1,680	\$0
1083	Tampa International	1.0000	NC	NC	\$1,680	\$0

Table 10-16 (Continued)

Airport ID	Airport	Airport Weighting Factor	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)	Total Annualized ADF-Compliance-Related Costs (\$/yr 2006)	Urea Substitution Total Annualized Cost (\$/yr 2006)
1084	Bismarck Municipal	3.8679	\$770,509	\$1,215,970	\$1,680	\$0
1086	Palm Beach International	1.0000	\$0	\$0	\$1,680	\$0
1087	El Paso International	3.0457	\$0	\$0	\$1,680	\$0
1088	Outagamie County Regional	2.4841	\$1,011,102	\$2,412,516	\$1,680	\$0
1089	John F Kennedy International	1.0000	\$3,215,317	\$10,136,241	\$19,653	\$0
1090	Boise Air Terminal/Gowen Fld	1.5043	\$0	\$0	\$10,959	\$159,636
1091	Rochester International	3.1749	\$0	\$0	\$1,680	\$0
1094	Boeing Field/King County International	5.8985	\$0	\$0	\$1,680	\$0
1095	Chicago Midway International	1.0000	\$0	\$0	\$9,279	\$0
1097 ¹	Lovell Field	4.9996	\$3,745	\$3,745	\$1,680	\$0
1099 ¹	Sacramento International	1.0000	NC	NC	\$1,680	\$0
1100	Toledo Express	2.0917	\$0	\$1,767,861	\$1,680	\$0
1101	Portland International	1.0000	\$0	\$2,792,934	\$19,653	\$0
1102	John Wayne Airport-Orange County	1.0000	NC	NC	\$1,680	\$0
1103	Juneau International	1.0000	\$957,795	\$2,343,519	\$1,680	\$231,436
1104	Nome	1.0000	\$618,441	\$1,904,296	\$1,680	\$0
1105	Spokane International	1.5192	\$0	\$0	\$10,959	\$282,855
1107	Pittsburgh International	1.0000	\$0	\$0	\$9,279	\$0
1108	Louisville International- Standiford Field	1.0000	\$0	\$0	\$9,279	\$0
1111	Port Columbus International	1.0000	\$2,029,946	\$4,321,331	\$19,653	\$0
1113	Cincinnati/Northern Kentucky International	1.0000	\$0	\$0	\$9,279	\$0
1114	Stewart International	2.8661	\$0	\$0	\$1,680	\$59,734
1115	Jacksonville International	1.0000	\$0	\$0	\$1,680	\$0
1116	Reno/Tahoe International	1.0000	\$0	\$1,614,875	\$21,333	\$2,848
1117	Cherry Capital	3.5400	\$0	\$0	\$1,680	\$0
1118	Bethel	1.0000	\$643,331	\$1,936,511	\$1,680	\$56,625
1119	Rickenbacker International	4.3659	\$710,969	\$1,433,955	\$1,680	\$0
1120	Rapid City Regional	3.1082	\$838,073	\$4,548,952	\$1,680	\$0
1121	Theodore Francis Green State	1.0000	\$0	\$0	\$9,279	\$0
1122	Southwest Florida International	1.0000	\$0	\$0	\$1,680	\$0

Table 10-16 (Continued)

Airport ID	Airport	Airport Weighting Factor	Annualized Cost for 20% Control and Treatment Scenario (2006 \$)	Annualized Cost for 40% Control and Treatment Scenario (2006 \$)	Total Annualized ADF-Compliance-Related Costs (\$/yr 2006)	Urea Substitution Total Annualized Cost (\$/yr 2006)
1123	James M Cox Dayton International	1.0000	\$0	\$0	\$9,279	\$0
1124	Des Moines International	1.6211	\$0	\$0	\$9,279	\$0
1126	Minneapolis/St Paul International/Wold-Chamberlain	1.0000	\$0	\$0	\$9,279	\$0
1128	Charlotte/Douglas International	1.0000	\$1,574,890	\$2,111,996	\$19,653	\$91,667
1129	Bradley International	1.0000	\$0	\$0	\$9,279	\$6,590
1130	San Antonio International	1.0000	\$780,240	\$5,064,195	\$1,680	\$0
1131	Wilkes-Barre/Scranton International	2.6815	\$971,556	\$1,476,180	\$1,680	\$0
1133 ¹	Phoenix Sky Harbor International	1.0000	NC	NC	\$1,680	\$0
1135 ¹	Lafayette Regional	6.6425	\$1,536	\$1,536	\$1,680	\$0
1136	General Mitchell International	1.0000	\$0	\$0	\$9,279	\$0
1137	Dallas Love Field	1.0000	\$0	\$0	\$1,680	\$0
1138	Detroit Metropolitan Wayne County	1.0000	\$0	\$0	\$9,279	\$0
1139	Philadelphia International	1.0000	\$0	\$0	\$9,279	\$0
1140	Memphis International	1.0000	\$1,740,377	\$3,651,474	\$19,653	\$0
1141	Ronald Reagan Washington National	1.0000	\$0	\$0	\$9,279	\$24,660
1142	Washington Dulles International	1.0000	\$0	\$0	\$19,653	\$0
1143	San Francisco International	1.0000	\$0	\$0	\$1,680	\$0
1144	Central Wisconsin	3.0156	\$952,550	\$1,451,583	\$1,680	\$33,209
1145	Newark Liberty Intl	1.0000	\$5,366,144	\$9,674,611	\$19,653	\$0
1146	Northwest Arkansas Regional	1.8782	\$873,730	\$1,644,615	\$1,680	\$41,278
1147	Raleigh-Durham Intl	1.0000	\$1,294,323	\$4,254,332	\$19,653	\$65,807
1148	Kansas City Intl	1.0000	\$0	\$0	\$9,279	\$0

NC – Not Calculated.

¹ Airport is in a warm climate and uses either no ADF or small amounts of ADF, and EPA assumes the airport will contract out all ADF removal and disposal operations.

² Airport was sent an airport questionnaire but did not respond.

10.6 References

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11. REGULATORY OPTIONS CONSIDERED AND SELECTED FOR BASIS OF FINAL REGULATION

This section presents the technology options evaluated by EPA for the Airport Deicing Category as the basis for the final effluent limitation guidelines and standards. It also describes the methodology for EPA's selection of the final technology options. Specifically, this section describes the basis for BAT and NSPS; as detailed in this section, EPA is not establishing BPT, BCT, PSES or PSNS at this time.

The regulatory option selected provides the technology basis of the final effluent limitation guidelines and standards (ELGs). Entities subject to these regulations would not be required to use the specific technologies selected by EPA to establish the ELGs. Rather, an entity could choose to use any combination of operational changes, pollution prevention, and treatment technologies to comply with the limitations and standards, provided the limitations and standards are achieved.

11.1 BPT and BCT

EPA considered whether in this rule it was necessary to establish BPT limits, given that pavement deicers will be controlled at the BAT level. The Agency concluded that it is not necessary to promulgate BPT effluent limitation guidelines for the Airport Deicing Category, given that the BAT collection and treatment requirements would be at least as stringent as BPT requirements. Similarly, EPA is not establishing BCT limitations for this industry because the same wastestream that would be controlled by BCT is being controlled by BAT.

11.2 BAT

For airfield deicing (runways), EPA concludes that the "best available technology" for reducing ammonia in wastewater discharges from airfields consists of using deicing products not containing urea, instead of those that contain urea. The administrative record for this rulemaking shows that products without urea are widely available in the industry, and in fact are already in use at a majority of airports across the country. In addition, using only deicers without urea is economically achievable by the industry, as explained in the discussion of EPA's economics analysis below.

To comply with this limitation, a discharger subject to the rule must either certify annually that it does not use airfield deicing products that contain urea or airfield pavement discharges must achieve a numeric limitation for ammonia as nitrogen of 14.7 mg/L. Table 11-1 presents the in-scope airports impacted by EPA's BAT standards and EPA's estimates of costs and loading removals associated with the final rule.

Table 11-1. Final Rule BAT Annualized Costs and Load Removals for In-Scope Airports

Airport ID	Airport	Airport Weighting Factor	Urea Substitution Total Annualized Cost (\$/yr 2006)	Potential Load Reduction (lbs of COD)	Potential Load Reduction (lbs of Ammonia)
1007	Yeager	2.1508	\$41,141	42,471	15,572
1010	Fairbanks Intl	1.0000	\$150,844	512,432	187,883
1012	Ted Stevens Anchorage Intl	1.0000	\$657,442	3,881,674	1,423,212
1017	Austin Straubel Intl	2.3269	\$16,346	69,240	25,387
1018	Piedmont Triad Intl	1.0000	\$38,826	143,028	52,441
1022	Fort Wayne Intl	1.9682	\$105,445	440,728	161,593
1041	Glacier Park Intl	3.1409	\$27,256	514	189
1043	Ralph Wien Memorial	1.0000	\$3,935	15,435	5,659
1053	General Edward Lawrence Logan Intl	1.0000	\$52,122	15,769	5,782
1066	Salt Lake City Intl	1.0000	\$577,406	1,730,588	634,519
1074	South Bend Regional	2.1417	\$43,419	50,070	18,358
1079	Manchester	1.0000	\$8,854	56,851	20,844
1090	Boise Air Terminal/Gowen Field	1.5043	\$159,636	416,584	152,740
1103	Juneau Intl	1.0000	\$231,436	737,779	270,506
1105	Spokane Intl	1.5192	\$282,855	768,648	281,824
1114	Stewart Intl	2.8661	\$59,734	234,299	85,905
1116	Reno/Tahoe Intl	1.0000	\$2,848	17,265	6,330
1118	Bethel	1.0000	\$56,625	103,927	38,105
1128	Charlotte/Douglas Intl	1.0000	\$91,667	231,340	84,821
1129	Bradley Intl	1.0000	\$6,590	25,849	9,478
1141	Ronald Reagan Washington National	1.0000	\$24,660	120,391	44,141
1144	Central Wisconsin	3.0156	\$33,209	190,526	69,856
1146	Northwest Arkansas Regional	1.8782	\$41,278	27,782	10,186
1147	Raleigh - Durham Intl	1.0000	\$65,807	97,753	35,841

Source: Airport Deicing Loadings Database (EPA, 2010).

11.2.1 Airfield Deicing: Product Substitution of Pavement Deicers Containing Urea

In general, airports discharge airfield pavement deicing chemicals without treatment, due to the difficulty and expense of collecting and treating the large volumes of contaminated stormwater generated on paved airfield surfaces. EPA is not aware of an available means to control these pollutants by collecting and using a conventional, end-of-pipe treatment system. It is possible, however, to reduce or eliminate certain pollutants by modifying deicing practices, such as using alternative chemical deicing products. In particular, EPA has identified ammonia and COD from airfield deicing as pollutants of concern, and both of these pollutants are a by-product of pavement deicers containing urea. Accordingly, to address discharges of ammonia from airfield pavement, EPA identified one candidate for best available technology: product substitution, or discontinuing the use of pavement deicers containing urea and using alternative

pavement deicers instead. EPA found that using deicers without urea is the best available technology for reducing discharges of ammonia from pavement deicing because it is safe, technologically feasible, and available across the industry. Currently only about 10 percent of chemical pavement deicers applied nationwide contain urea. The most widely used pavement deicer is potassium acetate, which represents 63 percent of all chemical pavement deicers applied nationwide.

11.2.2 *Aircraft Deicing: ADF Collection Requirements and Effluent Limitations*

11.2.2.1 Available ADF Collection Technologies and Scope

EPA is not aware of an available and economically achievable technology that is capable of capturing 100 percent of the sprayed ADF. As described above, the available technologies for collecting ADF are glycol collection vehicles, plug and pump equipment, and CDPs. EPA estimates these technologies collect 20 percent, 40 percent, and 60 percent of available ADF, respectively.

After considering the comments provided on the proposed regulation and reviewing the information in its record, EPA is not establishing a 60 percent ADF collection requirement based on CDPs for BAT. First, in response to FAA's concerns about the exclusive use of deicing pads for aircraft deicing, EPA contacted a number of Large Hub airports that currently use CDPs. EPA found the current percentage of flights for which these airports use the CDPs ranges from 50 to 95 percent. The airports explained that various operational or weather-related issues may make deicing pad use for all flights cumbersome if not impossible (i.e., severe system-wide delays), and require them to deice at the gate in some circumstances. EPA shares the commenters' and FAA's concerns that moving to exclusive use of CDPs for all deicing might lead to operational issues and delays. EPA, in discussions with FAA, attempted to craft regulatory provisions to allow an airport limited ability to bypass the use of a centralized pad to avoid these circumstances. However, limited data on the site-specific nature of this industry left EPA unable to develop regulatory provisions that would give airports the flexibility they need to avoid significant operational issues and delays. Second, based on public comments and information from FAA, EPA is concerned that some large airports critical to efficient air traffic operations in this country are space (land) constrained and that building well-located CDPs for all deicing operations at these airports is likely not feasible for that reason. At the time of the proposal, EPA estimated that 14 airports would be subject to the 60 percent collection requirement. Because the data in EPA's record indicate that many of these airports currently meet this requirement, EPA estimated approximately seven airports would likely need to install pads as a result of the proposed requirement. Of these seven airports, four are Large Hubs that, over years of expansions and other improvements, have already built out the majority of the land available to them. EPA has concluded that the lack of remaining available land, coupled with their existing layouts, has left these airports in a position where they cannot construct a CDP that conforms to FAA's Advisory Circulars on deicing pad design (e.g., in a location that aircraft can travel to safely and efficiently to conduct deicing operations).

Therefore, for the final rule, EPA has not established a 60 percent ADF collection requirement, which would have been based on identifying centralized deicing facilities as BAT for 100 percent of aircraft departures. Because of land constraints and the other reasons

discussed above, EPA finds that centralized deicing facilities should not be identified as BAT for this nationwide rulemaking.

EPA then considered the other two technologies described in the proposed rule as a possible basis of BAT for aircraft deicing discharges for the final rule: 40 percent ADF collection requirement based on plug and pump with GCVs and 20 percent ADF collection requirement based on GCVs. With either of these collection technologies, as was the case in the proposed rule, EPA also included numeric COD limitations for direct discharges of collected ADF based on anaerobic treatment.

11.2.3 *Options Considered for Today’s Final Regulation for Identification of BAT for ADF Collection and Discharge Requirements*

Using the technology bases identified above for airfield and aircraft deicing discharges, EPA developed three primary options for the final rule. All three of these options have the same airfield pavement deicing discharge requirements based on product substitution of deicers that do not contain urea, but would vary the approach to control aircraft deicing discharges:

- **Option 1:** 40 percent ADF collection requirement for large and medium ADF users (based on plug and pump with GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment);
- **Option 2:** 40 percent ADF collection requirement for large ADF users (based on plug and pump with GCVs) and 20 percent ADF collection requirement for medium ADF users (based on GCVs); numeric COD limitations for direct discharges of collected ADF (based on anaerobic treatment); and
- **Option 3:** Site-specific aircraft deicing discharge controls: Do not establish effluent limitation guidelines in the final rule for aircraft deicing discharges, but instead, leave the determination of BAT requirements for each airport to the discretion of the permit writer on a case-by-case, “best professional judgment” basis based on site-specific conditions.

Under the first option, in addition to the airfield pavement requirements, all airports that use greater than or equal to 60,000 gallons of normalized ADF annually would be required to collect 40 percent of available ADF based on plug and pump with GCV technologies. In the proposed rule, EPA considered but did not identify this as its lead option because it found its costs to be comparable to those of CDPs, while CDPs collect more ADF. In the proposed rule, EPA therefore identified CDPs as BAT. Because EPA no longer considers CDPs to be the best available technology for existing airports, the plug and pump with GCV option represents the technology, among those that remain under consideration for the final rule, that would collect the most ADF.

Under the second option, in addition to the airfield pavement requirements, all airports that use greater than or equal to 60,000 gallons of normalized ADF annually but less than 460,000 gallons of normalized ADF (“medium ADF users,” estimated to be 42 airports) would be required to collect 20 percent of available ADF based on GCVs, and airports that use more than 460,000 gallons of normalized ADF (“large ADF users,” estimated to be 14 airports) would

be required to collect 40 percent of available ADF based on the use of plug and pump with GCV technology.

Under both Options 1 and 2, facilities would need to meet numeric effluent limits for COD for the collected ADF prior to commingling it with other wastestreams prior to discharge.

Under the third option, EPA would establish national deicing discharge controls for airfield pavement deicing only. BAT limitations for aircraft deicing discharge would continue to be established by the permitting authority on a case-by-case basis.

11.2.4 BAT Options Selection

EPA is selecting Option 3 as best available technology for controlling airport deicing discharges. EPA has determined the best available technology for controlling airfield pavement discharges is product substitution. The administrative record for this rulemaking shows that products without urea are widely available in the industry, and in fact are already in use at a majority of airports across the country.

With respect to aircraft deicing discharge controls, EPA's record demonstrates that ADF collection and associated treatment technologies are technically feasible for many airports. Data supplied from the industry through EPA's nationally representative survey of airports indicates that dozens of airports currently use GCVs and plug and pump collection systems as well as myriad pollution prevention technologies and practices, ranging from alternative means of applying ADF (e.g., forced air nozzles) to alternate deicing technologies (e.g., infrared deicing). Thus, this industry has numerous technology options available for mitigating the pollutants associated with aircraft deicing activities.

However, EPA concludes that none of the ADF collection technologies considered for the final rule represents the "best available technology" for the entire category. Rather, EPA concludes that best available technology determinations should continue to be made on a site-specific basis because such determinations appropriately consider local operational constraints (e.g., traffic patterns), land availability, safety considerations, and potential impacts to flight schedules. Based on the information in its administrative record, EPA cannot identify with precision the extent to which such limitations may preclude any particular airports from implementing the technologies that it considered for BAT control of aircraft deicing discharges. However, the record demonstrates that such limitations exist and are not isolated or insignificant. More specifically, comments provided by airport and airline industry on the proposed regulation raised concerns about the impacts that ADF collection technologies may have on safety and operations at airports across the country. They also commented on the lack of available space at many land-constrained airports for ADF collection and treatment technologies. EPA reviewed the information submitted in comments, subsequent information provided by industry, and information obtained from site visits to thoroughly evaluate these concerns. After reviewing this information, EPA agrees with commenters that, while many airports likely are able to implement some form of collection or pollution prevention technologies to mitigate pollutant discharges associated with aircraft deicing, other airports may not be able to implement specific technologies due to space, safety, and operational considerations. This became particularly apparent after reviewing questionnaire responses from some of the airports at which EPA also conducted site visits. EPA found that its "model facility" approach was not a suitable substitute

for a detailed analysis of the site constraints at each airport. For example, a permit authority may need to evaluate existing traffic patterns at an airport, not only of the aircraft, but also of the service vehicles, to determine if additional collection vehicles would lead to unacceptable safety concerns. With respect to land constraints, without detailed airport schematics or conducting a detailed site visit at each airport, EPA cannot determine if adequate space exists to incorporate the specific treatment and collection technologies evaluated as the basis for the final rule.

Additionally, industry, and FAA in particular, have expressed concerns about possible delays and economic impact that could result from using plug and pump and GCVs, both at specific airports and nationwide. EPA agrees that delays must be a factor in considering today's possible requirements and recognizes that such delays fundamentally affect U.S and international business and recreational interests.

Airplane deicing activities, by their nature, occur during freezing precipitation events. For some airports, even small amounts of precipitation can lead to delayed aircraft departures – even without deicing activity and/or ADF collection and treatment. As such, it is difficult to determine if delays at an airport during inclement weather are associated with the weather, the ADF collection and treatment technologies, or both. Further, even small delays at certain hub airports have a ripple effect that can affect the entire national air traffic schedule.

Some airports have identified procedures to mitigate or prevent delays associated with aircraft deicing discharge controls, but these approaches may not be applicable nationwide. Further, the extent of delays deemed acceptable is likely to vary by airport. As with land constraints, the confounding factors that need to be considered to evaluate possible delays that may be associated with the technology bases do not lend themselves to a national determination using a model facility approach. Further, EPA does not have detailed site-specific information to evaluate delays on an airport-by-airport basis.

While the facts stated above do not preclude the ability of an airport to collect and treat spent ADF, they do illustrate why EPA did not select any of the technologies considered as BAT for the final rule, and why a site-specific BAT determination for ADF collection and treatment requirements is the proper approach.

Therefore, for the reasons identified above, EPA determined Option 3 is the only technologically feasible and available option considered for today's final BAT requirements. Option 3 would remove 4.4 million pounds of ammonia and 12 million pounds of COD, with a projected annual cost of \$3.5 million. The costs of Option 3 are reasonable in terms of the pollutant reductions achieved (\$0.21/lb). Further, as discussed in more detail in the preamble to the final rule, EPA finds Option 3 is economically achievable. In addition, EPA examined the non-water-quality impacts anticipated from compliance with Option 3 requirements and found none or only very minor impacts in comparison to typical industry energy use, emissions generation, and sludge generation. Therefore, based on all the factors above, EPA is identifying Option 3 as BAT and has based today's final rule on the Option 3 BAT requirements.

11.3 NSPS

For today's final rule, EPA evaluated "best available demonstrated control technologies" for purposes of setting new source performance standards under CWA section 306. Section 306 directs EPA to promulgate NSPS "for the control of the discharge of pollutants which reflects the

greatest degree of effluent reduction which the Administrator determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.” Congress envisioned that new treatment systems could meet tighter controls than existing sources because of the opportunity to incorporate the most efficient processes and treatment systems into the facility design. As a result, NSPS should represent the most stringent controls attainable through the application of the best available demonstrated control technology for all pollutants (that is, conventional, nonconventional, and priority pollutants).

After careful consideration of the information in its record, EPA is today promulgating the same NSPS requirements for both airfield pavement deicing discharges and airplane deicing discharges as it proposed. However, the applicability of the NSPS requirements has changed and EPA has revised the new source definition in the rule to mean new airports only and exclude new runways at existing airports. EPA determined that, just as with existing sources, all new sources would be able to substitute airfield deicing products without urea for those with urea. Furthermore, product substitution represents the greatest ammonia level reduction among the available technologies considered. Accordingly, EPA identifies product substitution of non-urea-containing airfield deicers as the best demonstrated available control technology for all new sources. As with BAT, there would be two alternatives for meeting this effluent limitation: either a certification requirement or a numeric limit on ammonia for all direct discharges of the stormwater from the airfields.

The final rule NSPS also includes a 60 percent collection (based on CDP technology) and control requirement for ADF-contaminated stormwater at new airports anticipated to conduct significant aircraft deicing activities. EPA, in consultation with FAA, finds that safety, space, and operational constraints that may be present at existing airports for the collection and treatment technologies discussed in the final rule (CDPs, plug and pump with GCVs, and GCVs alone), would not apply to new airports. New airports can be designed to minimize space and logistical constraints identified for retrofits at existing airports. Further, among the collection technologies for ADF that EPA considered, CDPs collect the greatest level of available ADF. Meeting the new source requirements would not be an economic barrier to entry for new airports, as the cost of new airport construction, even small airports, is significantly greater than the costs associated with collection and/or treatment of spent deicing fluids (see DCN AD01260 for further detail). Moreover, according to FAA, when designed properly, CDPs often improve traffic flow and reduce delays associated with aircraft deicing. When designing a new airport, the local operating agency plans the site for all needed facilities, such as runways, taxiways, terminal(s) and other components needed to comply with safety and environmental requirements, and this includes deicing facilities. See FAA Advisory Circular 150/5070-6B, “Airport Master Plans,” and FAA Advisory Circular 150/5300-14B, “Design of Aircraft Deicing Facilities,” DCN AD00852. Finally, EPA notes that it did not receive any negative comments on its proposal to base the NSPS ADF collection requirements on CDPs. See DCNs AD01260, AD01284, and AD01335 for EPA’s rationale for setting NSPS applicability.

As a point of clarification, EPA is promulgating the same numeric COD limitations for collected ADF that is discharged directly from new sources as were proposed. The technology basis of the COD limitations, AFB, is available to new airports and achieves the greatest level of pollutant removals of those technologies considered during the development of this regulation.

Further, installing and using this technology is not economically a barrier to entry for new airports.

11.4 PSES and PSNS

EPA is not promulgating PSES and PSNS for the Airport Deicing Category. Although some airports in the United States discharge ADF-contaminated stormwater to POTWs, EPA received no comments or other information indicating that POTWs currently have problems of pollutant pass-through, interference, or sludge contamination stemming from these discharges that would necessitate the promulgation of national categorical pretreatment standards.

Like the biological treatment system that forms the basis for today's COD limitations, POTWs typically use biological treatment systems and are similarly designed to remove organic pollutants that contribute to COD and/or BOD₅. In general, POTWs can achieve comparable removals to the BAT technology basis. However, some airports and POTWs may need to make operational adjustments to process the wastewater effectively while avoiding POTW upset. EPA received a comment about the Downriver Treatment Facility in Detroit, Michigan, which accepts ADF wastewater from the Detroit Metropolitan Wayne County Airport. The treatment plant experienced viscous bulking due to a nutrient imbalance that occurred during the months that ADF was accepted. The issue was resolved by removing phosphorus at a later stage in the treatment plant system, rather than from the raw wastewater. The airport also made significant changes to segregate their deicing stormwater, capture and recycle the most concentrated ADF-contaminated stormwater, and control the amount and concentration of stormwater discharged to the POTW.

EPA is aware that high concentration or "slug" discharges of deicing stormwater can create POTW upset. The national pretreatment program regulations specifically prohibit industrial users from discharging high concentrations of oxygen-demanding pollutants to POTWs if they cause interference to the POTW (see 40 CFR 403.5(b)(4)). Under 40 CFR 403.5(c), control authorities may set and enforce "local limits" for airport discharges to POTWs to implement the prohibitions listed in § 403.5(b)(4). This provision ensures that any potential limits would protect against POTW interference by the oxygen-demanding pollutants in airport deicing discharges. See "Local Limits Development Guidance," document no. EPA 833-R-04-002A, July 2004, available on EPA's website at: <http://cfpub.epa.gov/npdes/pretreatment/pstandards.cfm>.

As a result, many airports that discharge to POTWs have airport-specific requirements on allowable BOD₅ or COD discharge loadings per day to the receiving POTWs. Airports usually meet this requirement by storing deicing stormwater in ponds or tanks and metering the discharge to meet the POTW permit loading requirements.

11.5 References

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12. NON-WATER QUALITY IMPACTS

Sections 304(b) and 306 of the CWA require EPA to consider non-water-quality environmental impacts (including energy requirements) associated with effluent limitation guidelines and standards. As explained in the preamble to the final rule, EPA evaluated three regulatory options for today's rule. The first two options are based on technologies to control aircraft and airfield deicing discharges, while the third option is based on technology solely to control airfield deicing discharges.

In considering non-water quality environmental impacts, EPA first analyzed the potential impact of the Option 1 technologies on energy consumption, air emissions, and solid waste generation. Because Option 2 is similar to Option 1, but would result in fewer operational changes at a subset of airports and therefore lead to fewer non-water quality impacts than Option 1, EPA did not analyze non-water quality impacts associated with Option 2. Rather, EPA concluded that the results for Option 2 will be similar to or less than Option 1. Additionally, Option 3 has no associated non-water quality impacts as substituting one airfield deicing product with another causes no increase in energy usage, air emissions, or solid waste generation.

12.1 Energy Requirements

EPA estimated that the total incremental electrical usage for Option 1 to pump ADF-contaminated stormwater into storage tanks would be approximately 1.2 million kilowatt hours per year (kWh/yr). EPA also developed a relationship between electrical use and COD removal by the AFB bioreactors based on information provided by Albany International (ALB) airport. Using ALB's information, EPA estimated the electrical requirement for COD removal for Option 1 as approximately 1.3 kWh/lb COD removed. Using this unit rate, EPA estimated total electrical requirements to remove COD for Option 1 to be a maximum additional 22 million kWh/yr.

EPA also analyzed fuel use by GCVs collecting ADF-contaminated stormwater. EPA used airport questionnaire data for diesel fuel costs for GCVs and then estimated an average diesel fuel use based on the unit cost for diesel fuel of \$2.07/gal.⁶ EPA then estimated annual fuel usage per gallon of applied ADF to be 0.08 gal/gal ADF applied. Using this relationship, EPA estimated that the total incremental consumption of No. 2 diesel fuel, at all airports subject to BAT and installing additional collection equipment, is 354,500 gallons per year.

Additionally, as EPA assumes that aircraft operations will not be delayed as a result of Option 1 and that deicing will occur at the gates, there is no increase in jet fuel consumption associated with Option 1.

Below are the calculations to determine the net energy requirements associated with Option 1 of the final rule for the collection and treatment of ADF-contaminated stormwater. Detailed calculations regarding net energy consumption for the various collection and treatment technologies considered for the rule are provided in a separate memorandum entitled *Energy Requirements for ADF Contaminated Stormwater Collection and Treatment Alternatives* (ERG, 2008a).

⁶ This diesel fuel price was the average reported by the Energy Information Administration (EIA) for the 2004-05 winter season, the same period that EPA is analyzing for airport deicing activity.

To estimate incremental electrical requirements associated with pumping collected ADF to storage tanks, EPA assumed airports would continuously operate three well-pit pumps with 40-horsepower (hp) electric motors during each deicing day. EPA also conservatively assumed that all airports would use pumps rather than allow ADF-impacted stormwater to flow by gravity to holding tanks. To estimate electrical use by airport based on the number of deicing days per year, EPA developed the following equation:

$$\text{Pumping Electrical} = 3 \text{ pumps} \times 40 \frac{\text{HP}}{\text{pump}} \times 0.7456 \frac{\text{kW}}{\text{hp}} \times 24 \frac{\text{hr}}{\text{day}} \times \text{SOFP} \frac{\text{days}}{\text{yr}} \quad (12-1)$$

Using the equation above, the total SOFP days for those airports that EPA assumed would install additional collection equipment, and a wire-to-water efficiency of approximately 40 percent (Bower, H., 1978), the total incremental electrical usage to pump ADF-contaminated stormwater into storage tanks would be approximately 1.2 million kilowatt hours per year (kWh/yr).

EPA developed another relationship between electrical use and COD removal by the AFB bioreactors based on information provided by Albany International (ALB) airport. Using ALB's information, EPA estimated the electrical requirement for COD removal as approximately 1.3 kWh/lb COD removed. Using this unit rate, EPA estimated the total electrical requirements associated with COD treatment. EPA estimates an additional 22 million kWh/yr will be required to remove 16,602,900 total pounds per year of COD as a result of the final rule.

The national estimated increase in electrical power consumption related to increased pumping and AFB treatment is 23.2 million kilowatt hours per year. This represents a very small fraction (0.0006 percent), of the electrical energy used annually in the United States, which is 3,950 billion kWh based on EIA statistics.

EPA notes that AFB treatment systems also generate biogas that can be used as a source of heat when burned in facility boilers or when converted to electricity using technologies such as microturbines or fuel cells. EPA did not include microturbine costs in its option-costing methodology. However, to estimate the potential electricity that could be generated if all AFB treatment systems installed microturbines to generate electricity, EPA developed a relationship between biogas generation and COD removal based on data provided by ALB airport. EPA estimated the AFB reactors will generate approximately 8 cubic feet of biogas per pound of COD removed, and the biogas is approximately 60 percent methane. Because one cubic foot of methane provides 100 therms and 1 therm is equivalent to 29.3 kWh when converted to electrical energy (U.S. Code, Title 15), EPA was able to predict the potential electrical energy available from biogas generated by the AFBs treating ADF-contaminated stormwater (see Table 12-1).

Table 12-1. Potential Electricity Generation from AFB Biogas Generation

Regulatory Scenario	Total COD Removal (pounds/yr)	Potential Biogas Generation (million ft ³ /yr) ¹	Potential Methane Generation (million ft ³ /yr) ²	Potential Electrical Generation (million kWh/yr) ³
40% ADF Capture	16,602,900	129	77.5	23

¹Calculation based on 8 cubic feet of biogas per lb COD removed.

²Assumes biogas is approximately 60% methane per Metcalf and Eddy Wastewater Engineering and Design (Metcalf and Eddy, 1979).

³Calculation based on 100 therms per cubic foot of methane and 29.3 kWh per therm.

Comparing the potential electrical generation from converting biogas to electricity to the electrical requirements discussed above indicates that AFB treatment of ADF-contaminated stormwater could generate most of the electricity needed to operate the treatment systems.

Fuel use by GCVs collecting ADF-contaminated stormwater is another incremental energy requirement for compliance with Option1. To estimate incremental diesel fuel use by GCVs, EPA obtained annual diesel fuel costs for GCVs from the airport questionnaire (U.S. EPA, 2006) and then estimated diesel fuel use based on the unit cost for diesel fuel (e.g., \$/gal). According to questionnaire data, one airport spent \$17,600 on diesel fuel to operate GCVs to recover ADF-contaminated stormwater during the 2004-2005 deicing season, collecting approximately 20 percent of their applied ADF in stormwater. Based on an average diesel fuel cost of \$2.07 per gallon during the 2004/2005 deicing season (U.S. DOE, 2006), EPA estimates this airport burned approximately 8,500 gallons of diesel fuel in GCVs. Based on annual ADF use and size, EPA estimated diesel fuel use in GCVs to be 0.08 gal/gal ADF applied. Using this relationship, EPA estimated total incremental No. 2 diesel fuel consumption at in-scope airports installing additional collection equipment to be 354,500 gallons per year. This volume is a conservative estimate because it is based on an airport that currently uses only GCVs to collect ADF-contaminated stormwater (e.g., 20 percent ADF collection). If airports install a plug and pump system to collect ADF-contaminated stormwater, GCV usage and therefore diesel fuel use are expected to be less.

EPA compared incremental diesel fuel use by GCVs at all airports to diesel fuel use on a national basis. According to the EIA, approximately 25.4 million gallons per day of No. 2 diesel fuel was consumed in the United States in 2005 (U.S. DOE, 2006). Total annual diesel fuel use by GCVs to collect ADF-contaminated stormwater at airports would account for a small fraction, 0.004 percent, of the annual diesel fuel use on a national level.

12.2 Air Emissions

Additional air emissions as a result of the final rule can be attributed to added diesel fuel combustion by GCVs collecting ADF-contaminated stormwater and from anaerobic treatment of ADF. Emissions from these sources are discussed below.

12.2.1 *Emissions from GCV Collection*

As discussed in Section 12.1, EPA conservatively estimated that GCVs collecting ADF-contaminated stormwater at airports will consume an additional 354,500 gallons per year of No. 2 diesel fuel. To estimate air emissions related to combustion of No. 2 diesel fuel in GCVs'

internal combustion engines, EPA used published emission factors for internal combustion engines (U.S. EPA, 1996 AP-42). The Agency selected emission factors for gasoline and diesel industrial engines rather than on-road mobile sources because the emission factors for the industrial engines include equipment such as forklifts and industrial sweepers and scrubbers (U.S. EPA, 1996 AP-42). To estimate emissions from the GCVs, EPA first converted the additional 354,500 gallons of diesel fuel to million British Thermal Units (MMBtu) and then applied the appropriate emission factors (U.S. EPA, 1996 AP-42). Table 12-2 shows the estimated increase in criteria pollutant emissions associated with the use of GCVs. Additional details regarding emissions from GCVs are contained in a memorandum titled *Air Emissions from Airport Deicing Collection and Treatment Technologies* (ERG, 2008b).

Table 12-2. Estimated Incremental Pollutant Emissions from GCVs

Criteria Pollutant	Diesel Fuel Consumption in GCV Internal Combustion Engine (gal/yr)	Diesel Fuel Consumption in GCV Internal Combustion Engine (MMBtu/yr) ¹	Emission Factor for Diesel Fuel Combustion in Internal Combustion Engine (lbs/MMBtu) ²	Estimated Annual Emissions from GCVs Burning Diesel Fuel (tons/yr)
Carbon Monoxide	354,500	49,630	0.95	24
Carbon Dioxide	354,500	49,630	164	4,070
Nitrogen Oxides	354,500	49,630	4.41	109
Sulfur Dioxide	354,500	49,630	0.29	7
PM ₁₀	354,500	49,630	0.31	8

¹Heat content of diesel fuel is approximately 140,000 Btu/gal per Perry's Chemical Engineers Handbook, 6th Edition, Figure 9-4.

²Emission factors from EPA Compilation of Emission Factors AP-42.

PM₁₀ – Particulate matter less than 10 um.

The annual emissions provided in Table 12-2 indicate that an additional 4,070 tons per year of carbon dioxide would be emitted from GCVs combusting additional diesel fuel to comply with the regulatory options evaluated in the final rule. Carbon dioxide is the primary greenhouse gas attributed to climate change; although 4,070 additional tons per year appears to be considerable, the amount is very small relative to other sources. For example, in 2006, industrial facilities combusting fossil fuels emitted 948 million tons of CO₂ equivalents. An additional 4,070 tons per year from GCVs is an increase of 0.0004 percent in the overall CO₂ emissions from all industrial sources (U.S. EPA, 2008).

Comments provided by industry on the proposed rule correctly indicated that additional nitrogen oxides would be emitted by equipment constructing the ADF-contaminated stormwater collection systems, the AFB treatment system, and any ancillary systems such as roadways and storage tanks. According to comments, the Environmental Assessment for the Portland ADF collection and treatment system estimated annual nitrogen oxide emissions at 4.48 tons/yr during construction. Construction of the ADF collection and treatment system in Portland was estimated to occur over approximately 2.5 years, resulting in total nitrogen oxide emissions of 11.2 tons. Based on the number of in-scope airports that would potentially require construction under EPA's Option 1, total construction-related nitrogen oxide emissions will be approximately 168 tons. In comparison, EPA estimated total nitrogen oxide emissions in the United States at 18.3 million tons (U.S. EPA, 2005).

12.2.2 Emissions from AFB Treatment Systems

Anaerobic digestion of glycols found in ADF-contaminated stormwater generates biogas containing approximately 60 percent methane and 40 percent carbon dioxide. Airports installing AFBs to treat ADF-contaminated stormwater are expected to burn a portion of the gas in on-site boilers to maintain reactor temperature. The remainder of gas can be either combusted in a microturbine for electricity generation or flared. Regardless of the combustion technology, nearly all biogas generated by AFBs is converted to carbon dioxide, the primary green house gas. Table 12-3 shows biogas generation and potential carbon dioxide emissions from AFB treatment systems for the costed collection scenario.

Table 12-3. Potential Air Emissions from AFB Treatment Systems

Regulatory Scenario	Total COD Removal (pounds/yr)	Potential Biogas Generation (million ft ³ /yr) ¹	Potential Carbon Dioxide Generation (tons/yr) ²
40% ADF Capture	16,602,900	129	3,730

¹ Calculation based on 8 cubic feet of biogas per lb COD removed. Biogas is 60% methane and 40% CO₂.

² Assumes 99.9 percent of biogas is converted to CO₂ during combustion.

Carbon dioxide is the primary greenhouse gas attributed to climate change; although 3,730 additional tons per year for 40 percent ADF capture appears to be considerable, the amount is very small relative to other sources as discussed in 12.2.1.

12.3 Solid Waste Generation

AFB bioreactors will generate sludge that will require disposal, likely in an off-site landfill. To estimate the potential for annual sludge generation by AFB bioreactors treating ADF-contaminated stormwater under Option 1, EPA first estimated the potential COD removal for the collection and treatment scenario and then applied published anaerobic biomass yield information (Metcalf & Eddy, 1979) to estimate potential total sludge generation on a national basis. The biomass yield calculation, which simply multiplies the COD removal by the yield, is a rough method of estimating sludge generation and does not account for other factors such as degradation or inorganic material (e.g., AFB media) that may be entrained into the sludge. However, this method does provide an order of magnitude estimate of sludge generation that can be compared to other types of common biological treatment systems to determine if AFB sludge generation would be unusually high at airports treating ADF-contaminated stormwater.

Table 12-4 shows the total COD removal for the collection and treatment scenario and the estimated sludge that would likely require disposal. This sludge is expected to be nonhazardous and can be disposed of in a municipal landfill. Detailed calculations showing how EPA estimated biomass amounts are provided in a memorandum entitled *Estimated Sludge Generation from AFBs Treating ADF-Contaminated Stormwater* (ERG, 2008c).

Table 12-4. Estimated Sludge Generation from AFB Bioreactors Treating ADF-Contaminated Stormwater

Regulatory Scenario	Total COD Removal (pounds/yr) ¹	Anaerobic Biomass Yield (lbs biomass/lb COD removed) ²	Total Sludge Generation (dry tons/yr)
40% ADF Capture	16,602,900	0.03	271

¹ Total COD removal from all AFB bioreactors that may be installed at airports.

² Biomass yield from Metcalf and Eddy.

To provide some perspective on the potential total amount of biomass produced annually by the AFB biological reactors treating ADF-contaminated stormwater, EPA compared the total biomass generation data in Table 12-4 to the national biosolids estimates for all domestic wastewater treatment plants throughout the United States. According to EPA's Municipal and Solid Waste Division, approximately 8.2 million dry tons of biosolids will be produced in 2010 (U.S. EPA, 1999). Using the biosolids generation amount shown in Table 12-4 (271 tons/yr), EPA estimates that AFB bioreactors treating ADF-contaminated stormwater would increase biosolids generation in the United States by approximately 0.003 percent.

12.4 Summary

EPA reviewed the potential non-water quality impacts of collection and treatment of spent ADF using plug and pump with GCVs combined with an AFB treatment system and determined that there was an insignificant increase in energy usage and generation of air emissions and solid waste.

EPA then determined that the other regulatory options under consideration would have similarly insignificant impacts because the other regulatory options involve fewer or no GCVs and smaller or no treatment system. Based on this evaluation of non-water quality impacts, EPA concludes there are no non-water quality impacts associated with today's final rule.

12.5 References

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13. LIMITATIONS AND STANDARDS: DATA SELECTION AND CALCULATION

This section describes the data selection and statistical methodology that EPA used to calculate the final rule limitations for the Airport Deicing Category. As described in this section, the effluent limitations and standards account for variation in treatment performance of the model technology. For simplicity, the following discussion refers only to effluent limitation guidelines; however, the discussion also applies to new source standards.

EPA is finalizing limitations for COD and ammonia as nitrogen (the latter as a compliance alternative), and Section 13.1 briefly describes the pollutant parameters. Section 13.2 provides an overview of EPA's data review and selection process. Section 13.3 describes EPA's data conventions. Sections 13.4 and 13.5 describe the COD and ammonia as nitrogen data selected as the basis of the final limitations. Section 13.6 describes the percentile basis and calculations used for the limitations. Section 13.7 describes achievability and compliance related to the limitations.

13.1 Selected Pollutant Parameters

As described in Section 6, there are a number of pollutants associated with discharges from airport deicing operations. EPA is setting effluent limitations for two pollutant parameters, COD and ammonia. This section briefly describes the pollutant parameters and the chemical analytical methods used to measure their concentrations.

13.1.1 *COD*

COD is a measure of the total organic matter content of both wastewaters and natural waters. Measurement of COD can be used to rapidly recognize deterioration in wastewater treatment plant performance and the need for corrective action. EPA evaluated data collected by the Albany International Airport in New York and by EPA. The Agency evaluated data for COD that was measured using EPA Method 410.4 and Hach 8000, both of which are approved for compliance monitoring in 40 CFR Part 136. EPA measured COD using Method 410.4, and Albany Airport used Hach 8000. Data from the two methods are directly comparable.

Method 410.4 is a colorimetric procedure with a measurement range of 3 to 900 mg/L for automated procedures and a measurement range of 20 to 900 mg/L for manual procedures. The Hach 8000 method is a colorimetric procedure that utilizes a preliminary digestion procedure and can be used for various concentration ranges. A user has the option of purchasing three different sets of reagents and standards. The first has a measurement range of 0 to 40 mg/L; the second, 0 to 150 mg/L; and the third, 0 to 1500 mg/L. The industry data had a lower measurement limit of 2.0 mg/L.

13.1.2 *Ammonia as Nitrogen (Ammonia)*

Ammonia as nitrogen (ammonia) is generated as a by-product of using urea-containing products for deicing operations. Ammonia can be directly toxic to fish and other aquatic organisms and can reduce ambient dissolved oxygen concentrations in receiving surface waters. In the data EPA evaluated, ammonia was measured using Methods 350.1 and 350.2, both of which are approved for compliance monitoring in 40 CFR Part 136. Albany Airport supplied

data that was generated using Method 350.1 (ERG, 2008), and EPA used Method 350.2. Both methods produce comparable results.

Method 350.1 is an automated colorimetric method that uses a continuous flow analytical system and has a detection range of 0.01 to 2.0 mg/L. Method 350.2 utilizes either colorimetric, titrimetric, or electrode procedures to measure ammonia. Method 350.2 has a lower measurement range limit of 0.20 milligrams per liter (mg/L) for the colorimetric and electrode procedures and a lower measurement range limit of 1.0 mg/L for the titrimetric procedure.

13.2 Overview of Data Review and Selection

As described in Sections 13.4 and 13.5, EPA qualitatively reviewed all the available influent and effluent data for COD and ammonia. For purposes of limitation development, data are defined to be numerical values resulting from laboratory determination of pollutants in physical samples collected from influent and effluent wastestreams. A laboratory expresses the results of its analysis either numerically or as “not quantitated” for a pollutant in a sample. When the result is expressed numerically, the pollutant was quantitated, or more commonly referred to as “detected,” in the sample. The definition includes measured values (e.g., 10 mg/L) and values reported as being below some level of quantification (e.g., <10mg/L). The latter are often referred to as “nondetected” and are usually reported with a “detection limit.” (EPA also uses terms such as “quantitation limit” in other documentation.) The definition of “data” excludes estimated values and statistical summaries, such as averaged values.

This section describes EPA’s review of the available data. Section 13.2.1 describes the criteria that EPA applied in selecting data for the development of the final limitations. Section 13.2.2 describes other considerations that were evaluated as part of the data review.

13.2.1 *Data Selection Criteria*

This section describes the criteria that EPA applied in selecting data to use as the basis for the final effluent limitations. EPA has used these or similar criteria in developing limitations and standards for other industries. EPA uses these criteria to select data that reflect consistently good performance of the model technology in treating the industrial wastes under normal operating conditions. Model technology is technology that is carefully designed and diligently operated. The following paragraphs describe the criteria and modifications specific to the Airport Deicing Category.

One criterion generally requires that the influent and effluent from the treatment components represent typical wastewater from the industry, with no incompatible wastewater from other sources (e.g., sanitary wastes). By applying this criterion, EPA selects only those facilities where the commingled wastewaters did not result in substantial dilution, unequalized slug loads that result in frequent upsets and/or overloads, more concentrated wastewaters, or wastewaters with different types of pollutants than those generated by the categorical (i.e., airport deicing) wastewater.

A second criterion typically ensures that the pollutants were present in the influent at sufficient concentrations to evaluate treatment effectiveness. To evaluate whether the data meet this criterion for the final rule, EPA often uses a “long-term average test” for sites where it has paired influent and effluent data. EPA has used such comparisons in developing regulations for

other industries (e.g., the Iron and Steel Category (USEPA, 2002)). The test looks at the influent concentrations to ensure a pollutant is present at sufficient concentration to evaluate treatment effectiveness. If a pollutant fails the test (i.e., is not present at a treatable concentration), EPA excludes the data for that pollutant at that facility from its long-term average and variability calculations. In this manner, EPA would ensure that the limitations resulted from treatment and not simply the absence or substantial dilution of that pollutant in the wastestream. If industry supplies EPA with effluent data, but not the corresponding influent data, EPA may choose to use the effluent data without performing a long-term average test provided it determines that the pollutant would have been present at consistently treatable concentrations at the facility. This approach would satisfy EPA's objective to include as much data from as many facilities as possible in the calculation of limits.

A third criterion requires that the facility must have the model treatment technology and demonstrate consistently diligent operation. The Agency may include facilities with treatment or performance that is equivalent to the model technology, but this is rare. EPA generally determines whether a facility meets this criterion based upon site visits, ability to comply with its existing discharge requirements, discussions with facility management, and/or comparison to treatment system performance at other facilities. EPA often contacts facilities to determine whether data submitted were representative of normal operating conditions for the facility and equipment. Based on this review, EPA typically eliminates facilities that experience repeated operating problems with their treatment systems. In addition, EPA typically excludes data when the facility has not optimized its treatment. For example, facilities may use the model technology as a pretreatment step before sending the wastewater to a POTW and consequently might not fully optimize its system.

A fourth criterion typically requires that the data cannot represent periods of frequent unequalized slug loading treatment upsets or shut-down periods⁷ because these excursion data do not reflect performance that would be expected from well-designed and operated treatment systems. Furthermore, it would not be appropriate for the limitations to be based, in part, upon data reflecting extreme events that are beyond the control of the facility, because regulatory provisions at 40 CFR 122.41(n) would apply to such circumstances. More specifically, after the final limitations are incorporated into permits, EPA expects that, when such events occur, the facility would abide by the procedural requirements in §122.41(n) to obtain an affirmative defense to any potential enforcement action.

In applying the fourth criterion, EPA evaluates the pollutant concentrations, flow values, mass loadings, plant logs, and other available information. As part of this evaluation, EPA typically asks the facility about process or treatment conditions that may have caused extreme values (high and low). EPA may consequently identify certain time periods and other outliers in the data that reflect poor performance by an otherwise well-operated site.

⁷ EPA applies this criterion to data from two types of shut-downs. First, treatment systems are sometimes halted to control upset conditions. As part of the recovery activities, the facility may pump out wastewater from the equipment (e.g., tanks) which contains highly concentrated wastes associated with the upset. Second, the facility may shut down its operations for maintenance and other atypical operations. During these periods, the facility may still operate its treatment system, but typically discharges effluent associated with atypical influent. For example, the influent might include cleaning solvents instead of process wastewater.

EPA also applies the fourth criterion in its review of data corresponding to “start-up” periods, an adjustment period that most industries incur only when installing, acclimating, and optimizing new treatment systems. During this adjustment period, the concentration values tend to be highly variable with occasional extreme values (high and low). After this period, the systems should operate at steady state for years with relatively low variability around a long-term average. Because start-up conditions typically reflect one-time operating conditions, EPA generally excludes such data in developing the limitations. In contrast, EPA expects airports to encounter start-up operations at the start of every deicing season because they probably will cease treatment operations during warmer months. Because this adjustment period will occur every year for the Airport Deicing Category, EPA is including start-up data in the data set used as the basis of the limitations. However, through its application of the other three criteria, EPA would exclude extreme conditions that do not demonstrate the level of control possible with proper operation and control even during start-up periods.

In part, by retaining start-up data for limitations development, the limitations will be achievable because EPA based these limits on typical treatment during the entire season. Once the treatment system reaches steady state, EPA expects a typically well-designed and operated system to run continuously until the end of the deicing season.

13.2.2 *Other Considerations in Data Selection*

In comments on proposed regulations across a range of industry categories and subcategories, industries often suggest that EPA consider additional criteria in selecting data as the basis of the limitations. EPA routinely evaluates whether the suggested criteria are relevant and should be considered as it develops new regulations. As explained below, EPA also considered additional criteria for the airport deicing rulemaking, but determined that they were not relevant in selecting data as the basis of the final limitations. EPA’s rationale is consistent with its findings for other industries.

Commenters often suggest a criterion related to the size of facilities because of concerns about a perceived impact of volume, or flow, of wastewater on treatment performance. In considering this issue for the airport deicing industry, EPA concluded that the size of the airport, collection technology, and other features by themselves would not affect the performance of the treatment system. Instead, the airport size and water flow would determine the size of the treatment system, rather than its performance. EPA expects that each airport would build and operate a system that is sized appropriately for its volume of wastewater. Because the method of treatment is the same regardless of the flow, properly sized systems should all perform in the same manner, and achieve the same effluent concentrations. Before reaching this conclusion for airport deicing and other industries, EPA reviewed treatment technologies such as biological treatment, oil-water separators, dissolved air floatation, and settling tanks. EPA’s record supports the finding that, for a variety of industrial sectors, well-operated and designed treatment systems treat different wastewaters with varying flows to a narrow range of effluent concentrations (USEPA, 2010).

In addition, commenters typically suggest a criterion that would require a minimum number of facilities be used as the basis of the limitations. Such suggestions are based upon two main concerns. First, commenters are concerned that the limitations do not reflect treatment from a range of typical influents, because the concentration levels vary from facility to facility.

Second, commenters are concerned that not all facilities could achieve the same high level of performance using the model technology. For the first concern, as part of its evaluation of the effect of flow described above, EPA also considered the impact of influent pollutant concentrations. EPA found that well-operated and designed treatment systems are capable of treating the wastewaters to a narrow range of effluent pollutant concentrations. For the second concern, EPA only needs to demonstrate that the model technology can be operated at the level of performance on which the limitations are based. EPA's selection of the model technology used at the Albany International airport as the basis of the limitations is appropriate because that facility demonstrates that the technology can achieve the levels reflected in the final limitations.

The CWA authorizes EPA to base BAT/NSPS limitations and standards on the performance of a single facility and it is not unusual for EPA to base effluent limitations on data from a single facility. For example, in the Organic Chemicals, Plastics and Synthetic Fibers (OCPSF) effluent guideline promulgated in 1987, EPA based 38 percent of the limitations on the performance of a single facility (USEPA, 1987). Courts have recognized that EPA must act on the information it has and need not wait for perfect information (e.g., see *BASF Wyandotte Corp. v. Costle*, 598 F.2d 637, 652-653 (1st Circuit, 1979)).

13.3 Conventions for Modeling Multiple Data Sets from the Same Facility

This section describes EPA's conventions for modeling multiple data sets from the same facility. Data from a particular facility are sometimes collected at different times, from different treatment units, or by different organizations. In such cases where multiple data sets exist for the same facility, EPA often statistically models the data as if each data set represents a different facility. This section describes conventions applied to the data from the airport deicing industry.

EPA generally considers data from different time periods to characterize different operating conditions due to changes such as management, personnel, and procedures. Because EPA expects airports to operate treatment systems only for a limited time each year, it considered whether the conditions and performance for each deicing season tend to vary in a manner that more appropriately reflects different treatment systems. Because it may better capture the variability of airport deicing operations under a range of conditions, EPA has calculated the final limitations using all of the data, without regard to season. For informational purposes, the data and summaries are presented by season.

EPA generally uses data from separate treatment units (depending on the rulemaking, also called "trains" or "systems") as if they characterized separate facilities. EPA has determined this is appropriate because the units were operated separately. Even if the wastes were generated by the same processes or drawn from the same storage pond, EPA considers that the performance of each system can vary due to slightly different influents, equipment, and other factors.

EPA generally considers data from different organizations to characterize different collection methods and analytical methods. The different organizations typically are EPA sampling teams and the facility's monitoring crew at the treatment system. EPA often separates such data into multiple data sets, to better model the variability consistent with the use of a single analytical method and the same collection procedures. Consistent use of a single method and procedure is often required by permits and is typical of compliance monitoring. Therefore, the

Agency generally uses this convention to model typical variability that each facility would experience in compliance monitoring activities. EPA then determines which, or all, multiple data sources are appropriate choices as the basis of the limitations.

13.4 COD: Data Selected as Basis of Final Limitations

In establishing the final limitations, EPA reviewed COD data from a treatment plant at the Albany International airport, which used the model BAT. (Selection of the model technology is described in Section 8 and in the preamble to today's rule.) EPA collected COD data during a sampling episode at Albany International airport and obtained several years of monitoring data and other information from the airport. After evaluating these data, EPA determined that the Albany data were the only available performance data from the model technology.⁸ Thus, all other data sets were excluded by applying the third criterion in Section 13.2.1, because they did not demonstrate the performance of the model technology. The following sections describe the Albany airport and apply the criteria in identifying the specific data points used as the basis of the final limitations.

13.4.1 *Albany Treatment System*

EPA based the final limitations for COD upon data from Albany Airport's treatment system. This system consists of two identical units that are consistent with EPA's model technology described in Section 8. The airport diverts stormwater from deicing operations into a lagoon. Facility personnel then pump water from the lagoon to one anaerobic unit or the other for treatment. The airport generally operates the two treatment systems in parallel, but sometimes runs them in series. At the end of each unit, regardless of whether the system is in parallel or series, the airport monitors COD concentrations each morning by collecting grab samples to evaluate the treatment performance. These locations are labeled as ArprtR-101 and ArprtR-102 in Figure 13-1. During its five-day sampling episode conducted from February 5-9, 2006, EPA measured COD and ammonia concentrations in composite samples collected at a point (labeled EPA_SP-2) where the two units combine into a single flow before entering an aerobic polishing pond for more treatment. After this step, the airport typically directly discharges waste into Shaker Creek, a tributary of the Mohawk River, which has been classified as a New York State Class A drinking water stream. As a consequence, the airport is required to meet stringent limitations when it discharges directly to the creek. In warmer weather (i.e., when the soil is 50 degrees or warmer), the airport sometimes uses the treated wastewater for irrigation. In addition, the airport is able to discharge to a POTW, although it seldom does.

⁸ Akron Canton Airport in Ohio started operating the model technology in mid-November in 2007. When EPA was completing its technical analysis of the industry in late spring 2008, the airport's treatment unit was not operating at full capacity.

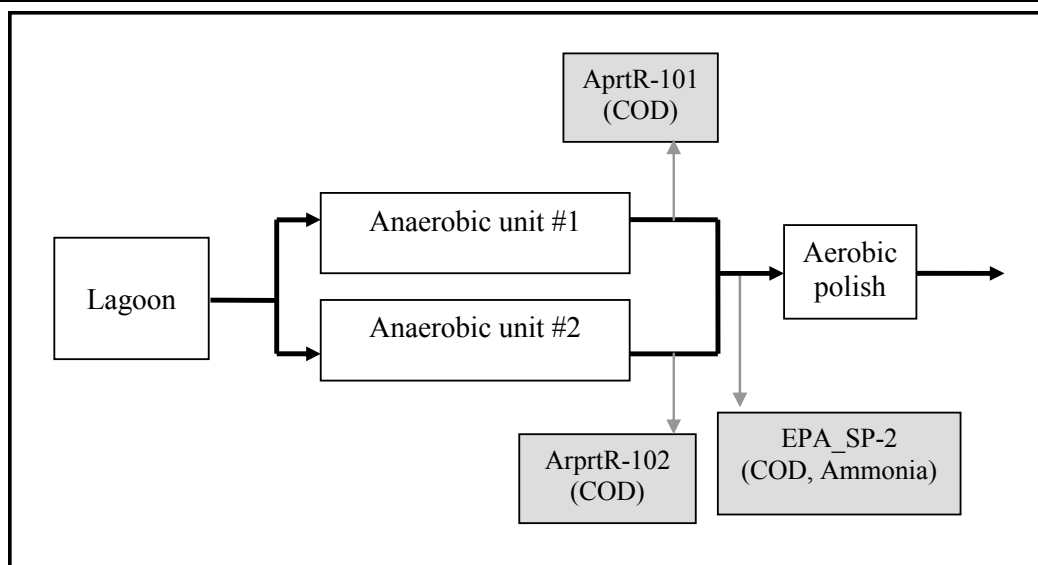


Figure 13-1. Simplified Drawing of Albany Airport Treatment System and Sample Points

As the basis for the final limitations for COD, EPA selected the data at sample points ArprtR-101 and ArprtR-102 because each unit is the same as the model treatment system that EPA identified in Section 11. The airport has monitored its performance for a relatively long time and provided EPA with data from December 1, 1999, through April 10, 2009 (10 deicing seasons). Because the influent was highly concentrated, it was not necessary to perform the long-term average test described in Section 13.2.⁹

DCN AD01181 provides the influent and effluent COD data as originally submitted by the airport and the data are graphically displayed in the statistical support memorandum (USEPA, 2006). The following sections describe the exclusion of data collected from the EPA sampling episode and the airport's self-monitoring data.

13.4.2 COD Data from EPA Sampling Episode at Albany

During EPA's sampling episode, EPA and the airport collected separate sets of samples (see Table 13-1 analytical results). At sample point EPA_SP-2, EPA collected samples of the combined flow from the two units. In contrast, the airport monitored the effluent directly from each unit at sample points ArprtR-101 and ArprtR-102 and filtered the samples prior to analyzing for COD. Both sets of samples demonstrate the performance of the model technology because no additional treatment steps exist between the airport sample points and EPA's sample point. Rather than include data from two different sources (i.e., EPA and the airport) for the same dates, EPA preferentially selected the airport data because they were part of longer-term monitoring. Although the EPA data were therefore excluded as the basis of the limitations, EPA notes that all of the values are less than the value of 271 mg/L for the final daily maximum limitation.

⁹ EPA typically compares average influent levels to a multiplier of 5 to 10 times the quantitation limit (or reporting limit). As explained in Section 13.1.1, the airport data had a lower measurement limit of 2.0 mg/L. Thus, in the long-term average test, EPA would probably have compared the influent data to a reference level of 10 to 20 mg/L. However, because the minimum influent value of 100 mg/L exceeded this range of potential reference values, the average values also will meet the requirements of the long term average test.

Table 13-1. COD: EPA and Albany Airport Self-Monitoring Effluent Data Collected During EPA's Sampling Episode

Sample Date	COD Concentrations (mg/L)			
	EPA Sampling Episode Data		Airport Self-Monitoring Data	
	Original Sample	Field Duplicate (where collected)	AprtR-101	AprtR-102
2/5/06	72		29	74
2/6/06	228	208	53	108
2/7/06	92	177	56	94
2/8/06	81		31	90
2/9/06	193		48	96

13.4.3 COD Self-Monitoring Data from Albany Airport

The airport typically runs the two units in parallel. EPA considers each unit's performance, when operated in this manner, to be consistent with the model technology. In its evaluation of the data from each unit, EPA applied the criteria and other considerations described in Section 13.2. As a result of this evaluation, EPA excluded data associated with atypical operations, influent concentrations reported as zero, estimated values, and poor performance. The exclusions are described below.

By applying the third criterion in Section 13.2.1, EPA excluded all periods when the units were operated in series because the data did not reflect treatment by the model technology. Table 13-2 identifies these time periods by deicing season (e.g., Season99 started in 1999 and continued into 2000). During these periods, one unit provided initial treatment and the second provided additional treatment. Although the facility reported effluent values from each unit during this period of operating in series, it only discharged the effluent from the second unit in the series. EPA considers the effluent data from the first unit to reflect less than optimal performance, because the operators presumably would have not optimized treatment as they intended to treat the wastes a second time (criterion 3). EPA considers the effluent data from the second unit to characterize treatment of atypical influent (i.e., effluent that had been treated by the first unit).

Table 13-2. COD: Dates Excluded Because Units Operated in Series

Season	Number Days Excluded	Beginning Date	End Date
Season99	32	2/9/2000	3/11/2000
Season00	31	12/12/2000	1/11/2001
Season01	3	2/7/2002	2/9/2002
Season02	8	11/17/2002	11/24/2002
	3	4/5/2003	4/7/2003
Season05	25	1/10/2006	2/3/2006
Season06	79	1/15/2007	4/3/2007
Season07	31	2/2/2008	3/3/2008
Season08	25	11/17/2008	12/11/2008

EPA excluded effluent values for both units when the influent concentration was reported as “zero” for two reasons. First, if COD could not be detected in the influent (criterion 2), then the effluent concentrations would not reflect any additional treatment. Second, it appears that the plant used this convention to indicate shut-downs of the system (criterion 4). Table 13-3 identifies the dates when the influent concentration was reported to be zero.

Table 13-3. COD: Dates Excluded Because Influent Concentration Reported as Zero

Season	Date
Season01	6/14/2002
Season02	11/16/2002
Season06	4/10/2007

EPA also excluded any values that were estimates because they did not meet EPA’s definition for “data” described in Section 13.2. There were two types of estimated values. One type was in italics in the facility’s spreadsheets, indicating that the operator’s log noted issues with the sample or its analysis, and thus, the reported value was an estimate. The second type was a series of identical values reported over consecutive monitoring days. Although it is possible to find exactly the same pollutant concentrations on consecutive days, variations from day to day are more typical. In response to EPA’s questions about the strings of identical values, the facility stated that it sometimes repeated the last known number when they did not monitor (ERG. 2008a). To model the variability likely to be present in the effluent, EPA assumed that the first non-zero value was the only day when COD was monitored when three or more days had identical values for the same unit. Therefore, EPA retained the value for the first day and deleted the (identical) values on subsequent days for that unit. If the values were zero, EPA assumed that the unit was not operating and excluded the entire time period, including the first reported zero value. The statistical support memorandum (USEPA, 2010) identifies these exclusions.

In addition, by applying the fourth criterion in Section 13.2, EPA excluded periods that did not reflect the typical performance of the technology. As shown in Table 13-4, these exclusions included treatment system upsets and method error. For example, EPA excluded the maximum value of 1,283 mg/L recorded at ArprtR-101 on 3/21/2001 because it was inconsistent with the other data values during that time period. The plant management agrees that the value

does not reflect normal operations and suspects that it was likely a sample with high solids content (ERG. 2008b).

Table 13-4. COD: Dates Excluded Because of Performance Excursions

Season	Number Days Excluded	Beginning Date	End Date	Reason
Season99	11	12/1/2000	12/11/2000	System Upset
Season00	42	1/12/2001	2/22/2001	System Upset
	1	3/20/2001	3/20/2001	Method Error
	1	3/21/2001	3/21/2001	System Upset

After the exclusions were incorporated, more than 2,500 measurements of COD remained and were used as the basis of the final limitations. Table 13-5 summarizes the data. The statistical support memorandum (USEPA, 2010) provides a list and plots of the data.

Table 13-5. COD: Summary of Albany Airport Self-Monitoring Effluent Data After Exclusions

Unit	Season	# of Days	Standard Deviation	COD Concentrations (mg/L) ¹			
				Minimum	Maximum	Median	Mean ²
ArprtR_101	Season99	147	50.31	1	326	14.0	28.60
	Season00	112	71.93	2	575	64.0	75.46
	Season01	168	20.97	9	157	37.0	44.02
	Season02	180	64.41	20	655	73.0	86.80
	Season03	146	103.19	2	699	50.0	76.32
	Season04	140	30.76	2	275	25.0	31.51
	Season05	90	18.08	8	162	29.5	31.56
	Season06	62	24.08	1	136	17.0	23.10
	Season07	124	98.07	9	1042	41.5	54.48
	Season08	120	59.85	15	674	35.0	42.74
	ALL	1289	66.67	1	1042	37.0	52.28
ArprtR_102	Season99	141	17.41	1	93	11.0	16.85
	Season00	117	51.50	11	393	55.0	63.09
	Season01	165	20.23	10	168	35.0	40.01
	Season02	183	51.73	25	685	51.0	57.61
	Season03	147	30.03	1	210	60.0	63.12
	Season04	145	73.96	2	725	76.0	87.42
	Season05	95	33.21	22	275	72.0	77.19
	Season06	62	41.68	2	148	46.5	61.34
	Season07	98	10.01	12	58	34.0	33.70
	Season08	120	24.92	12	282	37.0	39.07
	ALL	1273	45.65	1	725	45.0	53.40

¹ In this summary, nondetected values are set equal to the detection limit.

² The mean is calculated as the arithmetic average.

13.5 **Ammonia: Data Selected as Basis of Final Limitation**

For ammonia, EPA is promulgating a compliance alternative with a daily maximum limitation for airports that use deicers containing urea on the runways. This section describes the data selected as the basis of the final limitation for ammonia.

After evaluating the available data, EPA transferred the 1-day-lag serial correlation value from the AFB technology, which is the model technology for COD. This transfer was necessary because an AFB system by design creates ammonia as a by-product of wastewater treatment. Consequently, AFB discharges could have higher ammonia concentrations than typically found in airfield stormwater when airfield deicers containing urea are not used. If the treated aircraft deicing stormwater discharges then were discharged to the same pipe as the runway wastewater, the airport might have difficulties complying with the ammonia limitation. EPA also confirmed that ADF treatment provided less concentrated discharges than observed from the application of urea products (ERG. 2009). For these reasons, EPA determined that it was appropriate to use the

ADF data as a basis of limitations that would apply to discharges associated with runway deicing.

As it had for COD, EPA initially evaluated the Albany data for setting final limitations for ammonia, because EPA had data on the performance of its model technology. In contrast to its practice of monitoring COD at the end of each treatment unit, the airport monitored ammonia at its permit compliance point after additional treatment provided by an aerobic polishing step. The anaerobic polishing step would result in decreased ammonia concentrations and would not represent ammonia discharges from using urea on airfields. Thus, to promulgate an effluent limit consistent with the model technology, EPA used the EPA data and excluded the Albany ammonia data (criterion 3).

Instead, because they reflect the capability of the model treatment system, EPA used its sampling data from EPA_SP-2, shown in Table 13-6, as the basis of the final ammonia limitations. (Section 13.6 describes field duplicates and the importance of daily values for the limitation calculations.) In analyzing samples from this episode, the laboratory achieved a detection limit of 0.05 mg/L. During the laboratory's quality assurance step of the chemical analysis, it detected ammonia in the laboratory preparation blank at a concentration of 0.069 mg/L. Other quality assurance parameters, initial calibration blanks and continuing calibration blanks, were between 0.052 mg/L and 0.054 mg/L. The ammonia results for all samples are greater than 10 times the blank result, with the exception of four influent and one source water samples that were not used as the basis of the final limitation. Consequently, EPA determined that the data were of acceptable quality to use as the basis of the final limitation.

Table 13-6. Ammonia: Data from Albany Airport Used to Develop Limitations

Sample Day	Ammonia Concentrations (mg/L)			
	Influent	Effluent		
		Original Sample	Field Duplicate (where collected)	Daily Value Used in Limitations Calculations
1	ND (0.1)	2.58		2.58
2	ND (0.1)	4.14	3.95	4.05
3	ND (0.1)	4.45	5.54	5.00
4	ND (0.1)	6.12		6.12
5	0.91	6.65		6.65

ND – Not Detected

13.6 Limitations: Basis and Calculations

The final limitations, as presented in the final rule, are provided as the daily maximum limitations for COD and ammonia. In addition, the notice includes a weekly average limitation for COD. This section defines the limitations (Section 13.6.1) and describes the statistical percentile basis of the limitations (Section 13.6.2) and the estimation of the percentiles for COD and ammonia (Sections 13.6.3). The statistical support memorandum (USEPA, 2010) describes the calculations used to model the ammonia data.

13.6.1 ***Definitions***

Definitions provided in 40 CFR 122.2 describe the limitations in terms of “daily discharge,” which it defines as “the ‘discharge of a pollutant’ measured during a calendar day or any 24-hour period that reasonably represents the calendar day for purposes of sampling.” Therefore, EPA generally arithmetically averages all measurements recorded for each uniquely reported time period (e.g., 12/21/2004) before calculating limitations. EPA refers to this averaged value as the “daily value.”

First, in calculating the limitations, EPA ensures that it has only one value for each day. Field duplicates are one example of multiple measurements, and were included in the ammonia data used to develop the final limitations. Field duplicates are two samples collected at the same sample point at approximately the same time, flagged as duplicates for a single sample point, and measured separately. Because the analytical data from each duplicate pair characterize the same conditions at that time at a single sample point, EPA typically averages the data to obtain one data value for those conditions on that day. For example, Table 13-6 shows the field duplicates and daily, averaged values for ammonia.

Second, EPA uses the daily values in calculating the limitations. Definitions provided in 40 CFR 122.2 further describe the “maximum daily discharge limitation” as the “highest allowable ‘daily discharge.’” The “average weekly discharge limitation” is the “highest allowable average of ‘daily discharges’ over a calendar week, calculated as the sum of all ‘daily discharges’ measured during a calendar week divided by the number of ‘daily discharges’ measured during that week.”

13.6.2 ***Percentile Basis of the Limitations***

EPA uses a statistical framework to establish limitations that facilities are capable of complying with at all times. Statistical methods are appropriate for dealing with effluent data because the quality of effluent, even in well-operated systems, is subject to a certain amount of fluctuation or uncertainty. Statistics is the science of dealing with uncertainty in a logical and consistent manner. Statistical methods together with engineering analysis of operating conditions, therefore, provide a logical and consistent framework for analyzing a set of effluent data and determining values from the data that form a reasonable basis for effluent limitations. Using statistical methods, EPA has derived numerical values for its final daily maximum limitations and weekly average limitations.

The statistical percentiles upon which the limitations are based are intended to be high enough to accommodate reasonably anticipated variability within control of the facility. The limitations also reflect a level of performance consistent with the CWA requirement that these limitations be based on the best technologies that are properly operated and maintained.

In establishing daily maximum limitations, EPA’s objective is to restrict the discharges on a daily basis at a level that is achievable for an airport that targets its treatment system design and operation at the long-term average while allowing for the variability around the long-term average that results from normal operations. This variability means that at certain times airports may discharge at levels that are greater or considerably lower than the long-term average. To allow for possibly higher daily discharges, EPA has established the daily maximum limitation at a relatively high level (i.e., the 99th percentile). Due to routine variability in treated effluent, an

airport that discharges consistently at a level near the daily maximum limitation, instead of the long-term average, may experience frequent values exceeding the limitations. For this reason, EPA recommends that airports target the treatment system at the long-term average that it derived for the model technology.

In its derivation of the weekly average limitation for COD, EPA used an estimate of the 97th percentile of the weekly averages of the daily measurements. This percentile basis is the midpoint of the percentiles used for the daily maximum limitation (i.e., 99th percentile of the distribution of daily values) and the monthly average limitation (i.e., 95th percentile of the distribution of monthly average values). Courts have upheld EPA's use of these percentiles, and the selection of the 97th percentile is a logical extension of this practice. Compliance with the daily maximum limitation is determined by a single daily value; therefore, EPA feels the 99th percentile provides a reasonable basis for the daily maximum limitation by allowing for an occasional extreme discharge. Because compliance with the monthly average limitation is based upon more than one daily measurement and averages are less variable than daily discharges, EPA has determined that facilities should be able to control the average of daily discharges to avoid extreme monthly averages above the 95th percentile. Similar to the monthly average limitation, compliance with the weekly average limitation also would be based upon more than one daily measurement. However, the airport would monitor for a shorter time and thus would have fewer opportunities to counterbalance highly concentrated daily discharges with lower ones. For this reason, EPA is utilizing a larger percentile for the weekly average limitation than the one used for the monthly average limitation. Consequently, EPA is using the 97th percentile as an appropriate basis for limiting average discharges on a weekly basis. EPA also considers this level of control in avoiding extreme weekly average discharges to be possible for airports using the model technology.

13.6.3 *Estimation Procedures for Percentiles*

This section describes the estimation procedures that EPA used to calculate the limitations for the final rulemaking. Sections 13.6.3.1, and 13.6.3.2 describe the estimation procedures used to model the COD data and the June 8, 2009, memorandum on calculation of percentiles (Westat. 2009) describes the calculations used by the statistical software. Section 13.6.3.3 describes the procedures for ammonia.

Table 13-7 summarizes the limitations that EPA established for COD and ammonia. Because of the importance of targeting treatment to the long-term average, EPA recommends that facilities design, maintain, and operate the treatment system to achieve a long-term average of 52.8 mg/L, which is the median of the averages from the two units (52.28 mg/L for ArprtR_101 and 53.40 for ArprtR_102, as shown in Table 13-5). The allowance for variability, or the ratio of the limitation to the long-term average, is 5.13. (EPA usually refers to this allowance as the "variability factor.") In other words, the daily maximum limitation is 5.13 times greater than the long-term average achievable by the model technology. By targeting the system to the long-term average and controlling its variability within this range, the facility will be able to comply with the limitation.

Table 13-7. COD and Ammonia: Final Limitations with Long-Term Averages and Variability Factors

Parameter	Time Period	COD	Ammonia
Limitations (mg/L)	Daily Maximum	271	14.7
	Weekly Average	154	NA
Long-Term Average (mg/L)	All	52.8	5.24
Variability Factors	Daily	5.13	2.81
	Weekly	2.92	NA

NA – Not applicable

13.6.3.1 COD: Daily Maximum Limitation and the 99th Percentile

For COD, EPA based the final daily maximum limitation on an estimate of the 99th percentile of the distribution of the daily values. This section describes the percentile estimates and the long-term average.

First, EPA used nonparametric methods to estimate the 99th percentile of the daily values from each unit. A simple nonparametric estimate of the 99th percentile of an effluent concentration data set is the observed value that exceeds 99 percent of the observed data points. Because EPA had more than 1,200 data points for each unit, it determined that the empirical approach would provide reasonable estimates of the 99th percentiles.

Second, EPA set the final limitation equal to the median of the two 99th percentile estimates, or 271 mg/L. The median is, by definition, the midpoint of all available data values ordered (i.e., ranked) from smallest to largest. As result, half of the unit 99th percentiles are higher than the median and half are lower. (In this particular case, because there are two units, the median is equal to the arithmetic average (or mean).)

Table 13-8 summarizes the percentile estimates for the two units, the minimum and maximum values observed in the data, the 50th percentiles, and the 99th percentiles.

Table 13-8. COD: 99th Percentile Estimates from Each Treatment Unit

Treatment Unit	Number of Daily Values	Concentrations (mg/L)			
		Minimum	50 th Percentile	Maximum	99 th Percentile
ArprtR-101	1,289	1	37	1042	326
ArprtR-102	1,273	1	45	725	216
Median Values			41		271

13.6.3.2 COD: Weekly Average Limitation and the 97th Percentile

For the weekly average limitation of COD, EPA first calculated, for each unit, the arithmetic average of the measurements observed during each week, excluding weekends (to be consistent with the assumed monitoring costs, although permit authorities may specify different monitoring requirements). EPA then used the nonparametric method to derive a 97th percentile of the more than 200 weekly averages for each unit, and set the final limitation equal to the median

of the two 97th percentile estimates, or 154 mg/L. The statistical support memorandum (USEPA, 2010) lists the weekly averages.

Because data were not always available for every weekday during a week, EPA examined whether the weekly averages were affected by the number of weekdays included in the average. As shown in Table 13-9, the value of the limitation varied only slightly if the weeks were required to have data for all five days. The June 23, 2009, memorandum on percentiles for weekly averages (Westat, 2009a) provides a more detailed evaluation.

Table 13-9. COD: Effect of Number of Daily Values in Weekly Averages

Number of Daily Values in Average	Unit ArprtR-101		Unit AirprtR-102		Median of 97th Percentiles
	Number of Weekly Averages	97th Percentile	Number of Weekly Averages	97th Percentile	
5	155	176.8	157	133.6	155.2
4 or 5	181	176.8	181	133.6	155.2
1 to 5 ¹	209	162.4	203	145.5	153.95

¹ Averages in this row were used as the basis of the final weekly average limitation.

13.6.3.3 Ammonia: Percentile Estimates Based Upon the Lognormal Distribution

Because the ammonia data set had fewer than 100 observations, EPA used a parametric approach to model the data. If a data set comprises fewer than 100 observations, the best that can be done, using nonparametric methods, is to use the maximum value as an approximate nonparametric estimate of the 99th percentile, but this can underestimate the true value. Parametric methods require that a probability distribution be specified, which allows estimation of unknown parameters from the available data. The estimated parameters are a function of the defined distribution and the data, and thus the parametric method enables the percentiles of effluent concentrations to be computed analytically. EPA's selection of parametric methods in developing limitations for other industries is well documented (e.g., Iron and Steel, Pulp, Paper, and Paperboard, and Metal Products and Machinery categories). EPA considers the lognormal distribution to be appropriate for the ammonia data, and this section describes its application in estimating the final daily maximum limitation. The daily maximum limitation of 14.7 mg/L is based upon an estimate of the 99th percentile of the lognormal distribution of the daily values.

The calculations include an adjustment for possible bias due to statistical autocorrelation. The adjusted variance then better reflects the underlying variability that would be present if the data were collected over a longer period. When data are said to be positively autocorrelated, it means that measurements taken at specific time intervals (such as 1 day or 2 days apart) are similar. For example, positive autocorrelation would be present in the data if the final effluent concentration was relatively high one day and was likely to remain at similar high values the next and possibly succeeding days. EPA sampling data, used as the basis of the limitations, were collected on five consecutive days, and thus, the data may be autocorrelated, but the length of time was not sufficient for autocorrelation evaluations. Albany Airport's self-monitoring data also were not suitable for the evaluation because they were collected at three-week intervals rather than consecutive days. In contrast, the Iron and Steel rule had 244 data points for ammonia that generally were collected on consecutive days, so it was possible to evaluate autocorrelation in the data. Because the model technologies for both industries are biological systems, EPA

concludes that the Iron and Steel autocorrelation adjustment is a reasonable transfer that can be used to calculate the airport deicing limitations.¹⁰ Table 13-10 summarizes the final long-term average and daily maximum limitation, with and without the adjustment for autocorrelation. The final daily maximum limitation of 14.7 mg/L is 2.8 times greater than the long-term average, of 5.24 mg/L, achievable by the model technology. By targeting the system to the long-term average and controlling its variability within this range, the facility will be able to comply with the limitation. However, ammonia is generated as a by-product of the model technology, and EPA expects the concentrations of ammonia to have similar variability to what is being treated (i.e., COD). In contrast to the COD limitations, which are based on a mixture of start-up and steady-state periods, the ammonia limitation is based upon data collected only during steady-state operations.

Table 13-10. Ammonia: Consideration of Autocorrelation for Final Limitations, Long-Term Averages, and Variability Factors

Statistical Parameter	Adjusted for Autocorrelation?		Percent Difference
	No	Yes (Final)	
Long-Term Average (mg/L)	4.97	5.24	5%
Variability Factor	2.25	2.81	25%
Daily Maximum Limitation (mg/L)	11.2	14.7	31%

Unlike COD, EPA is not setting a weekly ammonia effluent limitation. The technology basis for the COD effluent limitations would operate throughout the deicing season with continuous discharges allowing for weekly monitoring. In contrast, urea is applied to airfield pavement as needed, and discharges would occur for a short time after the initial application, as the urea works its way through the stormwater collection and any associated treatment system that may be present. Most airports would have noncontinuous and somewhat infrequent urea discharges. Consequently, it would be difficult to assume a single value for the monitoring frequency that could reasonably be applied to all airports, regardless of climatic conditions.

13.6.3.4 Significant Digits for Final Limitations

In presenting the values of the final limitations, EPA rounded the values to three significant digits. EPA used a rounding procedure where values of five and above are rounded up and values of four and below are rounded down. For example, a value of 5.235 would be rounded to 5.24, while a value of 5.234 would be rounded to 5.23.

13.7 Achievability of Limitations

EPA promulgates limitations that sites are capable of complying with at all times by properly operating and maintaining their processes and treatment technologies. As a consequence of using the percentile basis for each final limitation, treatment systems that are designed and operated to achieve long-term average levels should be able to comply with the limitations, which incorporate variability, at all times. As verification that the limitations are achievable,

¹⁰ EPA has not incorporated a similar adjustment for autocorrelation into the data for the COD limitations because the limitation is based upon more than 2500 measurements collected over 10 years, which presumably would show a full range of variability expected by the model technology. (DCNs AD01210 and AD01214)

EPA performs additional statistical and engineering reviews, as described in Section 13.7.1. As a result of these reviews, EPA has concluded that these limitations are achievable, and thus EPA expects facilities to comply with the limitations as explained in Section 13.7.2.

13.7.1 Statistical and Engineering Review of Limitations

In conjunction with the statistical methods, EPA performs an engineering review to verify that the limitations are reasonable based upon the design and expected operation of the control technologies and the airport conditions. The following sections describe two types of comparisons. First, EPA compares the final limitations to the data used to develop the limitations. Second, EPA compares the limitations to the influent data.

13.7.1.1 Comparison to Data Used As Basis for the Limitations

As part of its data evaluations, EPA compared the value of the final limitations to the values used to calculate the limitations. None of the data selected for ammonia were greater than its final daily maximum limitation that supports the engineering and statistical conclusions that the limitation values are appropriate. Because of the statistical methodology used for the COD limitations, some values were greater than the final limitations.

For COD, appropriately one percent of the values were greater than the final daily maximum limitation, which is consistent with the statistical basis (i.e., use of the 99th percentile) of the limitation. Table 13-11 lists the data from both units and the influent, when one or both effluent values were greater than the limitation. Of the 27 values greater than the final limitation, 20 were from the ArprtR-101 unit, and 7 from ArprtR-102 unit. Both units had values greater than the final limitation on three dates: 3/31/2001, 1/4/2005, and 12/25/2008.

Of the 412 weekly averages of the COD concentrations, 12 averages had values that were greater than the final weekly average limitation of 154 mg/L. Of those 12 averages, 10 were during weeks when the unit also had one or more daily values that were greater than the daily maximum limitation. The statistical support memorandum (USEPA, 2010) identifies the weeks and the corresponding daily values.

13.7.1.1 Comparison to Influent

In addition to evaluating the data used as the basis of the limitations, EPA often compares the value of the final limitations to influent concentration levels. In these comparisons, EPA determines if the limitations perform as expected.

As part of its evaluation to determine if the COD limitation was sufficiently stringent to require that the influent be treated, EPA evaluated the COD influent discharges from Albany Airport. As shown in the summary statistics in Table 13-12, all influent values were greater than the final limitation during nine deicing seasons. For the season 06, only two values (1/1/2007 and 1/2/2007) were less than the final limitation.¹¹ This finding confirmed that the final limitation can only be met through treatment.

¹¹ For both dates, the facility reported the same values for influent (100 mg/L), the same values for ArprtR-101 (30 mg/L), and the same estimated values for ArprtR-102.

Table 13-11. COD: Dates and Values Greater than Final Limitation of 271 mg/L

Season	Date	COD Concentrations (mg/L) ¹	
		ArprtR_101	ArprtR_102
Season99	16MAR2000	326	33
	23MAR2000	315	93
Season00	01MAR2001	276	232
	11MAR2001	288	64
	12MAR2001	575	92
	22MAR2001	129	393
	31MAR2001	357	288
Season02	18MAY2003	(Estimated to be 800) ²	685
	19MAY2003	460	95
	20MAY2003	655	86
	22MAY2003	290	101
Season03	20DEC2003	278	2
	03JAN2004	690	36
	08JAN2004	387	37
	08FEB2004	435	74
	09FEB2004	453	49
	16MAR2004	316	124
	17MAR2004	699	118
Season04	04JAN2005	275	725
	04FEB2005	38	360
Season05	09DEC2005	162	275
Season07	09JAN2008	1,042	Out of service
	10JAN2008	433	Out of service
Season08	25DEC2008	674	282

¹ Bold text indicates effluent values greater than the limitations.

² This value was not used in calculating the limits because it was an estimated value (see DCN AD01246)

Table 13-12. COD: Summary Statistics of Influent Concentrations

Season	#of Days	COD: Influent Concentration (mg/L)				
		Standard Deviation	Minimum	Maximum	Median	Arithmetic Average
Season99	141	1,536	1,000	6,560	2,784	3,242
Season00	115	1,257	1,797	7,950	5,505	5,208
Season01	167	1,505	342	7,105	3,975	3,949
Season02	187	1,825	2,915	10,470	7,270	7,144
Season03	145	2,412	655	10,060	6,520	5,996
Season04	141	1,790	1,848	8,870	5,580	5,272
Season05	85	1,685	528	7,410	4,900	4,373
Season06	62	1,700	100	5,760	1,880	2,588
Season07	127	2,132	485	11,000	7,540	6,805
Season08	120	4,409	3,550	18,300	8,875	10,022
ALL	1,290	2,928	100	18,300	5,490	5,630

13.7.2 Compliance with Limitations

EPA promulgates limitations that sites are capable of complying with at all times by properly operating and maintaining their processes and treatment technologies. However, the issue of exceedances or excursions (values that exceed the limitations) is often raised. In other rules, including EPA’s final OCPSF rule, commenters suggested that EPA include a provision that a facility is in compliance with permit limitations provided its discharge does not exceed the specified limitations, with the exception that the discharge may exceed the daily maximum limitation 1 day out of 100. EPA’s general approach in that case for developing limitations based on percentiles was the same as this rule and was upheld in *Chemical Manufacturers Association v. U.S. Environmental Protection Agency*, 870 F.2d 177, 230 (5th Cir. 1989). The Court determined the following:

EPA reasonably concluded that the data points exceeding the 99th and 95th percentiles represent either quality-control problems or upsets because there can be no other explanation for these isolated and extremely high discharges. If these data points result from quality-control problems, the exceedances they represent are within the control of the plant. If, however, the data points represent exceedances beyond the control of the industry, the upset defense is available. *Id.* at 230.

This issue also was raised in EPA’s Phase I rule for the Pulp, Paper, and Paperboard Category (USEPA, 1998). In that rulemaking, EPA used the same general percentile approach for developing monthly average limitations that it used for daily maximum limitation for the airport deicing rule. The percentile approach for the monthly average limitation was upheld in

National Wildlife Federation et al. v. Environmental Protection Agency, 286 F.3d 554, 573 (D.C. Cir. 2002). The Court determined that:

EPA's approach to developing monthly limitations was reasonable. It established limitations based on percentiles achieved by facilities using well-operated and controlled processes and treatment systems. It is therefore reasonable for EPA to conclude that measurements above the limitations are due to either upset conditions or deficiencies in process and treatment system maintenance and operation. EPA has included an affirmative defense that is available to mills that exceed limitations due to an unforeseen event. EPA reasonably concluded that other exceedances would be the result of design or operational deficiencies. EPA rejected Industry Petitioners' claim that facilities are expected to operate processes and treatment systems to violate the limitations at some pre-set rate. EPA explained that the statistical methodology was used as a framework to establish the limitations based on percentiles. These limitations were never intended to have the rigid probabilistic interpretation that Industry Petitioners have adopted. Therefore, we reject Industry Petitioners' challenge to the effluent limitations.

As that Court recognized, EPA's allowance for reasonably anticipated variability in its effluent limitations, coupled with the availability of the upset defense, reasonably accommodates acceptable excursions. Any further excursion allowances would go beyond the reasonable accommodation of variability and would jeopardize the effective control of pollutant discharges on a consistent basis and/or bog down administrative and enforcement proceedings in detailed fact-finding exercises, contrary to Congressional intent. See, for example, Rep. No. 92-414, 92d Congress, 2d Sess. 64, reprinted in *A Legislative History of the Water Pollution Control Act Amendments of 1972* (at 1482); *Legislative History of the Clean Water Act of 1977* (at 464-65).

More recently, for EPA's rule for the iron and steel industry, EPA's selection of percentiles was upheld in *American Coke and Coal Chemicals Institute v. Environmental Protection Agency*, 452 F.3d 930, 945 (D.C. Cir. 2006). The Court determined that:

The court will not second-guess EPA's expertise with regard to what the maximum effluent limits represent. See *Nat'l Wildlife*, 286 F.3d at 571-73. As EPA explains in the Final Development Document, the daily and monthly average effluent limitations are not promulgated with the expectation that a plant will operate with an eye toward barely achieving the limitations. Final Development Document at § 14.6.2. Should a plant do so, it could be expected to exceed these limits frequently because of the foreseeable variation in treatment effectiveness. Rather, the effluent limitations are promulgated with the expectation that plants will be operated with an eye towards achieving the equivalent of the long term average for the BAT-1 model technology. *Id.* However, even operated with the goal of achieving the BAT-1 long term average, a plant's actual results will vary. EPA's maximum daily limitations are designed to be forgiving enough to cover the operations of a well-operated model facility 99% of the time, while its maximum monthly average limitations are designed to be forgiving enough to accommodate the operations of a well-operated model facility 95% of the time. See *id.* EPA's choice of percentile distribution represented by its maximum

effluent limitation under the CWA represents an expert policy judgment that is not arbitrary or capricious.

EPA expects that airports will comply with promulgated limitations at all times. If an exceedance is caused by an upset condition, the airport would be able to defend against an enforcement action if it meets the requirements of 40 CFR 122.41(n). If the exceedance is caused by a design or operational deficiency, EPA has determined that the airport's performance does not represent the appropriate level of control (best available technology for existing sources; best available demonstrated technology for new sources). For promulgated limitations and standards, EPA has determined that such exceedances can be controlled by diligent process and wastewater treatment system operational practices such as frequent inspection and repair of equipment, use of backup systems, and operator training and performance evaluations.

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Airport Planning Standards

Aviation Department - Port Authority of New York and New Jersey



PRELIMINARY DRAFT
Aviation Planning Division
Version 3

September 2018

Disclaimer

This draft is a working document of the Aviation Planning Division. The contents herein are currently under review by the Port Authority and are subject to change.

The Airport Planning Standards presented in this manual do not supersede any applicable codes or regulations. As codes are often updated, it is incumbent upon the designers to be aware of the current applicable codes for their project. Designers are required to comply with the requirements of the latest applicable building codes adopted by the State of New York and New Jersey, City of New York and Port Authority Engineering Department for the related buildings.

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INTRODUCTION

The airport passenger terminals owned by The Port Authority of New York and New Jersey are operated by private entities, commercial airlines, and the Port Authority. At most of the Port Authority's passenger terminals, aircraft gates are under the control of the terminal operators. Although there are several operating arrangements at PANYNJ airports, all terminal operator alteration proposals are subject to Port Authority approval under the Tenant Construction and Alteration Process (TCAP) - and permitting process.

The TCAP references the Port Authority's *Planning & Design for Terminals and Facilities, Airport Standards Manual*, dated May 2005 (First Edition); therefore, the terminal operators are subject to the terms of the Airport Standards Manual (the Manual), where applicable. The Manual establishes a general set of standards and performance criteria to maintain safe, functionally efficient, code-compliant, sound, and acceptable airport operations. The Airport Standards Manual from 2005 was updated and retitled to "Terminal Planning Guidelines" in August 2013. This document "Airport Planning Standards" supersedes the previous terminal planning guidelines as a definitive Port Authority planning guide for airport planning. This manual takes into consideration latest industry planning guidelines, standards and trends, including but not limited to:

- Latest FAA Advisory Circulars: evolution in aircraft sizes and capabilities influences the standards for airfield design
- Latest industry standards and guidelines for airport planning.
- Technology has increased the number of options customers have to complete their in-terminal transactions (i.e., self-service kiosks and self-tagging of baggage at check-in).
- A dynamic security environment stemming from changing passenger and baggage screening protocols continues to define the in-terminal experience of airport customers.
- Globalization of airline alliances and terminal concession programs has raised customer expectations for a consistent level of quality throughout all segments of their airline travel.
- Distinctive airline operating/business strategies are being manifested in the design of new facilities.
- Increasing emphasis of airports for enhanced passenger experience

Although the Port Authority's purview over such changes is dynamic for each airport, this document discusses how such changes should be considered when applying consistent planning principles. While the previous version of the standards included guidelines only on the terminal section, this document expands its scope to include standards for all planning elements: from developing a forecast to planning landside, terminal, and airside. The purpose of this document is to establish a general set of planning standards and performance criteria to evaluate development proposals from potential proponents. The document aims to serve as a reference document to various users such as planners, designers, analysts, and architects. The guidelines included in this document shall be representative of the Authority's Aviation Department's objectives in achieving the world-class level of customer satisfactions, and operational safety. The document guidelines and standards aim to:

- Incorporate changes to important spatial and design criteria and requirements brought about by emerging industry trends

- Enhance user understanding of issues that should be considered in developing or evaluating the facility requirements
- Expand the standards to address important airport facilities that were not discussed in the previous guidelines

This document is compiled based on information acquired through reviews of current federal and industry literature providing airport planning guidelines; reviews of completed contemporary airport facilities outside of and within the Port Authority's jurisdiction; and the knowledge, expertise, and opinions of Port Authority staff. Any deviations from the standards and guidelines published in this document is subject to the Port Authority's purview for approval.

Use and Organization of the Document

These Port Authority Airport Planning Standards are intended as a source of guidance for planning and designing airport facilities. The document includes the following elements which convey the Port Authority's expectations for planning and development of any new facility at the airport:

Forecast: This section provides methodology and expectations from a forecasting effort: which should be undertaken for any planning exercise. The section describes the methodology for developing a design day flight schedule, collecting airport specific survey data, and identifies the deliverable expectation.

Airside: This section identifies guidelines on assessing facility requirements for various airside elements such as gates, hardstand and deicing positions. It includes essential site planning criteria which should serve as the minimum framework for any new planning and design study. The section also identifies airside concept of operations and conceptual design criteria to guide planners and designers with minimum requirements in an airside design.

Terminal: The section describes the various elements of a terminal building, guidelines for programming of facility requirements and space criteria for designing a terminal. The latest version for IATA ADRM as of the writing of this document, describes an "optimum" level of service for planning terminal facilities.

Landside: The section provides a comprehensive view of various landside elements to be considered for an efficient landside design at an airport. It identifies guidelines and standards for analysis of landside traffic as it pertains in the context of airport planning. To assist users with designing landside elements, the section presents detailed conceptual design criteria that serve as the Port Authority's minimum expectations of a landside design.

The document identifies supplemental references and provides external publications that describe, in more detail, acceptable methodologies for calculating demand, capacity and requirements. New and emerging trends are also discussed to increase awareness of their potential effects on current guidance and the reasoning behind adoption of the current guidelines.

SECTION I: FORECAST AND FUTURE DEMAND

1. Future Annual Demand – Directional Forecast

Future forecast annual demand must, at a minimum, be provided for three project milestone years (year of commencement of operations, +5-year, +20-year), and must include the following information:

- a. Annual aircraft operations and fleet mix for:
 1. Passenger airlines (domestic, international, total)
 2. Cargo airlines (where applicable)
 3. General Aviation (where applicable)
- b. Annual passenger volumes (domestic, international, total)
- c. Compound Annual Growth Rates (CAGR) for aircraft operations and passenger volumes
- d. Annual average Load Factor (domestic, international, total)
- e. Annual average “Origin & Destination / Transfer” Rates (domestic, international, total)

For comparison purposes, all data and figures provided for the three project milestone years must also be provided for existing conditions (baseline).

- f. Accepted Format(s):
 - Demand forecast data: Microsoft Excel format
 - Reports: Microsoft Word / PowerPoint / Adobe PDF format

This future demand information must be submitted to the Port Authority for review in order to ensure its conformity to the Port Authority’s in-house forecasts and the FAA Terminal Area Forecasts (TAF).

Annual growth shall not be less than the greater of the Port Authority annual forecast or any forecast used by the proponent in the development of financial projections associated with the project.

At the discretion of the Port Authority supplementary incremental demand levels for additional milestone years (inside or beyond the 20-year planning horizon) , may be required.

2. Design Day Flight Schedule (DDFS)

Planning, concept validation, and design studies should be based on project-specific Design Day Flight Schedules (DDFS) that reflect the air service characteristics for the project. At a minimum, a detailed DDFS must be provided for the three project milestone years (year of commencement of operations, +5-year, +20-year).

While some calculations may be made on annual, daily or peak hour volumes, project-specific DDFSs are needed as some facilities may experience different peak periods. Planning Day schedules will also be necessary for simulation modelling where required.

For each project milestone year, the three following DDFS packages must be submitted to the Port Authority for review and approval:

- **DDFS Package 1: Flight Schedule Methodology and Daily Volumes Summary**
- **DDFS Package 2: Original Schedule files**

- **DDFS Package 3: Gate and Hardstand Chart (“Gantt Chart”)**

The information to be included in each DDFS package as well as the format(s) accepted are described below:

- a. **DDFS Package 1: Flight Schedule Methodology and Daily Volumes Summary**

- 1. **PART 1: DDFS Methodology and Key Assumptions**

The methodology for the selection of the baseline Design Day must be submitted to the Port Authority for review and approval. The proposed approach must be consistent with common FAA methodologies used to identify existing and forecast future peak activity. The typical selection methods used on PANYNJ projects are:

- Average Day of the Peak Month (ADPM)
- Average Weekday of the Peak Month (AWDPM)

For future flight schedules (year of commencement of operations, +5-year, +20-year), the “annualization” method used to derive Design Day passenger and aircraft operations volumes from the Annual Demand Levels must be submitted to the Port Authority for review and approval. The proponent should document assumptions, parameters and supporting methodology used for converting baseline ratios (design day: Annual demand ratio) to milestone year ratios, as applicable. Rationale for expecting changes in factors, including but not limited to, load factors, transfer percentage, peaking characteristics, seasonalities, markets, airline strategies, and slot assumptions should be documented and explained where applicable. This section must include, at a minimum, the Annual to Design Day Ratio selected for total passenger volumes and aircraft operations.

- 2. **PART 2: DDFS Daily Volumes Summary**

- i. Passenger volumes and operations per airline and aircraft type for the Design Day (domestic/international/total)
 - ii. 24-hour daily profiles (rolling hour) of aircraft operations and passengers (Graph – see sample Figure 1)
 - iii. Peak Hour volumes for the morning (3:00 AM-11:59 AM) and the afternoon (12:00 PM-2:59 AM), for the following categories:
 - Aircraft operations:
 - Arrivals (domestic/international/total)
 - Departures (domestic/international/total)
 - Total operations (domestic/international/total)
 - All passengers:
 - Enplanements (domestic/international/total)
 - Deplanements (domestic/international/total)
 - Total passengers (domestic/international/total)
 - O&D passengers:
 - Enplanements (domestic/international/total)
 - Deplanements (domestic/international/total)

- Total passengers (domestic/international/total)
- Transfer passengers:
 - Total passengers (domestic/international/total)

Load Factors of domestic, international and regional activity must be provided for multiple hours during the Design Day. At a minimum, load factors for the Peak Hour morning and afternoon, as defined in the previous section, must be included in the summary document.

O&D/Transfer rates of domestic, international and regional activity must be provided for multiple hours during the Design Day. At a minimum, the O&D/Transfer rates for the Peak Hour morning and afternoon, as defined in the previous section, must be included in the summary document.

Based on the project scope, the Port Authority may require additional details and information on the existing and future activity levels (e.g., cargo traffic, tonnage and peak operations).

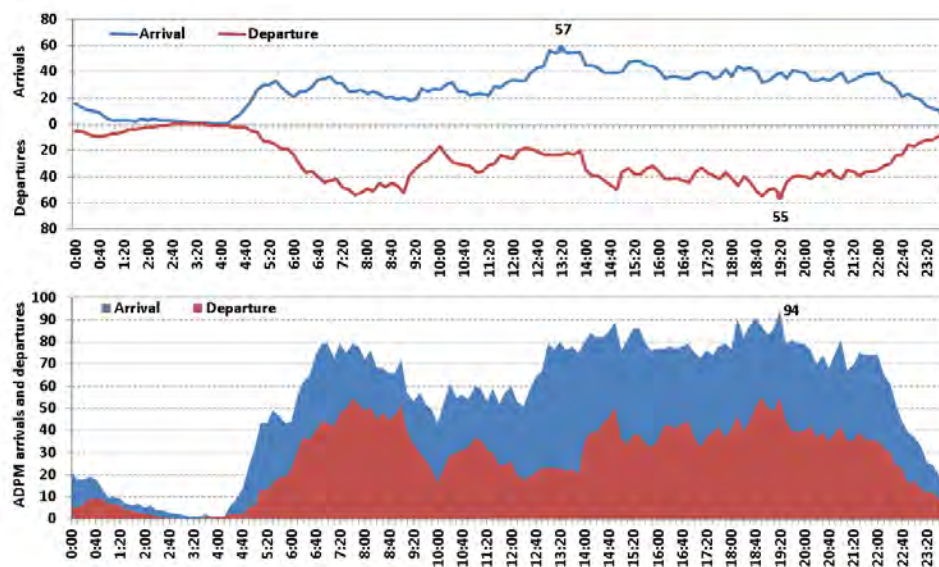


Figure 1: Example of a Typical 24-hour Traffic Profile (rolling-hour) ¹

b. DDFS Package 2: Original Schedule files

1. Information/Data to be included for each flight:
 - i. Air Carrier name and IATA code
 - ii. Aircraft equipment
 - iii. Seat capacity

¹ This figure is provided for illustration purposes only. The information and values included in it are not actual data and should not be used as part of any development project. Source: Port Authority of New York and New Jersey

- iv. Arrival and departure time and day (Port Authority standard DDFS is a 3-day paired flight schedule, that includes at a minimum, arrivals on Day 1, arrivals/departures on Day 2, and departures on Day 3)
- v. Arrival and departure flight numbers (or identifiers)
- vi. Origin and destination airports (or identifiers)
- vii. Gate assignment
- viii. Hardstand assignment
- ix. For arrivals: deplaning, terminating and transfer passengers
- x. For departures: enplaning, originating and transfer passengers

Accepted Format(s): Microsoft Excel file (see sample Figure 2). Each flight schedule should be submitted in a different file and should be clearly labeled with the corresponding milestone year.

B	D	E	F	G	H	I	J	K	M	N	Q	R
Published	Carrier	Equipment	Seat	ArrFlight	ArrOrigin	ArrSchTime	DepFlight	DepSchTime	Operation	PubCarrName	ArrSector	DepSector
			Confi	Number			Number		type			
2D	B-767-200	210	PUJ	408	7/7/2016 02:45	PUJ	407	7/7/2016 06:10	Passenger	Dynamic	Intl	Intl
PS	B-767-300ER	255	KBP	231	7/6/2016 14:20	KBP	232	7/7/2016 00:30	Passenger	Ukraine	Intl	Intl
AA	B-757-200	176	MIA	1048	7/6/2016 16:58	STT	936	7/7/2016 09:15	Passenger	American	Dom	Dom
JL	B-787-8	186	NRT	4	7/6/2016 18:20	NRT	3	7/7/2016 09:40	Passenger	Japan	Intl	Intl
AA	B-757-200	176	STT	936	7/6/2016 19:02	SIJ	1357	7/7/2016 07:30	Passenger	American	Dom	Dom
DL	B-737-800	160	PHX	537	7/6/2016 19:28	MBJ	441	7/7/2016 09:05	Passenger	Delta	Dom	Intl
DL	ERJ-145	50	ACK	3301	7/6/2016 19:45	IAD	4210	7/7/2016 07:45	Passenger	Delta	Dom	Dom
DL	B-757-200WL	168	SFO	1583	7/6/2016 20:08	SFO	434	7/7/2016 09:30	Passenger	Delta	Dom	Dom
AA	B-737-800	160	PHX	2527	7/6/2016 20:30	ORD	2296	7/7/2016 07:35	Passenger	American	Dom	Dom
AA	B-757-200	184	MIA	2254	7/6/2016 20:31	CLT	1495	7/7/2016 08:29	Passenger	American	Dom	Dom
XL	B-767-300	238	GYE	538	7/6/2016 20:45	GYE	539	7/7/2016 01:15	Passenger	LanEcuador	Intl	Intl
DL	B-757-200WL	168	SAN	856	7/6/2016 20:50	LAX	422	7/7/2016 09:30	Passenger	Delta	Dom	Dom
DL	CRJ-900	76	ROC	4110	7/6/2016 21:00	YYZ	4067	7/7/2016 07:29	Passenger	Delta	Dom	Intl

Figure 2: Example of a Typical Design Day Flight Schedule – Tabular Format ²

c. DDFS Package 3: Gate and Hardstand Utilization Chart (“Gantt Chart”)

1. Information/Data to be included for each gate and hardstand:
 - i. Design aircraft for each gate and hardstand
 - ii. International capability of gate (versus for domestic operations only)
 - iii. “Horizontal bars” representing gate occupancy time for each flight over a 24-hour period, including gate-in and gate-out times
 - iv. Indication on the type of operation (either departure/arrival or tow operation), usually depicted by a symbol
 - v. Indication on the buffer time used for each flight
 - vi. Air Carrier name (or IATA code)
 - vii. Aircraft equipment

² This figure is provided for illustration purposes only. The information and values included in it are not actual data and should not be used as part of any development project. Source: Port Authority of New York and New Jersey

Accepted Format(s): Microsoft Excel / Word / PowerPoint file, Adobe PDF (see sample below)

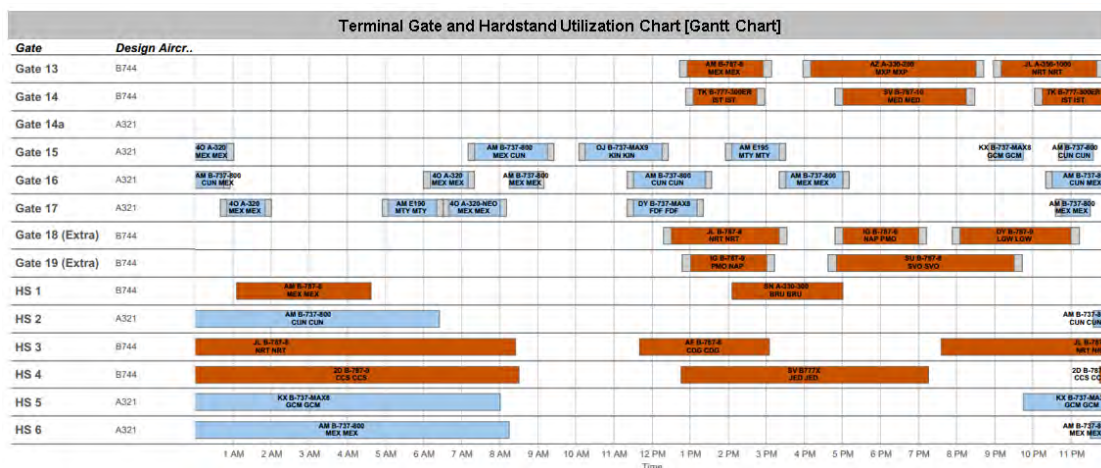


Figure 3: Example of a Typical Gate Utilization Chart – Gantt Chart Format ³

Please refer to the following section of this document for methodology guidelines and parameters to be used to generate the gates and hardstands requirements.

Note: Sensitivity Analysis

Flight delays, common in long-haul flights, can drastically change airport activity, which is not captured in a planning day flight schedule. For this reason, the Port Authority may require additional sensitivity analysis on demand activity for specific projects, to incorporate delay factors in facility planning.

3. Airport Facility Requirements (Airside / Terminal / Landside)

The utilization of the planning data and information described in this document to generate existing and future airport facility requirements will be described in the subsequent sections: Airside, Terminal, and Landside Guidelines. Specific details and methodology guidelines will be provided for the planning and conceptual design of development projects at PANYNJ airports.

For the Gate and Hardstand requirements, it was decided to provide the methodology guidelines and parameters in this section, as the process is generally correlated with the development of the Design Day Flight Schedule.

Gate and Hardstands Requirement – Methodology and Assumptions

The computation methodology to generate gates and hardstands requirements must be fully documented as part of the proponent's proposal.

The gating parameters and assumptions must be explicitly described in the proposal and summarized in a tabular format. The table below lists the mandatory parameters that need to be documented and

³ This figure is provided for illustration purposes only. The information and values included in it are not actual data and should not be used as part of any development project. Source: Port Authority of New York and New Jersey

provided to the Port Authority for review and approval. The table also provides the Port Authority Minimum Criteria for each gating parameter:

	Proponent's Planning Parameters (to be provided)	Minimum Planning Criteria*
Buffer Time (minimum time between two aircraft using the same gate)		
Regional Jets or Smaller Aircraft	-	15 minutes
All other Aircraft Design Groups if apron is equipped with dual taxilane or taxi-through taxilane and with sufficient on-site or close-in hardstand positions	-	15 minutes
All other Aircraft Design Groups	-	20 minutes
Shuttle operation	-	15 minutes
Minimum Aircraft Turnaround Time (minimum time between aircraft gate arrival time and gate departure time)		
ADG-II	-	30 minutes
ADG-III	-	45 minutes
ADG-IV	-	60 minutes
ADG-V	-	90 minutes
ADG-VI	-	105 minutes
Minimum Aircraft Unloading / Loading times (for towing operations)		
ADG-II	-	25min / 30min
ADG-III	-	30min / 45min
ADG-IV	-	45min / 60min
ADG-V	-	60min / 90min
ADG-VI	-	75min / 105min
Other Towing Parameters		
Towing Time (from/to Hardstand)	-	15 minutes
Minimum Ground Time on on-site or close-in hardstand position for ADG III or smaller	-	45 minutes
Minimum Ground Time on on-site or close-in hardstand position for all other Aircraft Design Groups	-	60 minutes
Minimum Ground Time on off-site Hardstand	-	90 minutes

* Consult with Port Authority Aviation Department for approval if any deviations from the above standards

Table 1: Ground Time Planning Criteria

In addition, detailed assumptions related to aircraft size considerations, airline assignments and other operational restrictions may be required by the Port Authority on a project basis.

For all proposed terminal developments, gate and hardstand requirements must be summarized for each planning horizon (year of commencement of operations, +5-year, +20-year) in a tabular format following the template below:

Contact Gates and Hardstands Summary – Proponent’s Plan (to be provided)						
	YEAR OF COMMENCEMENT OF OPERATIONS		+5-YEAR PLANNING HORIZON		+20-YEAR PLANNING HORIZON	
	Domestic	International	Domestic	International	Domestic	International
Contact Gates¹						
ADG-II (Regional Jets)	-	-	-	-	-	-
ADG-III	-	-	-	-	-	-
ADG-IV	-	-	-	-	-	-
ADG-V	-	-	-	-	-	-
ADG-VI	-	-	-	-	-	-
Total Contact Gates	-	-	-	-	-	-
Average Daily turns per Gate	-	-	-	-	-	-
Average Daily passengers per gate	-	-	-	-	-	-
Narrow Body Equivalent Gates (NBEG)	-	-	-	-	-	-
Hardstands / Parking Positions²						
ADG-II (Regional Jets)	-	-	-	-	-	-
ADG-III	-	-	-	-	-	-
ADG-IV	-	-	-	-	-	-
ADG-V	-	-	-	-	-	-
ADG-VI	-	-	-	-	-	-
Total Hardstands	-	-	-	-	-	-

Table 2: Contact Gates and Hardstands Summary - Template

Notes:

1. If the proposed development includes the use of MARS Gates (Multi-Aircraft Ramp System), they should be included in the table as a separate item. In addition, the aircraft layout and configurations of each proposed MARS gate must be submitted to the Port Authority for review and approval. Please refer to the Airside Standards section for more detail regarding MARS gate arrangements.

2. The above table considers that all hardstands and aircraft parking positions are independent. If the proposed plan includes inter-dependent parking positions, additional information will be required by the Port Authority as part of the proposal review process. In addition, for planning purposes, the use of live hardstands on a permanent basis is prohibited at PANYNJ airports. Any proposed plan considering the use of live hardstand operations must demonstrate the temporary need for them, by assessing all alternative options and justify that none of them meet the program’s objectives and requirements. Any

plan for live hardstand operations must be submitted to the Port Authority for review and approval in the early planning stages of the project. Please refer to the Airside Standards section for more detail regarding live hardstand operations.

4. Surveys and Data Collection

If the proponent is in a non-competitive position for expansion or redevelopment of an existing facility, they are responsible for conducting on-site surveys to confirm passenger characteristics that are specific and unique to each airport and terminal, including the following: landside modal split and dwell times, earliness distribution (“show-up profile”) of departing passengers arriving at the terminal before scheduled departure time, travel party size, percent of passengers checking bags, number of bags checked per passenger checking bags, terminal facility use and processing rates, load factors, and transfer percentages. The latter two must be specified by flight or time of day/flight type (i.e., Domestic vs International and aircraft size).

Some of this data can be collected from databases maintained by the Port Authority, terminal operators, and airlines as part of ongoing customer service monitoring. Gathering this data should be the designer’s first effort. For data that is not available from database sources, designers must carefully plan and execute on-site surveys at the terminal during peak demand periods. The survey methods can include active intercepts or passive observations of passengers, as appropriate. Active intercepts should be minimized to the extent practicable, because it causes an inconvenience to passengers.

For additional guidance on passenger surveys at airports, consult the Transportation Research Board (TRB) Airport Cooperative Research Program (ACRP) Report 26.

The proponent should coordinate the method, strategy, minimum acceptable sample sizes, and parameters for data collection with the Port Authority for review and approval, before starting any analysis.

If the survey is not conducted during peak periods, seasonality adjustments and factors on the data set need to be coordinated with the Port Authority to account for potential variations during peak periods.

SECTION II: AIRSIDE REQUIREMENTS

Part 1 - Airside Facility Requirements – Methodology Guidelines

1. Standards and References

Proposed developments should be compliant with all applicable industry codes, standards and regulations, including but not limited to the latest versions of the following documents:

- a. Federal Aviation Administration (FAA) Advisory Circulars (AC) and Orders
 - 1. AC 150/5220-21C: Aircraft Boarding Equipment
 - 2. AC 150/5300-13A: Airport Design
 - 3. AC 150/5300-14C: Aircraft Deicing
 - 4. AC 150/5320-5D: Airport Drainage Design Document Information
 - 5. AC 150/5340-1L: Standards for Airport Markings
 - 6. AC 150/5360-13A: Airport Terminal Planning
 - 7. Federal Aviation Regulations Part 107 – Airport Security
 - 8. Federal Aviation Regulations (FARS 14 CFR)
 - 9. FAA Order 8260.3B: US Standards for Terminal Instrument Procedures
 - 10. Applicable FAA Advisory Circulars
- b. Airport Cooperative Research Program (ACRP)
 - 1. ACRP Report 14 – Deicing Planning Guidelines and Practices for Stormwater Management Systems
 - 2. ACRP Report 25 - Volume 1: Airport Passenger Terminal Planning and Design
 - 3. ACRP Report 62 - Airport Apron Management and Control Programs
 - 4. ACRP Report 96 - Apron Planning and Design
- c. International Civil Aviation Organization (ICAO)
 - 1. ICAO Aerodrome Design Manual, Part 4: Visual Aids
 - 2. ICAO Annex 14, Volume I: Aerodrome Design and Operations
- d. International Air Transport Association (IATA)
 - 1. IATA Airport Development Reference Manual 10th Edition
- e. Port Authority of New York and New Jersey (PANYNJ) Standards
 - 1. PANYNJ Civil Engineering Design Guidelines
 - 2. PANYNJ Tenant Alteration Procedures and Standards Guide, December 20, 2013
 - 3. PANYNJ Tenant Construction Review Manual
- f. Airports Council International (ACI)
 - 1. Apron Markings and Signs Handbook, Third Edition, 2017
- g. United States Customs and Border Protection
 - 1. Airport Technical Design Standards (2017)

- h. National Safe Skies Alliance
 - 1. PARAS 0004 - Recommended Security Guidelines for Airport Planning, Design, and Construction 2017
- i. Americans with Disabilities Act (ADA), 2012 (or latest)
 - 1. Title III (28 CFR Part 36) ADA – ADOPTED July 1, 1994 (Updated September 15, 2010)
 - 2. Americans with Disabilities Act Accessibility Guidelines (ADAAG)
 - i. ADAAG published in 28 CFR Part 36 Federal Register
 - ii. ADAAG for Titles I (Employees) and III (Public Accommodation)
- j. Code of Federal Regulations (CFR)
 - 1. CFR Title 14, Part 77: Safe, Efficient Use, and Preservation of the Navigable Airspace
- k. Green Building Council (USGBC)
 - 1. Leadership in Energy and Environmental Design (LEED) New Construction Version 4.0
- l. Illumination Engineering Society of North America (IESNA)
 - 1. IES Handbook 10th Edition
 - 2. RP 37-15 Outdoor Lighting for Airport Environments
- m. International Building Code (IBC)
- n. International Fire Code (IFC), 2010
- o. National Electric Code (NEC), 2011
- p. National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) Standards:
 - 1. NTCIP 1201 Global Object Definitions,
 - 2. NTCIP 1203 Object Definitions for Dynamic Message Signs
- q. National Fire Protection Association (NFPA)
 - 1. NFPA 101: Life Safety Code, 2006
 - 2. NFPA 110: Standard for Emergency and Standby Power Systems
 - 3. NFPA 407: Standard for Aircraft Fuel Servicing
 - 4. NFPA 415: Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways
- r. Occupational Safety and Health Administration (OSHA)
 - 1. 29 CFR Part 1910 -211 (Definitions)
 - 2. 29 CFR Part 1910 – 212 (General Industry Standards and Requirements)
- s. All applicable federal, state and local codes

The following codes are applicable to projects in New York City only:

- a. New York City Building Code (NYC BC)
- b. New York City Department of Environmental Protection (NYC DEP)
- c. New York City Electrical Code
- d. New York City Fire Code (NYCFC), 2008

The following codes are applicable to projects in New York State only:

- a. New York State Department of Transportation

The following codes are applicable to projects in the State of New Jersey only:

- a. International Building Code (IBC), New Jersey edition, 2009
- b. International Fire Code, (IFC) New Jersey Edition 2006
- c. New Jersey Uniform Fire Code NJAC 5:70

When there is a conflict or discrepancy between two reference standards from different sources or documents listed above, the more stringent requirements shall apply.

2. Units

All structures shall be designed and detailed using Customary U.S. Units.

3. Datum

- a. Vertical Control: NAVD88
- b. Horizontal Control: State Plane NAD83

4. Contact Gates and Hardstands

The computation methodology to generate gates and hardstands requirements must be documented as part of the proponent's proposal, including all gating and towing parameters. Please refer to the section on Forecast and Future Demand for detailed guidance on the methodology and parameters to be used at PANYNJ airports.

Part 2 - Airside Concept of Operations

The following Concept of Operation plans and operational information must be provided to the Port Authority for any proposed airside development at PANYNJ airports:

1. Gates and Hardstands Usage

The proposed plan must illustrate and identify the following characteristics at each contact gate:

- Airlines common-use, versus Exclusive/preferential use
- Capability to accommodate international operations, versus domestic only
- Multi-Aircraft Ramp System (MARS) gates

For hardstands, the Port Authority recommends the design for independent parking positions. If inter-dependencies exist between hardstands, they must be identified in the plan.

2. General Aircraft Circulation/Movements Plan

- a. The apron concept of operations plan must include at a minimum the following elements and details:

1. Taxiway alignment and marking:

- i. Pavement marking centerline
- ii. Pavement marking hold bars
- iii. Hold position lights

2. Aircraft ground flows on proposed taxiways

3. General pushback maneuvering and engine startup position locations and utilization, including jetblast analysis from startup to entrance to the airfield.

4. Interface with Airfield: proposed aircraft sequencing at each apron entrance/throat (e.g., arrival priority versus departure priority, typical holding times)

- b. Aircraft pushback maneuvering and other apron operations shall be contained within the limits of the non-movement area. The Port Authority should be consulted if the proposed plan has impacts on the movement area.

- c. As part of the proposal review process, the Port Authority may require additional details if needed to ensure safe and efficient aircraft movements on the apron.

- d. Off-site Aircraft Parking:

1. If remote parking positions are considered off-site (outside of tenant's leasehold), detailed aircraft ground flow maps showing towing operations on taxiways from on-site gate/hardstand to off-site parking positions must be provided to the Port Authority for review and approval.



Figure 4: Aircraft Pushback Maneuvering

3. Detailed Aircraft Maneuvering Plan for each contact gate and aircraft parking position

- a. Detailed aircraft maneuvering plans, including power-in and pushback operations must be provided for each gate and hardstand position to the Port Authority for review and approval.
- b. Computer simulation software such as PathPlanner Airside, and AviPlan must be used for aircraft maneuvering simulations. Files of the maneuvering drawings must be provided to the Port Authority for review.
- c. As part of the proposal review process, the Port Authority may require additional information on specific gates and/or hardstands.

Part 3 - Site Planning Criteria

In developing site layouts for new facilities, the applicant should be aware that building and paving set back limits exist but vary depending on the type of airport, location within the airport boundary, and adjacent jurisdictions. The main goals of these setbacks include, but are not limited to, establishing right-of-way easements including fire equipment access around structures and utility / infrastructure access. Setbacks are also essential to retain a feeling of open space, integration with adjacent parkways, for aesthetic considerations, and meeting the required local ordinances for New York and New Jersey.

General landscaping for the area includes programming for flood resistance, stormwater absorption, infiltration, and treatment. Bioswales, plantings for ground cover, screening of elements and for accent shall be planned for the open areas. Refer to the Port Authority Sustainable Infrastructure Guidelines⁴, for additional information.

In addition to setback defined in this section appropriate clearances from airside security fencing shall be maintained.

When there is a conflict or discrepancy between two standards, the more stringent requirements shall apply.

1. Setback Requirements for Property Leaselines

The following minimum standards shall be maintained for property lease line setbacks based on hierarchy of roadway types:

a. High-speed Expressways / Highways

New leaselines adjacent to high-speed expressways / highways shall maintain a minimum offset of 100 feet measured from the inner curbline of roadway. See Figure 5: Lease line setback at High-speed Expressways / Highways



⁴ PANYNJ Sustainable Infrastructure Guidelines, March 23, 2011 Appendix 06: Aviation Landscape and Sustainable Design Criteria, Engineering Department, PANYNJ, March 17, 2010

Figure 5: Lease line setback at High-speed Expressways / Highways

b. Primary Entrance / Exit Roadways:

New leaselines adjacent to primary / main access roads shall maintain a minimum offset of 25 feet measured from the inner curbline of roadway. See Figure 6: Lease line setback at primary / main access roadways

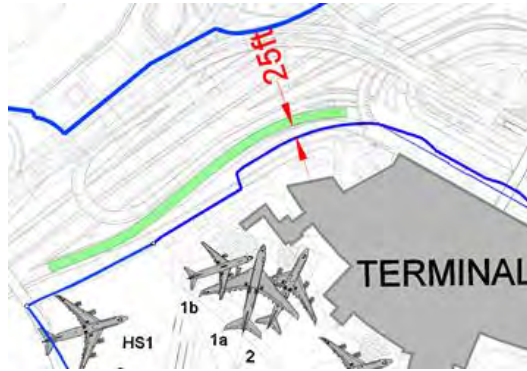


Figure 6: Lease line setback at primary / main access roadways

c. Secondary Roadways:

New leaselines at secondary roads shall maintain a minimum offset of 15 feet measured from the inner curbline of roadway. See Figure 7: Lease line setback at secondary roadways

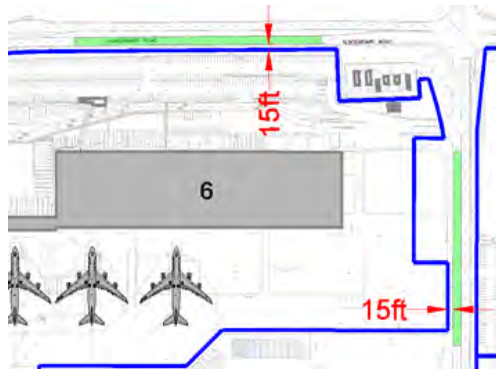


Figure 7: Lease line setback at secondary roadways

d. Airside Restricted Service Roads:

New leaselines at airside restricted service roads shall maintain a minimum offset of 10 feet measured from the inner edge of airside restricted service road (Port Authority service road). See Figure 8.



Figure 8: Lease line setback at airside restricted service roads

2. Setback Requirements for New Structures and Utilities

The following minimum standards shall be maintained for new structures and utilities setbacks:

a. Buildings / Structures:

New buildings or structures must comply with the following setback requirements whichever is greater 50 feet or more from lease line at primary or secondary roadways. See Figure 9.



Figure 9: Building / Structure setback from lease line at primary / secondary roadway

30 feet or more from lease line of adjacent property or local access roadway. See Figure 10.

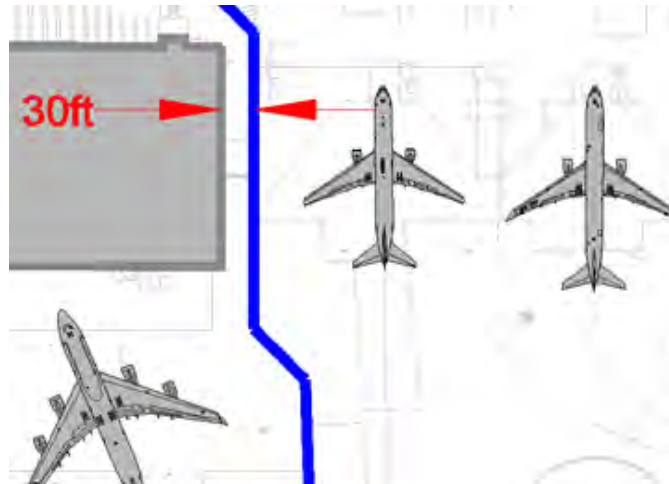


Figure 10: Building / Structure setback from lease line of adjacent property or access roadway

b. Auto parking

At grade auto parking lots must comply with the following setback requirements. See Figure 11.

1. 35 feet or more from any expressway and primary roadway (median consisting of a single row of trees, low hedge and security fence).
2. 30 feet or more from any secondary roadway.



Figure 11: Auto parking lots setbacks from primary and secondary roadways

c. Utilities Easement:

Utilities easement requirements will be reviewed on case by case basis.

3. AirTrain

Consult the Port Authority Rail Operations group at each airport for minimum clearances to be maintained from existing AirTrain (automated people mover) systems at John F. Kennedy and Newark Liberty International airports.

4. Security

There are numerous advantages to incorporating security concerns into the airport planning and design process at the earliest phases of planning and development. Timely consideration of such needs will result in less obtrusive, less costly, and more effective and efficient security systems⁵.

General planning, design, construction, and operational requirements of a commercial airport are established and overseen by the FAA under airport certification requirements identified in 14 CFR § 139. Approaches to physical security should reflect applicable federal, state, and local laws, regulations, and policies to ensure the protection of all persons and assets.

a. Security-Specific Reference Documents

- *PANYNJ Security Manual*
- *ACRP - Assessment of Technologies Deployed to Improve Aviation Security: First Report*
- *FAA AC 150/5300-13 - Airport Design*
- *FAA AC 150/5360-13 - Planning and Design Guidelines for Airport Terminal Facilities*
- *Safe Skies PARAS 0004 - Recommended Security Guidelines for Airport Planning, Design, and Construction*
- *ACI Landside Security Handbook, First Edition*

b. General Airport Security Guidelines and State of The Practice

General planning, design, construction, and operational requirements of a commercial airport are established and overseen by the FAA under airport certification requirements identified in 14 CFR § 139. Ensuring the inclusion of security systems, methods, and procedures within this construction and operational process is a joint responsibility of the airport and the TSA.

c. Air Operations Area (AOA) Perimeter Fencing and Access Posts

To delineate and adequately protect the Air Operations Area (AOA) from unauthorized access it is important to consider boundary measures such as fencing, walls, or other physical barriers, and electronic boundaries (e.g., sensor lines and alarms) in the planning and design process. Access points for personnel and vehicles through the boundary lines, such as gates, doors, guard stations, and electronically controlled or monitored portals, should also be considered.

Regardless of boundary location or type, the number of access points should be minimized for both security and cost efficiency. Proper planning and design can often create fewer, more functional and maintainable access points that will benefit the airport in the long run.

Physical barriers can be used to deter and delay the access of unauthorized persons into nonpublic areas of airports. These are usually permanent barriers and designed to be an obvious visual barrier as well as a physical one. Where possible, security fencing should be aligned with security area boundaries. Some types of fencing are difficult to climb or cut, and many use such technologies as motion, tension, or other electronic sensing means. When fences have sensors, either mounted on the fencing or covering

⁵ Safe Skies PARAS 0004

areas behind fencing, they must be accommodated in the security system to monitor the sensors and to initiate response to intrusion alarms.

Chain link fencing is the most common and cost-effective type of fencing for deterrence, as opposed to the prevention of forced entry. The FAA Advisory Circular recommends chain link fences to be constructed with seven feet of fabric plus one or more coils of stranded barbed wire on top, which may be angled outward at a 45-degree incline from the airside. Fabrics should be secured to the fence posts and to the bottom rail in a manner that makes it difficult to loosen the fabric.

Clear distances of 10 feet must be maintained on both sides of AOA fence, within which there should be no climbable objects, trees, or utility poles abutting the fence line, nor areas for stackable crates, pallets, storage containers, or building materials. Likewise, service roads and parking of vehicles along the fence within the 10-foot buffer is prohibited. Landscaping within the clear zone should be minimized or eliminated to reduce potential hidden locations for persons, objects, fence damage, and vandal.

Additional security measures to consider that would enhance these boundaries and access points are security lighting, video surveillance systems, and signage.

d. Physical Hardening Methods

While it is not possible to fully protect passengers and facilities from an explosive attack, there are measures that can be put in place that can either reduce the potential for an attack or reduce the effectiveness of such an attack. The following is a brief overview of methods and materials that can be employed to physically protect the airport and its various components.

1. Bollards

A bollard is a vehicle barrier consisting of a cylinder, usually made of steel and filled with concrete placed on end in a deep concrete footing in the ground to prevent vehicles from passing, but allowing the entrance of pedestrians and bicycles. Bollards are also constructed of steel sections and reinforced concrete. An anti-ram bollard system must be designed to effectively arrest the vehicle and its cargo as quickly as possible and not create an opening for a second vehicle. Bollards can effectively protect facilities and columns from vehicular impact and bomb blasts by creating standoff between the target and the threat.

A typical fixed anti-ram bollard consists of a ½-inch thick steel pipe, eight inches in diameter projecting about 30 inches above grade and buried about 48 inches in a continuous strip foundation.

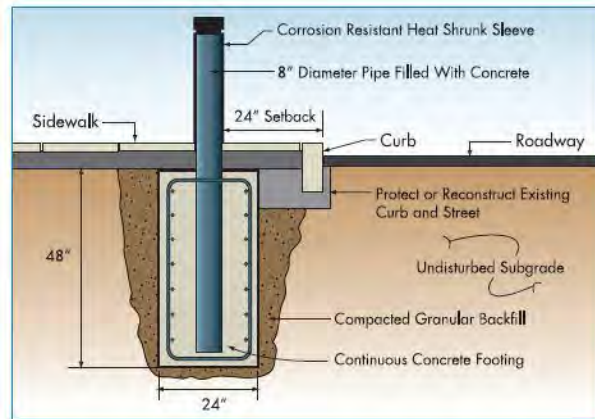


Figure 12: Typical Fixed Bollard installation⁶

Bollards are, by their nature, an intrusion into the streetscape. A bollard system must be very thoughtfully designed, limited in extent and well-integrated into the perimeter security design and the streetscape in order to minimize its negative visual impact. The design basis threat, in terms of vehicle size and speed, influences bollard height and construction material. Typically, bollards should not exceed a height of 38 inches inclusive of any decorative sleeve.

e. Building and Parking Setbacks

The landside is the area of an airport, including buildings and other structures, to which both traveling passengers and the non-traveling public have unrestricted access. Examples of landside facilities are public and employee parking, terminal and public roadways, rental car and ground transportation operations, hotel facilities, and commercial and industrial developments. The publicly accessible areas of terminal buildings are technically considered part of landside and have several security-related considerations that should be planned in conjunction with other landside facilities.

Security in landside areas is difficult to monitor and control due to public accessibility and the limitations of implementing security measures—often over varied terrain, or in some cases urban settings immediately adjacent to airport properties. There are many issues to address while keeping focused on terminal design, passenger throughput, aircraft operations, and the generation of revenues.

1. Landside Roads

When planning landside roadways, attention should be given to adjacent security fencing, airside access, and potential threats to terminal or aircraft operations. Designers should bear in mind landside road proximity to security fencing, the potential for unauthorized airside access offered by elevated roadways, and line-of-sight threats to adjacent areas of the terminal, apron, and/or nearby aircraft.

Drop-off and loading zones should be set as far away from the terminal as practical to minimize the blast effects of a vehicle bomb.

⁶ US Department of State

Planners should provide for emergency vehicle (fire and police) parking and staging areas near the terminal, potential inspection areas, and congested areas.

During periods of heightened security, planners should ensure vehicles cannot gain access to the terminal by bypassing the inspection area; and scenarios should be evaluated such as the potential to jump curbs, travel across open landscaping, or drive the wrong way down a road.

2. Landside Parking

Parking area entrances and exits should not be placed directly in front of the terminal. Elevated security levels may require inspections of vehicles entering and exiting parking facilities.

During periods of heightened security, designs should accommodate permitting vehicle access only after a detailed inspection process, closing parking areas off, or segmenting them to control access only by authorized personnel such as employees, first responders, or other known entities.

Planners should provide sufficient space in parking areas to facilitate the movement of police, fire, and emergency vehicles, as well as turning radius accommodations for tow trucks for removal of suspicious or abandoned vehicles.

Parking facilities shall be designed to have parked vehicles be more than 300 feet from nearest terminal building. Locating parked vehicles less than 300 feet from terminal may require development of local security plan based on approved blast analysis performed by a certified engineering firm and is to be instituted during periods of heightened security.

Truck access and loading docks present challenges to the landside protection of airports. Roadway access should be developed to limit unscreened trucks from accessing the landside frontage of the terminal. Delivery trucks should be identified and screened prior to having access to the terminal.

5. Phasing Criteria & Concepts

[Section under development]

6. Land Use and Zoning

[Section under development]

7. Line of Sight Requirements for the Airport Traffic Control Tower

This section describes line-of-sight (LOS) requirements for FAA Air Traffic Control (ATC) staff from the Airport Traffic Control Tower (ATCT). FAA ATC staff are responsible for the life-safety critical task of directing aircraft in the airspace and on the airfield in a safe and efficient manner, and their unobstructed view of the airfield is therefore of utmost importance.

a. Reference Documents

- *FAA Order 6480.4A - Airport Traffic Control Tower Siting Process*
- *Title 14 US Code of Federal Regulations (CFR), Federal Aviation Regulations (FAR) Part 77 – The Safe, Efficient Use, and Preservation of the Navigable Airspace*
- *FAA AC 150/5300-13A - Airport Design*

b. Airport Traffic Control Tower Line of Sight

FAA Order 6480.4A covers both the designing and sighting of a new ATCT as well as maintaining an unobstructed view of all movement areas on the airfield when a new development is proposed that could hinder the views of the FAA ATC staff in the ATCT.

Whenever there is new development project or addition to existing facility are proposed, that could hinder the views of the FAA ATC staff in the ATCT, a Visibility Siting Analysis shall be conducted to address the Unobstructed View requirements. The developer must submit a Visibility Siting Analysis along with plans and section views to the Port Authority for review and approval.

1. Unobstructed View

Port Authority requirement is for controllers in an ATCT cab to have an unobstructed view of all controlled movement areas including all runways, taxiways, and any other landing areas, and of air traffic in the vicinity of the airport. It is a Port Authority requirement for the FAA ATC staff to have a view of all pavement surfaces (edge to edge) from the ATCT. The simulation tool at Airport Facilities Terminal Integration Laboratory (AFTIL) located at the William J. Hughes Technical Center shall be used to do a dynamic visibility analysis including the evaluation of both moving and parked aircraft.”

The line of sight analysis (LOS) shall account for all existing portions of the airfield, as well as future planned modifications, including but not limited to: new or extended runways; new, extended, or adjusted taxiways and hold bays. Consult the latest approved ALP, as well as the Port Authority, for future airfield modifications that must be included in the LOS analysis and future movement area changes that may be implemented to address existing FAA Modification of Standards.

8. Runway Protection Standards

The Federal Aviation Administration (FAA) sets forth multiple guidelines for protecting the safe and efficient operations of aircraft on runways, with geometric and land use restrictions and airspace protection designed to protect aircraft operations and ground infrastructure. Terminal Developers must adhere to FAA airport design guidance with any airport development proposal. Failure to do so will result in rejection of development proposals; and if constructed would result in hazardous conditions.

a. References

Airport planners and designers should be familiar with the following reference documents, which are discussed in more detail in the following sections:

- Title 14 of the US Code of Federal Regulations (CFR), Federal Aviation Regulations (FAR), Part 77, *The Safe, Efficient Use and Preservation of the Navigable Airspace*
- FAA Order 7400.2, *Procedures for Handling Airspace Matters*
- FAA Order 8260.3, *United States Standard for Terminal Instrument Procedures (TERPS)*
- FAA Advisory Circular 150/5300-13, *Airport Design*
- Airport Cooperative Research Program (ACRP) Report 38, *Understanding Airspace, Objects, and Their Effects on Airports*

9. Modification of Standards

The FAA has established a system of airport design standards in Advisory Circular (AC) 150/5300-13, *Airport Design*, and related ACs and Orders. These serve as a framework for developing and maintaining safe, orderly, and consistent airport facilities nationwide, and are utilized in FAA reviews of proposed projects at airports. When an airport project proponent (e.g. airport sponsor, tenant, developer, etc.) proposes a project that would not be in compliance with a particular airport design standard, the proponent can appeal to the FAA for a special exception to the standard, known as a Modification of Standards or “MOS”. The FAA’s review and decision regarding an MOS will be recorded in a letter from the FAA describing the condition and reasons for approval or disapproval, and should be recorded on the subsequent update to the Airport Layout Plan (ALP) drawings.

The FAA’s definition of MOS is as follows:

Any deviation from, or addition to standards, applicable to airport design, material, and construction standards, or equipment projects resulting in an acceptable level of safety, useful life, lower costs, greater efficiency, or the need to accommodate an unusual local condition on a specific project through approval on a case-by-case basis.⁷

In addition to new construction, an MOS can also be granted by the FAA for a “grandfathered” condition. This occurs when airport design standards change, legacy facilities do not comply to the new standards, and it would be technically or financially infeasible to bring the facilities into compliance with the new standards in the immediate term. In these cases, the MOS may be granted by the FAA, with time limit and/or facility reconstruction triggers that obligate the airport to bring the condition into compliance at some point in the future.

b. Design Approach and Review Process

In general, proponents should plan and design projects such that they will be in compliance with all FAA airport design standards. An MOS should be considered a rare exception, acceptable only in cases when there is no feasible way to comply with a particular standard, and equivalent level of safety can be demonstrated by the proponent and agreed by the FAA.

Because FAA approval is uncertain, proponents wishing to be granted an MOS should begin the application process early in the planning phases of a project. Proponents should first consult with Port Authority for an initial assessment.

The FAA’s mechanism for reviewing airport standards compliance is via ALP update, and may also include review via FAA Form 7460-1, *Notice of Proposed Construction or Alteration*. The Port Authority Tenant Construction and Alteration Process (TCAP) Manual specifies how and when in the Tenant Alteration Application (TAA) process a project which may trigger an ALP update is required to do so, as well as submitting Form 7460-1. In the TCAP Manual, there is an internet link to a checklist of project types which may require an ALP update, and similar link to the checklist for Form 7460-1 submittal.

⁷ FAA Order 5300.1, *Modifications to Agency Airport Design, Construction, and Equipment Standards*

Proponents whose projects may trigger an ALP update, whether or not it contains an MOS, must coordinate with Port Authority on which ALP drawing(s) should be included in the ALP update, and how it is to be submitted to the FAA for review. In cases where an MOS is requested from the FAA, in addition to the ALP drawings depicting the proposed condition, documentation supporting the rationale for the MOS must be provided for FAA review.

Depending on the nature of the MOS and which airport design standard(s) are affected, the FAA may require any or all of the following:

- Full ALP drawings and/or larger scale detail drawings showing the FAA standard vs. proposed MOS condition. Detail drawings at a larger scale are recommended to illustrate the condition fully.
- Citations from AC 150/5300-13 and other ACs and Orders describing the design standard(s) and their rationale(s).
- Detailed explanations of why compliance with the design standard in question would be infeasible.
- Viable options considered for potential alternative designs, and the rationale for selection of the preferred alternative.
- Evidence and analyses demonstrating how an equivalent level of safety is achieved (e.g. operational restrictions) by the preferred alternative. This could include safety risk assessments, manufacturer's literature, and/or FAA Engineering Briefs (EBs).
- Precedents of previous similar MOS.
- Submission of FAA Form 7460-1.
- Other supporting documentation as may be requested by Port Authority or the FAA.

Please refer to FAA AC 150/5300-13 and FAA Order 5300.1 for additional detail.

The proponent must submit all of the above documentation to Port Authority for review before submitting to the FAA. Port Authority will then coordinate with the FAA on submittal of the ALP drawings, detail drawings, and supporting MOS documentation.

If granted an MOS with a limited timeframe, e.g. full compliance with the standard is required in a certain number of years, proponents are responsible for providing full compliance with the timeframe specified by the FAA.

This section will be supplemented in future versions of this standards manual.

Part 4 - Conceptual Design Criteria

1. Design Aircraft and Fleet Mix

Any proposed plan for airside and terminal development at PANYNJ airports must explicitly indicate the critical aircraft and/or fleet mix considered for the design of each airside element, including:

- a. Contact Gates and Hardstands:
 1. Design aircraft per gate and hardstand (larger aircraft in terms of wingspan), and associated Aircraft Design Group (ADG);
 2. Comprehensive aircraft service chart, in a tabular format, providing the full list of aircraft that each contact gate and hardstand can accommodate.
- b. Taxilane Design:
 1. Critical aircraft and/or ADG used for each taxilane in order to define the following clearances (as per FAA AC 150/5300-13A: "Airport Design"):
 2. Taxilane centerline to parallel taxilane centerline;
 3. Taxilane centerline to fixed or moveable objects (object free area).

The critical aircraft and fleet mix used for the design of Aircraft Layout Plans must be consistent with the forecast and future demand scenarios provided to the Port Authority.

The aircraft layout plan shall incorporate as much flexibility as possible in terms of apron size and configuration in order to potentially accommodate, when feasible, aircraft/activity outside of the forecasted fleet (larger or smaller).

2. Geometric Design Criteria

The proponent's plan must precisely indicate the geometric design criteria used for airside elements based on the Design Aircraft and Fleet Mix submitted to the Port Authority for review and approval.

a. Apron Depth:

Adequate apron depth must be provided to fully accommodate parked aircraft within the apron area. Based on the proposed apron configuration, the Apron Depth is defined as follows:

1. For aprons with both a tail-of-stand (TOS) and a head-of-stand (HOS) roads: distance from edge of HOS to edge of TOS;
2. For aprons with no tail-of-stand road: distance from edge of HOS to the tail of the design group aircraft, plus 5 feet;
3. For aprons with no head-of-stand road: distance from edge of apron (edge of terminal building plus 10 feet) to the edge of TOS.

The following table lists the Port Authority Minimum Criteria for any proposed airside development at PANYNJ airports:

Port Authority Minimum Standards – Apron Design			
	Apron Depth	Aircraft Nose to Head-of-Stand road or edge of apron*	Aircraft Nose to Building
ADG-II (Regional Jets)	175 feet	24 feet	34 feet
ADG-III	175 feet ¹	24 feet	34 feet
ADG-IV	230 feet	24 feet	34 feet
ADG-V	275 feet ²	27 feet	37 feet
ADG-VI	275 feet ³	27 feet	37 feet
Notes: * Edge of apron is defined as edge of terminal building plus 10 feet 1. If MD90 aircraft including in fleet mix, use 180 feet 2. If A340-600 used in fleet mix, use 280 feet 3. If B747-8 and/or B777-9X included in fleet mix, use 285 feet 4. As new, longer aircraft might have come to market after the release of this manual, the developer should always ensure that the apron depth is not less than the design aircraft length, plus the distance shown in the “Aircraft Nose to Head-of-Stand road” column, plus an additional tail clearance of 5 feet. For aprons with no head-of-stand road, the apron depth should not be less than the design aircraft length, plus the distance shown in the “Aircraft Nose to Building” column, plus an additional tail clearance of 5 feet.			

Table 3: PA Minimum Standards for Apron Design

b. Aircraft Clearances

Adequate aircraft clearances must be provided in order to ensure safe and efficient apron operations for aircraft maneuvering and servicing. The table below lists the Port Authority Minimum Criteria for any proposed airside development at PANYNJ airports:

Port Authority Minimum Standards – Aircraft Clearances on Apron						
	Parked Aircraft (stationary)			Aircraft in Motion ³		
	Wingtip Clearance between Parked Aircraft	Wingtip Clearance to Airport-Wide Service Road ¹	Distance between Aircraft and Tail-of-Stand or any other apron road ²	Wingtip Clearance to any fixed or movable object/vehicle Aircraft on Taxilane (FAA AC 150/5300-13A, Table 4-1)	Wingtip Clearance to any fixed or movable object/vehicle Aircraft on its own power between Taxilane and Gate [power-in]	Wingtip Clearance to any fixed or movable object/vehicle Tow operations only [pushback/tow-in] Aircraft not on its own power and with Wing Walkers
ADG-II (Regional Jets)	25 feet	10 feet	5 feet	18 feet	25 feet	15 feet
ADG-III	25 feet	10 feet	5 feet	22 feet	25 feet	15 feet
ADG-IV	25 feet	10 feet	5 feet	27 feet	25 feet	15 feet
ADG-V	25 feet	10 feet	5 feet	31 feet	25 feet	15 feet
ADG-VI	25 feet	10 feet	5 feet	36 feet	25 feet	15 feet

Table 4: PA Minimum Standards for Aircraft Clearances

Notes:

1. Airport-wide service roads are generally used by all ground vehicles at the airport, and can be either located in the movement or non-movement area. Please consult Port Authority before starting any analysis in order to identify the portions of the airport-wide service road that may be impacted by the proposed developments.
2. Apron service roads are primarily used by ground service equipment in close proximity of the contact gates and hardstands they are serving. Apron service roads are located within the non-movement area, and are usually not controlled by the Air Traffic Control tower.
3. Aircraft maneuvering plans must be submitted to the Port Authority in order to review and approve the proposed plans' compliance with these minimum standards. Please refer to the concept of operations section for further guidance on the development of the maneuvering plans.

c. Aircraft Safety Envelope and Jet Engine Intake Zone

Aircraft safety envelopes define the areas where no vehicles or GSE should be positioned unless they are specifically servicing the aircraft occupying that particular gate. The area outside of the aircraft parking and service envelopes and outside of the passenger boarding bridges (PBB) operational ranges, up to the building face, can be used for GSE parking and storage and other apron activities.

The envelopes should accommodate a safety zone around jet engine intakes to avoid adverse engine suction on personnel and equipment. Aircraft manufacturers provide information on the recommended safety zones around engines when idling. These markings are typically solid red bordered in white to provide additional contrast between the marking and the pavement. Many cargo operators use only white markings to identify the aircraft safety envelope. 10 feet is the minimum distance that the safety envelopes should protect from any point on the aircraft.

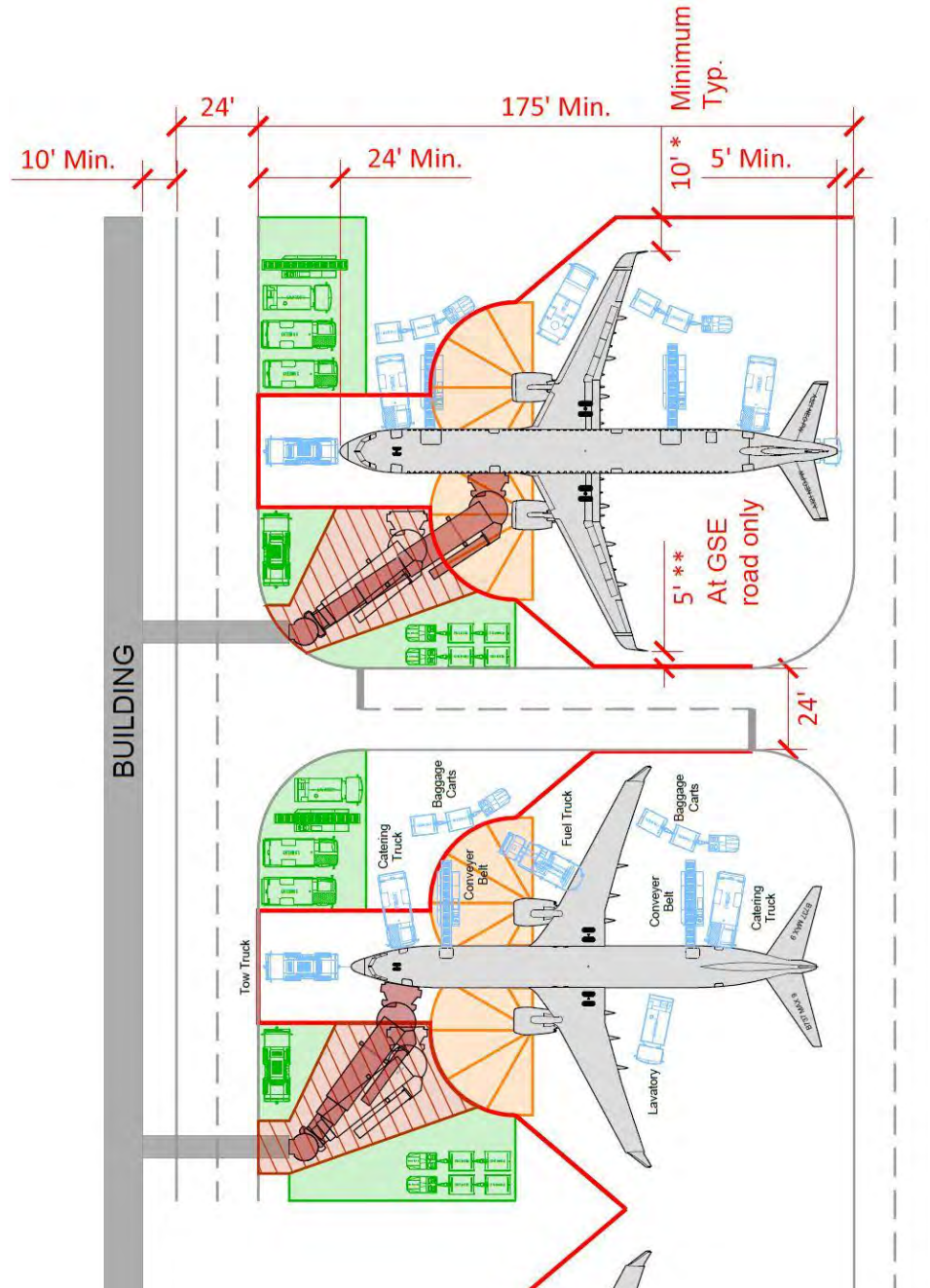


Figure 13: Typical Gate Layout for Group-III Aircraft (with head-of-stand road)
[The figure is given for illustration purposes only]

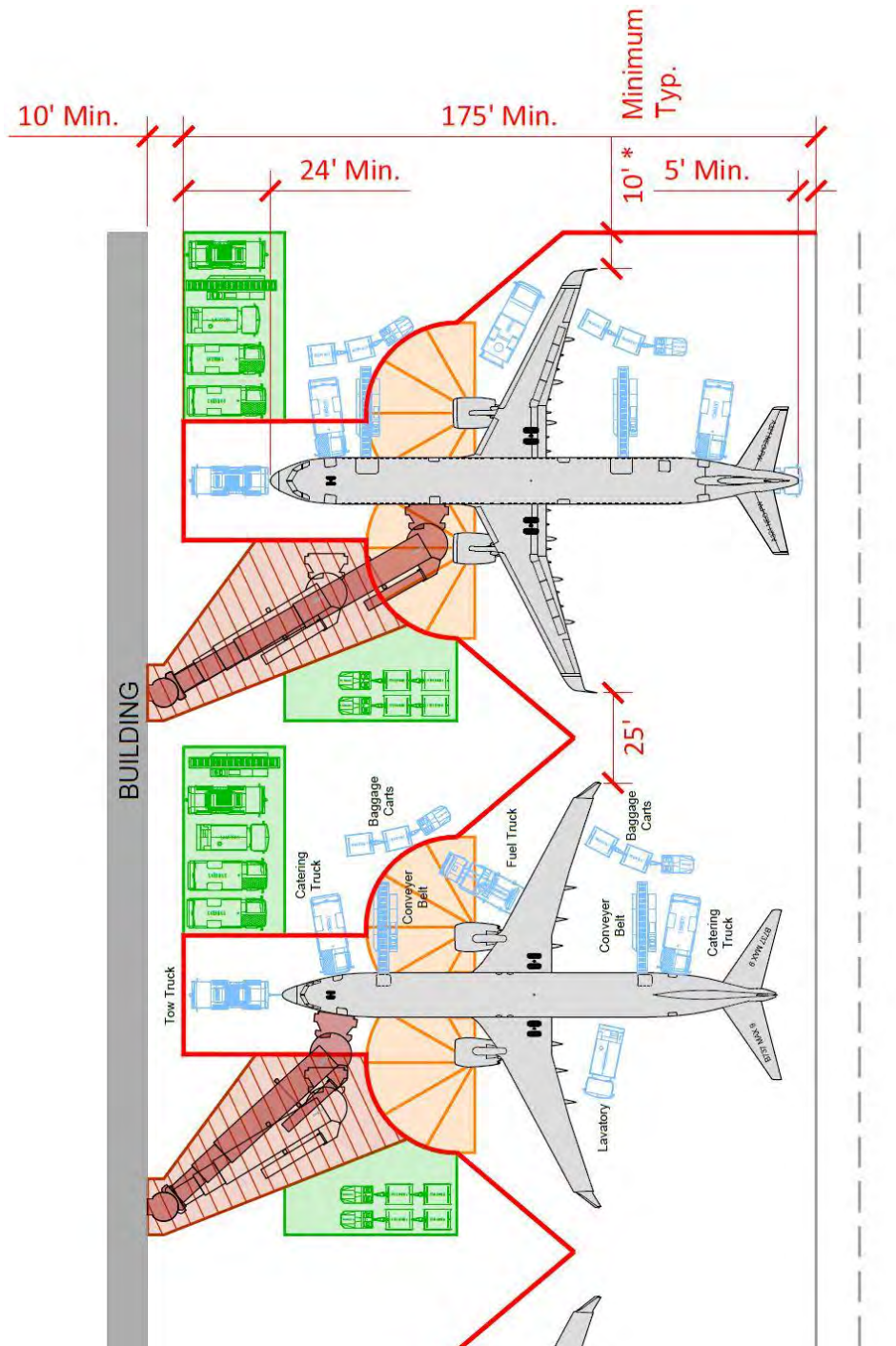


Figure 14: Typical Gate Layout for Group-III Aircraft (without head-of-stand road)
[The figure is given for illustration purposes only]

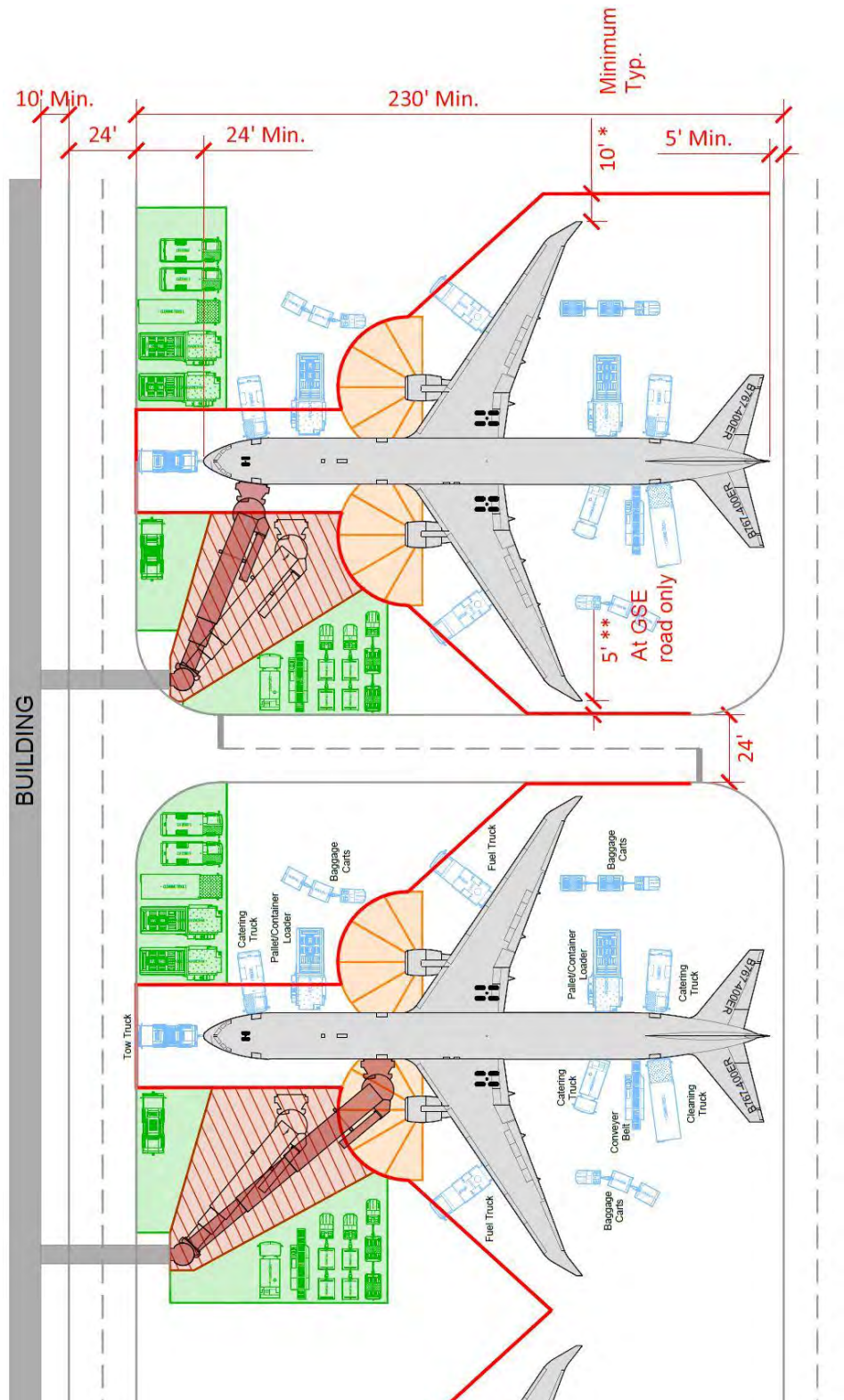


Figure 15: Typical Gate Layout for Group-IV Aircraft (with head-of-stand road)
[The figure is given for illustration purposes only]

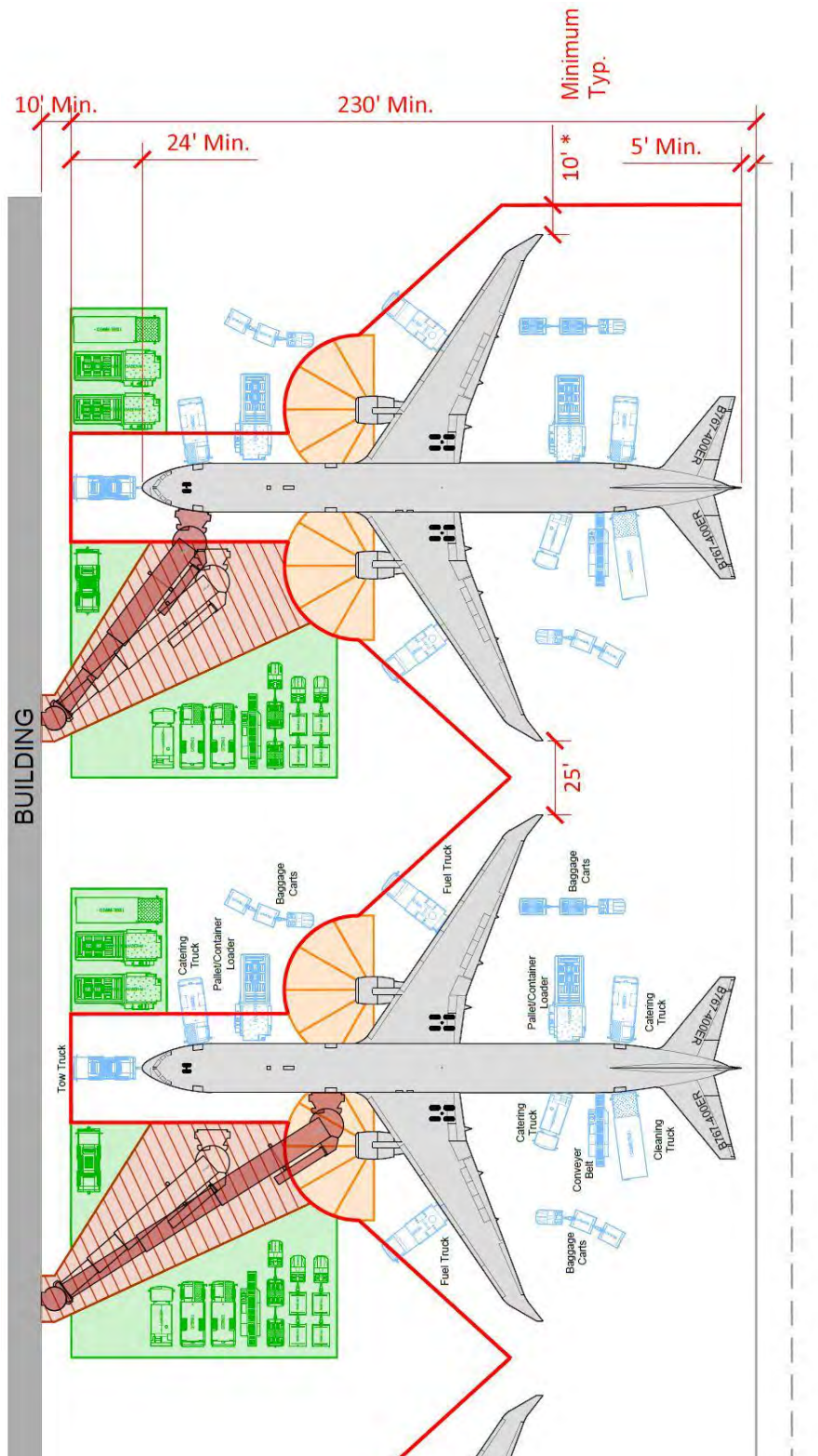


Figure 16: Typical Gate Layout for Group-IV Aircraft (without head-of-stand road)
 [The figure is given for illustration purposes only]

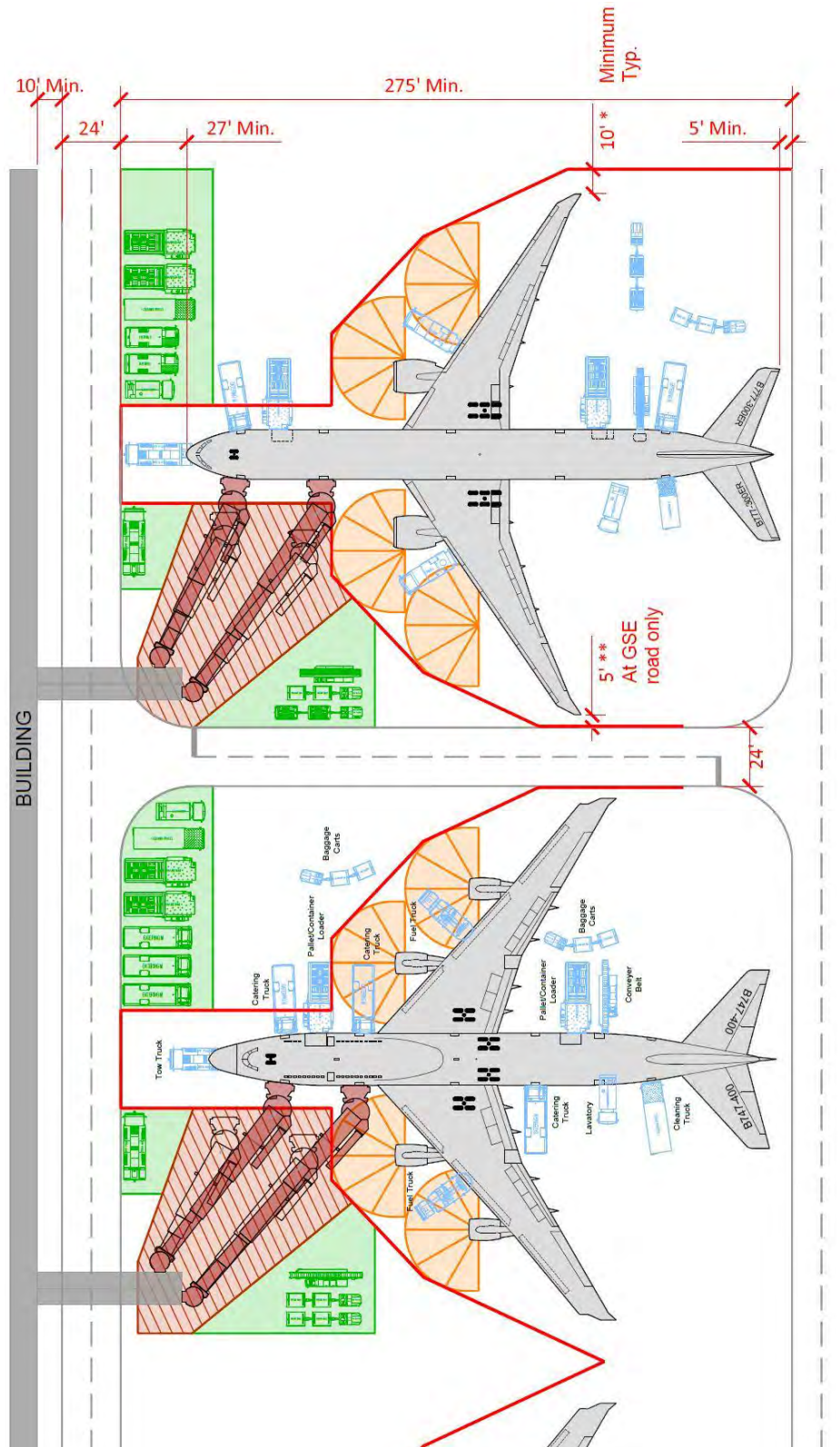


Figure 17: Typical Gate Layout for Group-V Aircraft (with head-of-stand road)
[The figure is given for illustration purposes only]



d. Live Hardstand Positions

“Live Hardstands” are defined by the Port Authority as any airside parking position where an aircraft operator loads and/or unloads passengers, regardless of the type of flight (scheduled or unscheduled) and the size of the aircraft.

For planning purposes, the use of live hardstands on a permanent basis is prohibited at the Port Authority airports. Any proposed plan considering the use of live hardstand operations must demonstrate the temporary need for them, by assessing all alternative options and justify that none of them meet the program’s objectives and requirements. Any plan for live hardstand operations must be submitted to the Port Authority for review and approval in the early planning stages of the project.

While all the geometric design criteria presented in this section must be met for live hardstand positions, the following additional requirements need to be considered for the temporary use of live hardstands:

- Aircraft engine must not be in use when passengers are boarding or deboarding the aircraft
- Passengers walking on the apron must be escorted at all times for security purposes
- For passengers walking on the apron, jetblast protection shall be provided from other aircraft operating in the vicinity
- Additional requirements may be prescribed by the Port Authority for night and winter season operations on a per-project basis.

3. Taxilane Layout Requirements (Dual-Taxilane)

As a general guidance, all proposed new apron or apron expansion should provide dual taxilanes for the critical aircraft in order to allow for simultaneous push-back of adjacent aircraft and by-pass ability for arriving aircraft during departing aircraft pushback.

The Port Authority does not recommend the use of single taxilanes on aprons that serve more than eight contact gates.

Where the implementation of dual taxilanes is not feasible, the proponent must consult with Port Authority Aviation Planning Division for review of the proposed alternatives.

4. Gate Equipment



Figure 19: Passenger Boarding Bridges

- a. Passenger Boarding Bridges (PBB) and Fixed Walkways:
1. PBBs should be positioned to maintain maximum flexibility to accommodate as many aircraft types as possible (in alignment with the mix of aircraft). PBBs should also be sited and specified so that the slope of the bridge is not greater than 1:12 for the gate's mix of aircraft.⁸
 2. PBB and Fixed Bridge Analysis must be incorporated as part of any proposed plan. The following information shall be depicted in the Aircraft Layout Plan drawing set for each gate (existing and proposed):
 - i. PBB Equipment Manufacturer and Model
 - ii. Operational ranges
 - iii. Rotunda heights
 - iv. Summary of aircraft to be serviced at each gate with PBB lengths and actual slopes realized for each aircraft type.
 - v. PBB-mounted equipment serving the parked aircraft such as preconditioned air (PCA), ground power, and potable water

⁸ FAA AC 150/5360-13A

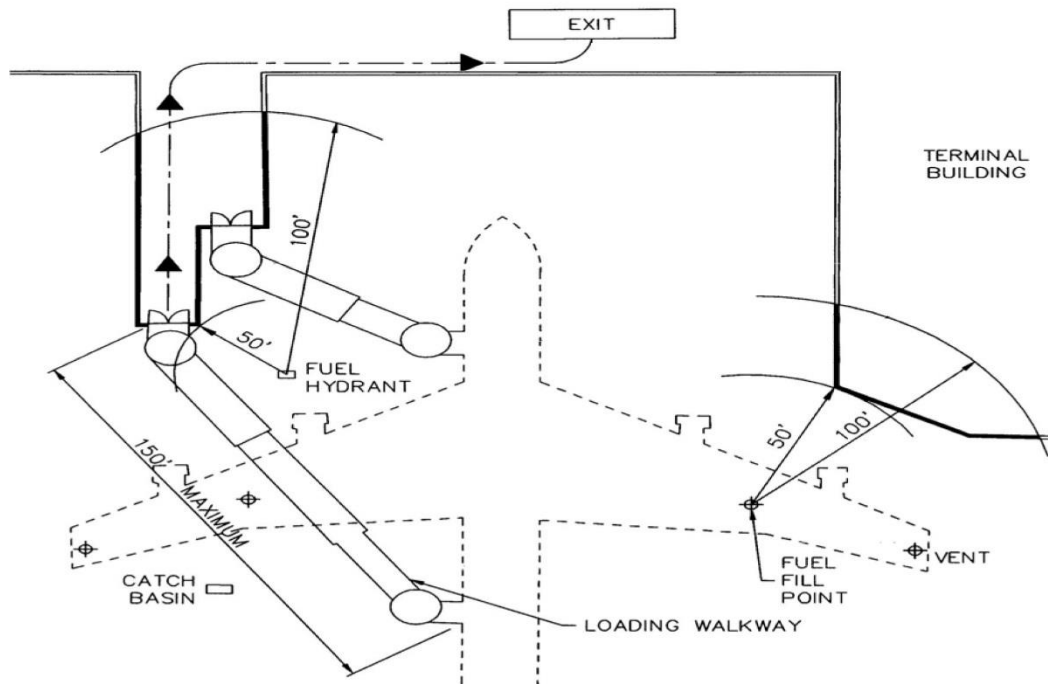


Figure 20: Airport Rampside Clearances

3. For new facilities the PBBs shall be designed and proven capable of servicing all specified aircraft without the use of manually-placed, doorsill transition ramps.
4. The PBB shall be capable of negotiating doors, stairs, fuselage diameters, Pitot tubes, TAT sensors, AOA probes, antennas, etc. for all specified aircraft, in a safe and commercially acceptable manner without the use or aid of a separate ramp.
5. Gates that are to be used by ADG-V aircraft for over 40% of daily operations as shown by the design day flight schedule (DDFS), shall have two passenger boarding bridges installed. Gates servicing high density ADG-VI aircraft shall have three passenger boarding bridges installed.
6. Port Authority requires that gate signs are mounted on each PBB included in the proposed plan.
7. The positive pressure ventilation fan shall be of sufficient capacity to provide and maintain a positive pressure throughout the bridge and shall be automatically activated anytime that an aircraft is at the bridge.
8. PBB design must be compliant with NFPA requirements and should be submitted to Port Authority for review and approval.
9. The design shall provide a safe exit route from the aircraft for a period of at least five (5) minutes under severe fire exposure conditions, equivalent to a free-burning jet fuel spill fire, in compliance with NFPA 415. The Engineer-of-record shall certify compliance in writing and submit the test reports and computations as defined in NFPA 415 to demonstrate compliance.
10. Loading Walkways shall be designed to prevent sudden failure (collapse, explosion, or development of excessive smoke and gases) during the ten (10) minute test.

11. Walkways shall comply with the following:

- i. A maximum combined travel length of passenger boarding bridge and fixed walkway shall not exceed 150 feet. Portions of fixed walkway exceeding 150 feet shall be designed as part of the terminal building.
- ii. A minimum width of 44 inches or the width of the aircraft door being served, whichever is larger.
- iii. Non-slip floor covering
- iv. Emergency lighting.
- v. Light diffusers of plastic material shall be of an approved type for exits, or wired glass shall be used.

12. Compliance shall include:

- i. Structural integrity of the walkway under the fire conditions.
- ii. Integrity of flexible closures, slat curtains, and miscellaneous seals with weather-stripping curtain with respect to smoke penetration through cracks and openings shall be established.
- iii. Particular attention must be paid to the following details:
 - There shall be no direct path for flame or smoke between the exterior and the interior of the bridge.
 - The junctures of bridge components, such as hinge pins and slat curtains, shall be covered or sealed with appropriate fire-resistant material.
- iv. The positive pressure ventilation fan shall be of sufficient capacity to provide and maintain a positive pressure throughout the bridge and shall be automatically activated anytime that an aircraft is at the bridge.

13. The door opening into the walkway shall have an electrical interlock to prevent opening until the passenger boarding bridge is engaged with the aircraft.

14. The aircraft loading walkway shall not be located over any drainage outlets. See NFPA 415.

15. The electrical installation shall comply with the applicable requirements of the National Electrical Code, particularly with the Hazard requirements; i.e., presence of flammable vapors from aircraft fueling, venting, and storage points.

16. For fixed walkways, minimum height cannot be lower than 7 feet 6 inches.

b. Ground Power

1. Ground Power must be provided at each gate with capability to service the existing and forecast fleet mix.

c. Preconditioned Air (PCA)

1. Preconditioned Air (PCA) must be provided at each gate with capability to service the existing and forecast fleet mix.

- d. Potable Water Cabinets (PWC)
 - 1. Potable Water Cabinets (PWC) must be must be provided at each gate with capability to service the existing and forecast fleet mix.
- e. Visual Docking Guidance Systems (VDGS)
 - 1. Automated VDGS must be provided for each lead-in line
 - 2. A summary of the type and utility requirements for each VGDS must be included as part of the proposed plan.
- f. Ramp Information Display System (RIDS)
 - 1. Automated VDGS must be provided for each lead-in line
 - 2. The VDGS system must include ramp information within the display unit (RIDS). The RIDS can be integrated with the terminal gate operating system as needed.
 - 3. A summary of the type and utility requirements for each VGDS must be included as part of the proposed plan.
- g. Emergency Egress Zone
 - 1. Emergency egress zones must be provided at the terminal façade to permit adequate clearance for terminal egress.
- h. Ground Service Equipment Considerations (GSE)
 - 1. Proposed plans must demonstrate that that there is adequate apron space to support typical Ground Servicing Equipment (GSE) storage and staging. At the project planning stage, the following information must be provided to the Port Authority for review and approval:
 - i. Program requirements for GSE support and maintenance, including a detailed list of equipment;
 - ii. Dedicated areas for parking:
 - 1. Staging/parking areas for day-to-day operations
 - 2. Parking of seasonal equipment
 - 2. Note: Port Authority may require vehicle maneuvering plans for some areas of concern.
- i. Apron Striping
 - 1. Apron striping for all gates must be provided to the Port Authority for review and approval:
 - i. Lead-in lines: proposed aircraft layout plans should aim at providing one lead-in line at each gate;
 - ii. Stop bars: proposed aircraft layout plans should aim at minimizing the number of stop bars required at each gate.

5. Aviation Services

a. Planning and Design

To mitigate inherent risk to passengers, refueling is normally performed on the side opposite passenger loading, i.e., the right side of the aircraft. However, this may vary depending on where the refueling points are located on the aircraft.

b. Regulatory Issues

Aircraft refueling facilities and ramps must be designed in accordance with National Fire Protection Association (NFPA) 407, *Standard for Aircraft Fuel Servicing*, and NFPA 415, *Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways*. Specific planning and design related guidance from these documents is as follows:

1. If possible, potential fuel spill points (pfsp) should be designed to be at least 100 feet away from the terminal or other buildings walls. When this is not possible, the use of glass or other glazing materials in the terminal or other buildings walls facing the apron should be avoided.
2. Large areas of window glass, covering more than 50% of a wall and located at a distance of less than 100 feet from a potential fuel spill point (pfsp), shall be protected by an automatic water curtain system or fire shutters activated by an appropriate fire detection system. In determining the previous percentages, only that portion of the wall not backed by the building's structural components should be included. The distances from the pfsp shall be measured horizontally to the center of the wall. This provision does not apply if openings covered with glazing material are listed for use in fire barrier and are installed in accordance with listing, or if the openings have the glazing material not less than 7 feet above each finished floor level.⁹
3. There shall be no pfsp such as fueling hydrants, catch basins, fuel tank fill connections, etc., within 50 feet of the building.¹⁰

The 100 foot rule against non-protected glazing was put in place because, although a fuel-spill fire may not reach the building, the intense radiant heat from a large jet fuel fire can cause the glass surface facing the fire to heat up several hundred degrees, while the interior surface remains cool, causing great internal stresses within the glass which cause it to shatter, leaving the interior of the building exposed to the intense radiant heat.

Potential fuel spill points considered for the 100 foot rule includes any of the following:

- Aircraft refueling points and fuel venting points, whether or not they are on the side routinely used for refueling
- Underground refueling system hydrants (also known as “fuel pits”)
- Refueling bowsers

⁹ NFPA 415, 4.1.5.1 - 4.1.5.3

¹⁰ NFPA 415, C1

- Apron drainage structures including catch basins and trench drains

c. Hydrant Fueling

Hydrant fuel system is an underground utility that is connected to a fuel farm. Under this concept fuel pits are installed at each aircraft position allowing smaller fueling vehicles to connect the fueling system to aircraft fuel intake points. A hydrant system fueling concept should be developed for any proposed airside development and should be submitted to the Port Authority for review and approval. Proposed concepts should identify areas where hydrant fueling systems will connect to the Port Authority system.

Proponents should provide fuel capacity requirements to the Port Authority based on the project specifications.



Figure 21: Hydrant Aircraft Fueling Operation¹¹

d. Bowser Fueling

This section covers planning and design guidance associated with aircraft refueling via tanker trucks, also known as “bowsers.” Bowsers are used if an underground hydrant system is not possible to provide, or is present but not functioning.

When refueling via bowsers, the positioning of the bowser should be based on the aircraft type.

¹¹ Refuel International



Figure 22: Bowser Fueling Operation

For B757, FAA Airplane Design Group III (ADG-III), and smaller aircraft, the truck should be positioned at the wingtip of the aircraft, at the edge of the wingtip clearance zone, also known as stand safety envelope. The stand should be configured so that this refueling position does not interfere with other aircraft servicing operations. The safety envelope should account for the refueling operations, because the refueling truck is considered an obstacle for the adjacent stand. The bowser should be parked facing away from the terminal, to allow for fast evacuation in case of an emergency; this is especially critical if a head-of-stand (HOS) apron service road is not available, and the bowser would be forced to make a multi-point turn or reverse away from the stand quickly.

When refueling widebody aircraft, the bowser can be positioned in front of the aircraft wing. As with smaller aircraft, the bowser should always be parked facing away from the terminal in order to be able to make a quick evacuation in case of emergency.

e. GSE Fueling/Charging

1. Proposed plan should indicate location for GSE fueling and charging.
2. Proponent should indicate share of electric-powered GSE.

f. Aircraft Deicing and Glycol Recovery

1. The proposed airside design must indicate the areas on the apron designated as deicing areas.
2. For each deicing designated area, the glycol collection system must be depicted and the specifications documented. In addition, calculation for peak hour demand during typical and heavy deicing events must be provided for Port Authority review and approval.
3. Glycol storage and dispensing plans must be provided.

g. Snow Melters Discharge

1. Strategy for snow melting, including list of equipment must be provided to Port Authority.

2. Snow storage area locations need to be identified in the proposed plans. The snow melting equipment should be connected to storm drainage.
3. A dedicated interface to storm drainage utilities for discharge must be provided.
4. Discharge from portable snow melters must be done via a designated chamber, or series of chambers within the storm water drainage system, which are to be specifically designed to accommodate the discharge.
5. The calculation of acreage and equipment capacity required must be submitted to the Port Authority for review and approval.

h. Triturator Facilities

1. Triturator facilities must be designed to provide disposal from aircraft bulk tanks into the sanitary sewer system.
2. The proposed facility must be fully enclosed in order to prevent undesirable odors and should be strategically located for access by toilet service vehicles.



Figure 23: Aircraft Ground Handling

6. Aircraft Jetblast Considerations

The effects of extreme heat and air velocities from aircraft jet and propeller engines must be considered when planning apron areas and adjacent service roads and buildings. Velocities greater than 30 mph can pose a threat to personnel, airport equipment, and facilities, as well as airfield pavement and erosion of unprotected soil along the edge of pavements. In addition, high velocities can cause sand, gravel, or other loose objects to become projectiles and be thrown for great distances or drawn into engines. Such flying objects can injure personnel and damage equipment, facilities and other aircraft. This chapter details the design considerations that need to be undertaken to minimize the effects of jet blast.

a. Design Thrust Levels

Most the areas adjacent to aircraft movement areas will be subject to jet blast of some level. There are three types of engine thrust that are commonly used to assess the critical velocities for use in building, apron, and taxiway/runway design.

1. Idle thrust

Nearly all facilities adjacent to aircraft movement areas will be subjected to idle thrust. Idle thrust is used when the aircraft is idling, or taxiing at constant, low speed.

2. Breakaway thrust

Breakaway thrust is the level of thrust needed to overcome inertia and initiate aircraft taxi movement. For most jet engines, it is generally 30-40% of maximum continuous thrust, depending on aircraft weight and taxiway gradient. Areas typically designed for breakaway thrust may include terminal buildings, apron and taxiway shoulders, holding bays and all pavements except for the runways.

3. Take-off thrust

Aircraft use 80-100% of maximum continuous thrust during take-off, and thus the runway pavement, shoulders and ends (blast pads) would be designed for this thrust level.

Aircraft manufacturers provide information on the exhaust velocities and temperatures for the three engine thrust settings described above, including horizontal and vertical jet blast velocity contours. This information is used when designing for jet blast mitigation measures.

b. Blast Fences

Blast fences are the most effective measure against jet blast effects. Blast fences are used to reduce or eliminate the detrimental effects of blast by deflecting the high air velocities, heat and noise associated with jet blast. Blast fences must be considered when it is impractical to provide a safe reasonable separation between aircraft engines and people, buildings or other objects on the airport. In addition, blast fences must be considered near runway ends, etc., to protect on and off-airport pedestrian and vehicular traffic from jet blast.

To determine where blast fences should be located all the possible aircraft movement patterns must be established. Each segment of the aircraft movement area, including the aprons, taxiways, holding bays and runways must be analyzed to determine the magnitude and all possible orientations for blast in that particular location.

Factors such as the location, purpose, aircraft fleet, height, etc. will influence the selection of the design of the blast fence.

The need and location of blast fences in the apron areas must be determined based on the movement pattern of the aircraft taxiing, entering or exiting aircraft stands, or aircraft parking area, when using their own power. Additional attention must be given to stands where passengers walk the apron to board the aircraft, because passengers are not trained to expect jet blast.

c. Other Types of Jet Blast Protection

Blast fences are the most effective means of jet blast protection. However, jet blast protection can be achieved by using other methods and materials. Natural or manmade obstructions located between the jet blast source and the area to be protected affords some level of protection. In areas where jet blast cannot be mitigated by a physical fence, other measures such as operational restrictions must be submitted to the Port Authority for review and approval.

d. Apron and Hardstand Considerations

When designing apron, taxilane, and taxiway areas, the design aircraft's blast contours provided by the aircraft or engine manufacturer must be analyzed to determine the jet blast impact to adjacent areas. Aprons and hardstands design must consider breakaway thrust even when only idle thrust is expected, because an aircraft may be required to stop taxiing unexpectedly at any location, and must be able to re-start taxiing using breakaway thrust; this includes aircraft taxiing into a gate. A safety review must be performed on turbojet aircraft departing their gate performing a powered turning maneuver onto the taxiway/taxilane (known as "power-out" from a gate). Additional jet blast hazards may be created when an aircraft executes a turning maneuver of 45 degrees or more from the gate/hardstand¹².

e. Velocity Exposure Rates

In general, maximum allowable jet blast velocities should not exceed the intensities listed below. Designers should review these, along with the velocities listed in FAA AC 150/5300/13A, Appendix 3, section A3-6(c) "Velocity Exposure Rates", and apply the more stringent requirement.

1. Recommended 20 mph, for all areas where members of the general public may be present, including passengers boarding aircraft at hardstands.
2. 35 mph, for apron areas where persons who are trained in air operations area (AOA) safety precautions, including the expectation of occasional exposure to jet blast are present.
3. 50 mph, for apron areas where no persons would be present in the open, but persons may be within enclosed vehicles.

For all areas with jet blast impacts, mitigation measures should be proposed as part of the development plan and shall be submitted for reviewed and approval by the Port Authority.

Appropriate mitigation measures include jet blast deflection fences, as described in FAA AC 150/5300-13A or ICAO Doc. 9157, Aerodrome Design Manual, Part 2 and special operational procedures.

7. Airside Pavement and Grading

a. Apron Grading:

1. Apron grading must be in accordance with FAA AC 150/5300-13A "Airport Design" and NFPA 415 "Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways."
2. Consideration for collection of runoff and drainage from must be included in proposed plans.
3. Proposed plans must indicate limits of apron pavement and the different pavement types between the proposed terminal building and the outer edge of the TOS roadway. Isolated "low-points" at catch basins or trench drains should be located outside of the parking area.

¹² NASA/Aviation Safety Reporting System [ASRS] Directline Issue No. 6, August 1993, Ground Jet Blast Hazard

b. Apron Paving

1. A pavement condition evaluation as well as of a future needs assessment must be performed based on the mix of aircraft using each pavement area.
2. The type of pavement used for each airside element (e.g., taxilane, TOS roadway) must be indicated.

c. Apron Slopes

1. Aircraft apron slopes should not exceed 1%. Fueling aprons shall slope away from the terminal with a minimum slope of 1% for the first 50 ft. Beyond the distance of 50 feet, a slope of 0.5% is permitted.
2. Transverse slopes across aprons should not exceed 1:200

8. Apron Floodlighting

Floodlighting is provided at aircraft parking and servicing areas (aprons) adjacent to the terminal (gates), and away from the terminal (remote stands, cargo stands, etc.) to assist the pilots in taxiing the aircraft into and out of the final parking position; provide suitable lighting for passengers to embark and debark; provide the personnel performing aircraft servicing work with a safe and workable level of illumination to move about, perform their tasks, and discern objects and hazards; and ensure airport security.

a. Reference Documents

- *FAA AC 150/5300-13A - Airport Design*
- Illuminating Engineering Society of North America (IESNA) Recommended Practice (RP) 37-15, *Outdoor Lighting for Airport Environments*
- *ICAO Aerodrome Design Manual (Doc 9157), Part 4*

b. Planning and Design Approach

A strategy for apron floodlighting and calculations must be provided to show that the proposal meets the requirements. Criteria that will be used to design apron floodlighting must be indicated in proposed plans.

Primary consideration must be given to the newest types of LED apron floodlights, which are energy efficient, have good color rendition, and can be more precisely focused.

During design work consideration must be given to the physical characteristics of the site, including:

- The movement and the physical characteristics of the aircraft to be served
- The maneuvering, staging, and location of ground service equipment
- Apron service roads
- Underground utilities
- The dimensional relationships of parked aircraft to terminal building
- The safety, security, and operational practices related to apron control

The apron must be lighted uniformly, and the illumination levels must comply with the IESNA RP-37-15 “*Outdoor Lighting for Airport Environments*” recommendations. Floodlighting calculations must be submitted to the Port Authority for review and approval. The following criteria must be adhered to:

1. Floodlighting must be adequate for personnel performing various tasks at aprons including baggage and catering loading and unloading, mechanical checks and pre-flight inspections, fueling operations, etc. Supplemental lighting must be provided for tasks that require high color rendering index (CRI) light source, where workers need to see and distinguish colors clearly.
2. Night-time illumination levels at aircraft apron must be a minimum of 2 foot-candles (~22 lux), with an average-to-minimum uniformity ratio of 4:1 maximum.
3. The design must consider the dimensions of various aircraft types using the apron stands.
4. The light angle and shielding of glare must be considered to assure there is not impact on aircraft landing, takeoff, or taxiing operations.
5. To minimize direct and indirect glare, mounting heights for floodlights must be at least two times the maximum eye level of the cockpit of aircraft regularly using the airport.
6. Spill light from the aircraft stand must be limited to 5% of the average illumination in the aircraft parked position measured vertically at 6 feet above the ground at either the farthest edge of the apron service road behind the aircraft, or 49 feet from the tail of the aircraft if no apron service road is present.
7. The location of the floodlights must take into consideration the dimensions of the apron and the arrangement of aircraft stands.
8. All floodlighting on the apron must be placed at a level that is adequately adjusted and shielded to prevent interference with air traffic control and aircraft operations, without reducing necessary illumination of critical areas, as required by the FAA regulations.
9. The location and height of light masts must be placed to keep inconvenience to ground personnel due to glare at a minimum but to provide desired illumination levels.
10. High mast poles or towers used for supporting high output floodlights must be located between the individual aircraft parking stands, with light being directed to both sides. It is preferred that poles are equally spaced to achieve the most desirable uniformity.
11. Light distribution must be such that all colors used for aircraft markings can be correctly identified.
12. Adequate exterior lighting must be provided to allow the jet bridge operator to safely maneuver the bridge into position to dock to the aircraft. All limits of boarding bridge movement must be considered when locating light poles.
13. Light must be projected to each aircraft stand from at least two or more directions to decrease shadows.

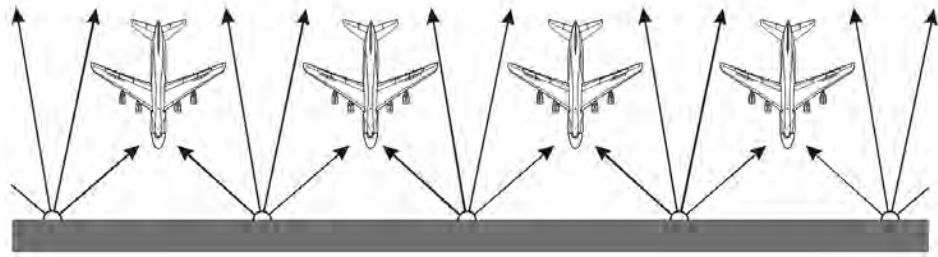


Figure 24: Typical floodlight arrangement and aiming for nose-in parking¹³.

14. Supplemental lighting must be provided for tasks that take place in areas where shadows cannot be avoided, such as under-the-body pre-flight inspections.
15. Emergency backup power supply must be provided for apron floodlighting. Emergency backup power must be designed to engage automatically in case of a main power failure.
16. When designing light poles, maintenance and accessibility must be taken into consideration.

c. Designated Deicing Facilities Floodlighting

1. Night-time illumination levels must be a minimum of 5 foot-candles (50 lux).
2. Adequate lighting for visual inspection of all the aircraft surfaces for ice must be provided.
3. Considerable vapor clouds can be generated when deicing fluid is sprayed on, which reduces the visibility in the designated deicing facility area. Designers must take this into account.
4. Floodlighting structures at designated deicing facilities must not generate distracting glare light that affects pilots or air traffic controllers.
5. FAA review and approval is required for deicing facilities located in close proximity to runways, where floodlighting could be distracting or confusing to pilots.

9. Aircraft Engine Startup Positions

- a. All aircraft engine startup positions must be identified on the proposed terminal area taxilanes. All startup procedures must remain within the non-movement area and should not impact the movement area.
- b. All startup positions must operate independently of each other.
- c. Restrictions to specific aircraft types must be documented (e.g., due to jetblast effects)

¹³ ICAO Aerodrome Design Manual (Doc 9157), Part 4

10. Restricted Service Roads

This section describes restricted service roads (RSR), which are generally designated via striping across the paved airside elements including aprons, taxilanes, taxiways, and other movement and non-movement areas.

The PANYNJ has established two distinct types of RSR:

- Airport wide access roads, which accommodate all types of vehicles including large trucks, which are comprised of two lanes 15 feet each (30 feet total).
- Apron service roads, which primarily accommodate aircraft servicing vehicles, which are comprised of two lanes 12 feet each (24 feet total).

“Zipper” dashed road markings must be used when any airside road crosses, or has a portion of a lane within, a taxiway or taxilane obstacle free area (OFA). This is done to increase driver awareness of taxiing or maneuvering aircraft. For new developments use of “Zipper” roads should be minimized to the extent possible. When unavoidable proposed “Zipper” road installations will be reviewed by the Port Authority on a case by case basis.

The image below shows the two types of airside roads, including portions with zipper striping.

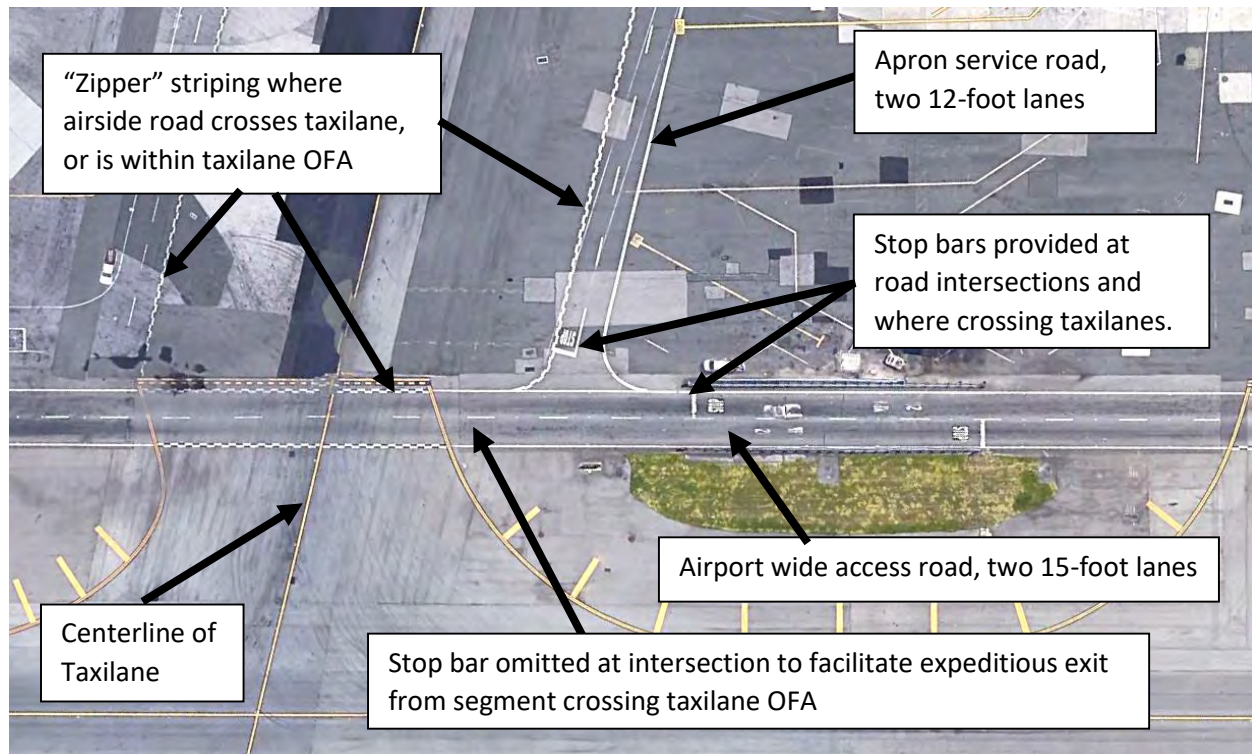


Figure 25: RSR image from JFK Airport

a. Planning and Design Criteria

1. RSR horizontal and vertical geometry must meet the Port Authority's Civil Engineering Design Guidelines. The design speed for common access roads is 25 mph.

2. The design vehicle to be airport specific and determined by the Port Authority.
3. Sight distances for each of the roadway speeds must meet the standards of Section 3.2.1 AASHTO: A Policy on Geometric Design of Highway and Streets.
4. Curve widening must be applied over the length of the horizontal transition curve. The design widths for curve widening will be for both the super elevation runoff length as well as required sight distance per ASHTO: A Policy on Geometric Design of Highway and Streets.
5. “Stop” bars and “Stop” markings must be used at RSR intersections and when the RSR cross a taxilane or taxiway.

11. Airside Utilities

[Section under development]

12. Aircraft Deicing

Aircraft deicing is a critical operation for any airport in climate zones subject to freezing conditions. Deicing involves spraying an aircraft with a deicing fluid (usually glycol-based) that remains liquid at temperatures well below the freezing point of water so that liquid water and water ice are washed away/melted and replaced with deicing fluid on aircraft surfaces. This reduces the likelihood of ice altering airflow over the wing and tail, decreasing the lift force and potentially causing aerodynamic stall. It also reduces the likelihood that moving parts of the aircraft (e.g., ailerons, flaps) will become dangerously immobilized by ice. Deicing must be done relatively shortly before takeoff, especially in a heavy snowstorm, so that the deicing fluid does not run off or evaporate and get replaced by water, snow, or ice.

The deicing run-off will be captured and stored for discharged off-site for treatment or recycling. Deicing run-off discharge into the airport’s stormwater drainage system is not permitted.

Developers must submit a detailed deicing plan and concept of operations, including but not limited to: calculations of peak hour and peak day aircraft deicing demand; glycol storage facility plan with glycol demand/capacity calculations for both discharge (usage) and storage; and spent fluid collection, storage, facility plan and capacity calculation; and spent fluid discharge to off-site treatment.

a. Designated Deicing Facilities

It is Port Authority’s policy that aircraft deicing is to be done at designated deicing facilities. Designated deicing facilities should be established within project lease lines on aprons, taxilanes, or just outside the terminal gate area. They can be simple aprons with deicer-laden runoff collection capabilities or technologically advanced facilities with electronics that monitor everything from aircraft positioning to glycol concentrations in the runoff collection system. Planning considerations should minimize deicing at gates unless approved by the Port Authority.

b. Site Planning and Design

New terminal developments must include designated deicing facilities sized to handle proposed terminal demand. Site-specific issues such as available area, drainage and deicing fluid collection infrastructure, prevailing wind conditions, and jet blast should be considered when planning designated deicing facilities. Proximity to and queuing for take-off runways must also be considered. These should include

taxiing time that begins with the start of the last step of the deicing/anti-icing treatment and ends with takeoff clearance, such that the holdover times of applied fluids are still in effect.¹⁴

An ideally-planned designated deicing facility will have positions for multiple simultaneous deicing operations, allow aircraft to taxi-in / taxi-out in a one-way, flow-through setup. Provisions should be made for enough room for aircraft queueing and aircraft ability to bypass other aircraft parking positions to facilitate traffic movement and avoid back-ups.

c. Requirements Analysis

Departure rates at peak hours during winter events that require deicing should be used for determining the required capacity of the designated deicing facilities. The size of the designated deicing facilities should be determined considering fleet mix, peak demand, and queueing area. The location, queue, and size of the designated deicing facilities must be supported by capacity analysis and calculations. Capacity study must be submitted for Port Authority review and approval.

d. Facility Options

The optimum method for deicing application, using either fixed-boom deicing equipment or deicing trucks, should be considered. Glycol storage and dispensing calculations and plans must be provided. If a support building is desired, sufficient space should be allowed. A clear view of the deicing positions from the control room should be provided.

e. Deicing Fluid Collection and Treatment

Glycol breaks down naturally over time, however it is considered a pollutant that should be contained and not allowed into the general stormwater system. Designated deicing facilities must therefore be graded favorably for collecting and containing deicing runoff. Drainage designs that capture deicer-laden runoff and segregate it from “clean” runoff to minimize runoff volumes for treatment and disposal or recycling must be considered. Sufficient capacity for spent deicer-laden runoff storage under design storm conditions should be allowed. The drainage system of the designated deicing facilities must be independent from the airport stormwater drainage system. For each deicing designated area, the glycol collection system must be depicted and the specifications documented. Considerations should include wind dispersion and jet blast, grading, inlet locations, and underdrains. Glycol collection can be done via vacuum trucks or dedicated drainage system linked to storage tanks located on airport property. Sufficient storage must be provided for run-off deicer.

Multifunctionality of the site for year-round use, such as aircraft parking, etc., should be considered. Plans should be documented and submitted to PANYNJ for approval.

For designated deicing facilities floodlighting refer to “*Apron Floodlighting*” chapter.

¹⁴ AC 150/5300-14C, Design of Aircraft Deicing Facilities.

f. FAA Guidance and Port Authority Policy Requirements

1. Planning and designing dedicated deicing facilities should follow the planning and designing guidelines specified in the FAA Advisory Circular AC 150/5300-14C, "Design of Aircraft Deicing Facilities."
2. Designated deicing facilities design must comply with PANYNJ Environmental Sustainability Policy.
3. Designated deicing facilities must meet the National Pollutant Discharge Elimination System (NPDES) permit requirements, such as sizing and siting the deicing facilities, designing aircraft deicing pads, aircraft access, collection capacity and recycling or disposal plan.

SECTION III: TERMINAL

Part 1 – Concept of Operation Parameters

The sections below describe the functional and qualitative characteristics of the various elements of airport terminals.

1. Passenger Check-in and Bag Check

Check-in is the first process undertaken by departing passengers at an airport. The check-in process allows passengers to check non-carry-on baggage with the airline and obtain a boarding pass. During check-in, passengers receive specific flight information, have the ability to purchase additional in-flight services (such as priority boarding, and upgrade seat assignments), and adjust their flight arrangements (reservations). At check-in, airlines verify passengers' identification documents and flight reservations and collect any outstanding fees.

Passenger preferences and recent trends and innovations in the check-in process must be considered and embedded in the design of terminal facilities. For example, IATA ADRM 10 indicates a shift in passenger preferences from using traditional check-in processes to the use of online check-in. Automation, innovations, and social behaviors are increasingly changing most passengers' flight check-in experience from the ubiquitous ticket agents standing behind check-in counters to self-service interactive displays—usually with roaming airline agents performing as personal assistants. In addition, the appearance of in-terminal check-in facilities is evolving as an extension of an airline's brand or a terminal brand (for example, a low-cost carrier terminal). Underpinning this evolution is the adoption of near field communication applications, such as going paperless and Internet-based transactions using mobile devices. These technologies are enabling the airlines to reduce the cost of most transactions and, instead, to offer segmented services, such as concierge-style flight check-in services for premium passengers. In other words, certain passengers will be offered a highly-tailored experience that will be increasingly differentiated and decentralized compared with the current experience in which all passengers of a given airline gather in the same physical space for essentially the same processes.

a. Off-site check-in (multiple types)

Prior to the 9/11 Attacks, remote check-in and bag check was available at major travel and tourist destinations, including theme parks, convention centers, cruise ship terminals, and major Las Vegas casinos. After the 9/11 Attacks, TSA regulations required bag screening at the airport. With the advent of internet and smartphone technology, remote check-in (but not bag check) is now widely available for most passengers. Remote check-in with bag check may again be established at certain venues, if the security protocols and chain-of-custody of checked bags can be resolved.

Passenger acceptance and preference for online check-in options have reduced the amount of terminal space historically needed for terminal check-in as certain passengers bypass airport check-in entirely and proportionally fewer agents are needed to serve the same number of departing passengers. The number of passengers bypassing airport check-in is increasing with passengers using mobile check-in applications (i.e., apps) to replace paper boarding passes with digital boarding passes that display Quick Response codes on a passenger's mobile device.

Designers should refer to ACRP Report 25 which provides a summary of recent trends in the development and operation of these facilities. Designers should also check with newer trends, as these tend to reflect emerging technologies and will be subject to TSA regulations.

b. Curbside Counters

Most airports provide for curbside check-in. Allowing for curbside check-in can improve the Level of Service (LOS) for customers and increases the volume of passengers serviced without increasing the size of ticket lobbies. Typically, curbside check-ins are equipped with conveyor belts located at the check-in podiums for direct input of bags into the outbound baggage system. Airlines who do not wish to pay for conveyors may have checked bags placed on carts and taken into the check-in lobby to be transferred to the ATO counter bag conveyor¹⁵.



Figure 26: Departures / Check-in Hall

c. Departures / Check-in Hall

The departures hall is the “front door” of an airport terminal, where first impressions are made, and often receives special architectural treatment, high quality finishes, natural daylight, and high ceilings. The area should have good acoustical quality so that normal speech and paging system announcements can be heard. Airline kiosks and ticket counters should be arranged such that passengers can easily find and circulate to them. Ample circulation should be provided around the queuing areas so that passengers who do not need to stop at a kiosk, counter, or bag drop, can easily flow through to the security checkpoint.

A minimal provision of pre-security retail concessions, such as cafés and newsstands, should be provided for well-wishers, airport employees, and other members of the public who are not authorized to go post-security. Refer to Part 2, Section i for the minimal requirements for pre-security retail concessions.

¹⁵ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.2.1, 2010

d. Traditional Counters

For the most part, the in-terminal check-in process is evolving to acceptance of checked baggage (non-carry-on baggage) from passengers, and in the case of certain travel destinations, to validation of travel documents by airline agents.

Even with the adoption of new technologies designed to put more of the check-in process with the passenger, a certain number of staffed traditional counters will always be required, to serve:

- Premium passengers who expect prompt, personal service
- Technology-averse passengers
- Unaccompanied minors
- Large, organized travel groups
- Passengers who were unable to complete their check-in and/or bag check transactions using smartphone, kiosk, bag drop, etc. due to technical glitches, failure to understand the technology, or other reasons
- Passengers with complex booking or re-booking transactions

1. Standard Counters

Standard counters have staffed airline personnel that check in and/or change flights for all passengers. It is meant for all passengers to use if other ticketing counter types are not available or if passengers prefer to be checked in through airline personnel rather than self-check alternatives. Refer to Part 2, Section 5 for traditional counter calculations.

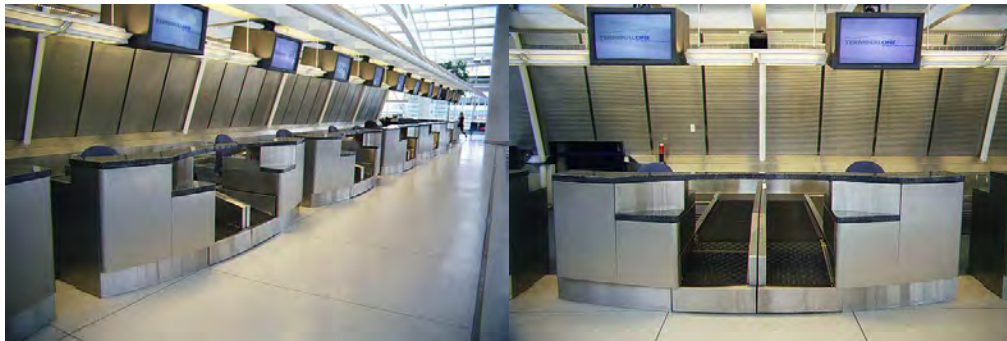


Figure 27: Typical Check-in Counters

2. Group Counters

Group check-in counters are oftentimes provided for airlines that have higher rates of group ticket processing. These counters are physically separated from standard counters and have their own queuing lanes and spaces as they may sometimes clutter the standard counters' queues. These are sometimes placed near baggage claim units as large groups may need higher space requirements to process. Refer to Part 2, Section 5 for traditional counter calculations.

3. Premium Counters

Airlines often provide a more personal service to their premium class passengers. These may include business class, frequent flyers or any other type of passenger requiring special attention. A dedicated

queue will be provided for them and many times the agents will serve premium passengers as soon as they arrive at the front of the queue. Additional counters will be made available to these passengers so that the maximum queuing time is kept to a minimum¹⁶.

Provisions for premium counters is largely an individual airline's business decision. Different airlines may have different number of tiers for premium passengers. Some airlines have a highest VIP tier where passengers and their bags are checked in and check bags in a separate private room. Refer to Part 2, Section 5 for traditional counter calculations.

4. VIP Counters

The provision of counters for VIP passengers is often a requirement at major airports, especially at capital city airports where senior government delegations and people of importance travel through often. These VIP counters are often separated from the traditional counters to maintain the privacy of the person. It is up the airport officials' and/or airlines' decision to have separate private rooms for VIP passengers or alongside other traditional ticketing counters. Refer to Part 2, Section 5 for traditional counter calculations.

e. Self-Serve Kiosks

The terminal check-in process continues to evolve with increasing reliance on passenger self-service transactions. Self-service equipment, by design, has a smaller physical footprint and is less costly to operate than an agent-staffed ticket counter, which allows for greater deployment of self-service units within a given area and increases the number of positions where passengers can complete check-in transactions. Self-serve kiosks traditionally minimize the time that passengers spend waiting for an airline agent and reduce the overall check-in transaction processing times.



Figure 28: Self-Service Kiosks (Check-in Only)

1. Check-In Only

Certain kiosks are available for check-in only, with the capability to provide boarding passes, but not bag tags. These kiosks, dedicated to passengers with carry-on bags only, are clearly labeled "Check-in Only"

¹⁶ IATA ADRM 10th Edition, Section 3.4.11.6, 2017

or “No Bags to Check”, and are often located at the terminal front wall or a similar location, distant from the counters and/or bag drop induction points.

2. Baggage Check, Weighing, and Tag

Transactions that can be conducted at self-service kiosks include those otherwise available online and, increasingly, the ability to acquire bag tags that passengers can self-apply to their non-carry-on baggage. This latter process is referred to as self-tagging. Currently, the Transportation Security Administration (TSA) requires that airline agents physically accept self-tagged baggage from passengers at a bag drop location (typically a counter). Currently, airlines do not offer passengers the options for fully automated (self-service) baggage drop procedures, but this may occur in the future.

Because there are weight classifications and limits for each individually checked bag, scales should be provided where self-tagging is available so that passengers can weigh their bags. Open space, tables and countertops should be provided as passengers may need to repack their luggage in order to meet the weight limits and avoid paying additional fees.

f. Baggage Drop Induction Points

Conventional processing facilities can be operated simply as bag drop desks. In this case, only the bag weighing, tagging and bag induction process are carried out by the agent. This option provides convenient and quick processing for passengers, and minimizes agent transaction time. Passengers using these facilities will have completed their check-in by other means (i.e., online, mobile app or at a self-service kiosk at the airport). In this way, a time-consuming part of the process is removed from space-demanding facilities and provided via very space-efficient self-service kiosks or removed altogether from the terminal¹⁷.

Bag Drop points are locations where passengers bring checked bags that are tagged and ready for induction into the system. The passenger places their bags on an induction belt, which is a bag belt near floor level that only runs when activated by an agent. The induction belt has a built in scale, to provide a final confirmation that the bag is within weight limits. The agent verifies the passenger’s identity and boarding pass, then scans the bags, and pushes a button to induct the bags into the system. Currently in the US, TSA regulations require airline agents to positively ID each passenger when inducting their bags. In other countries, no agent is required, the passenger simply scans their boarding pass and bag tags, and the bags are automatically inducted when the appropriate credentials are confirmed by the system. The US may migrate to this protocol.

g. Restrooms

Refer to Part 1, Section 7.

2. Outbound Baggage Handling System (BHS)

The airport baggage handling system (BHS) generally consists of two separate systems: outbound and inbound. The outbound system is used by the airlines for check-in, delivery to the Transportation Security Administration (TSA) security screening facilities, acceptance from TSA screening, storage,

¹⁷ IATA ADRM 10th Edition, Section 3.4.11.3.4, 2017

sortation, and loading of checked baggage onto baggage carts for delivery to departing aircraft. Most of the outbound BHS facilities are located downstream of TSA screening and are used for all originating passenger baggage, and any connecting passenger baggage not otherwise delivered to the passengers as part of a Customs inspection or a non-interlined itinerary. All transfer baggage incoming from international flights not yet screened by the TSA and outgoing to subsequent connecting flights, is required to be screened by the TSA before being loaded onto the departing aircraft. Depending on the size of the terminal facility and volume of transfer traffic, transfer bags can either be processed by the same system or through a separate, dedicated system.

Baggage is introduced to the conveyance system at different check-in locations, such as traditional counters, baggage drops, and curbside check-in, and is then transported by conveyors to the TSA screening location. After screening, cleared bags are then transported to the outbound baggage makeup areas by conventional conveyors or conveyance vehicles, such as linear (or chain) drive sorters or destination-coded vehicles. Contemporary outbound baggage facilities use automated sortation systems to distribute bags between individual baggage makeup devices, where the baggage for each individual flight undergoes the “make-up” process where it is picked from the makeup devices and placed on carts to then be transferred and loaded onto the aircraft.

Older or smaller systems may lack automated sortation systems and centralized baggage screening systems and will essentially operate as point-to-point systems. Automated sortation systems are able to deliver bags from a common baggage screening facility to specific baggage makeup devices, which may be organized by airline; or, in the case of a large hub airline with multiple makeup devices, by flight. System capabilities, such as automated sortation, can affect terminal configurations, airline lease agreements, and operating policies. In most cases, automated systems provide terminal operators greater flexibility to support common-use facility arrangements.

The following diagram from TSA’s Planning Guidelines and Design Standards for Checked Baggage Inspection Systems (PGDS), shows the process through the outbound BHS.

a. Take-Away & Collector Belts

Baggage is inducted into the BHS at different locations, such as the departures hall, curbside, and transfer offloads. Collector belts are used to consolidate flows from multiple induction points before conveying bags towards screening. Best practice for designing collector belts is that main line redundancy (e.g., cross-over belts) are provided to minimize loss of capacity during outages. Depending on the specific Checked Baggage Inspection System (CBIS) design, bags typically travel along the main line collector belts to the TSA screening zone. Optionally, bags can travel over several types of load-balancing devices prior to arriving at the screening zone¹⁸.

Pre-Explosive Detection System (EDS) main lines are conveyor lines where input lines are merged to create a main delivery conveyor line that delivers baggage for diversion to individual EDS lines. To provide redundancy in the system, designers should consider additional delivery conveyor lines such that a single point of failure will not cripple the entire system.

¹⁸TSA PGDS Version 5, Section 3.1.2, 2015

EDS lines are the conveyors that transport baggage from diversion off the main line to several individual EDS machines via queuing conveyors.

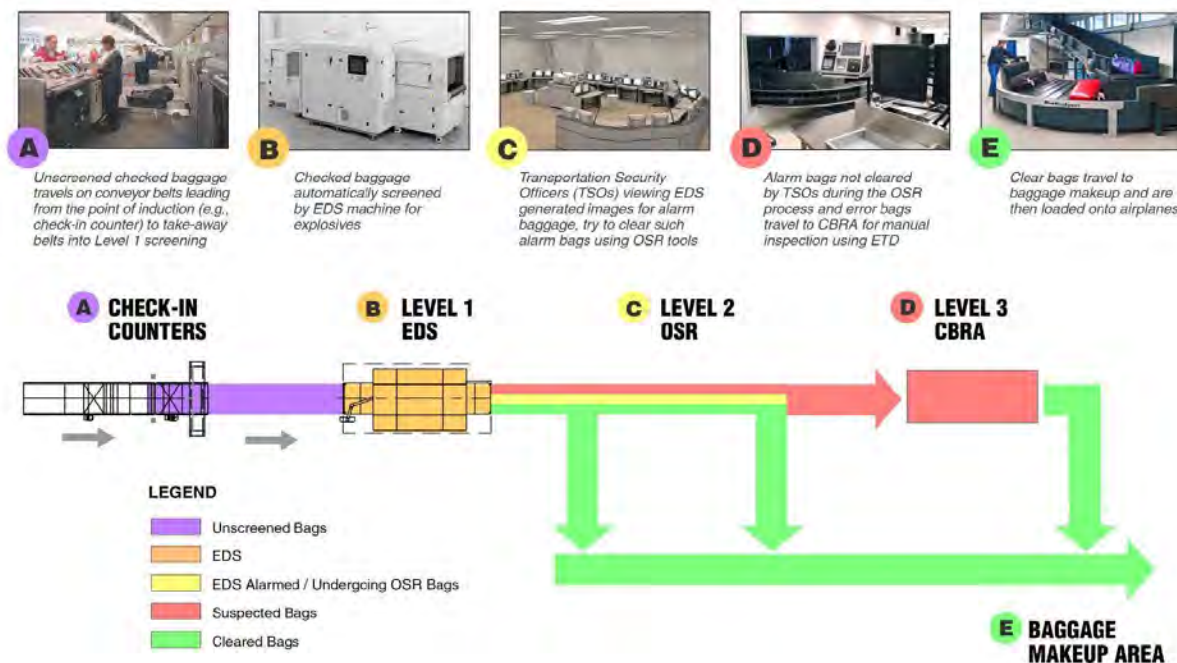


Figure 29: Schematic design of baggage induction sequence

b. Checked Baggage Inspection System (CBIS)

Unscreened bags are sent to EDS conveyor subsystems consisting of queue conveyors in front of each EDS. Various methods can be used to configure BHS control logic, which drives load balancing between or among EDS units¹⁹.

The Checked Baggage Inspection System (CBIS) process involves three screening levels²⁰:

- Level 1 screening is performed with EDS equipment. All bags that can physically fit in an EDS are directed to Level 1 screening and scanned using an EDS, which takes a 3D computed tomography (CT) image of the bag and its contents, and automatically alarms or clears the bag based on software detecting potential threat objects. Bags automatically cleared by the EDS typically exit and are transported through the first-chance cleared-bag divert point located at a relatively close location downstream from the EDS. All bags that automatically alarm at Level 1 are subject to Level 2 screening.
- During Level 2 screening, TSA personnel review 3D images of alarmed bags captured during the Level 1 EDS scan, focusing on alarmed objects in the bag, and then provide a Clear or Alarm designation to the bag. This process is referred to as On Screen Resolution (OSR) which allows the continuous flow of bags through the CBIS until a decision is made. All bags that cannot be

¹⁹TSA PGDS Version 5, Section 3.1.3, 2015

²⁰TSA PGDS Version 5, Section 3.1.3, 2015

resolved at Level 2 (e.g., Time Out Bag), and all bags that cannot be directed to Level 1 because of size restrictions, are sent to Level 3 screening.

- Level 3 screening is performed manually and involves opening the bag and the use of Explosives Trace Detection (ETD) technology. Bags that pass Level 3 screening are returned to the outbound BHS, while the very small percentage of bags that do not pass Level 3 screening go to Level 4 and are either resolved or disposed of per the current TSA checked baggage Standard Operating Procedure (SOP) which typically involves the local law enforcement officer.

c. Checked Baggage Resolution Area (CBRA)

Bags that are not cleared by OSR screening, unknown or system tracking error bags, and oversized bags, are diverted to the Checked Baggage Resolution Area (CBRA). When a bag arrives at the CBRA, its corresponding image, which is transmitted over the EDS network, is retrieved by the TSA screener using the bag identifier. Based on the bag image, the TSA screener identifies and locates the alarm object(s) within the non-clear bag and manually clears the object(s) using manual ETD inspection. If the bag image cannot be retrieved, the TSA screener must perform additional screening measures on the alarm bag per the current checked baggage SOP²¹.

- Bags clearing ETD screening are re-inserted onto a cleared bag conveyor and typically merged with the main flow of bags to the bag sortation or makeup area. A clear bag is any bag that has received a “Clear” security screening decision at Level 1, 2 or 3 security screening.
- Most non-clear bags (as well as unknown and oversized bags) at the CBRA are cleared using ETD.

d. Distribution Belts

Post-EDS main lines are the conveyor lines where all EDS clear lines, which includes Level 1, Level 2, and Level 3 cleared baggage, are merged for transport to the make-up area.

There are various types of sortation devices that divert bags from main lines to branch lines, including vertical sortation units (VSU), pushers, tilt-trays, Individual Carrier System (ICS) tippers, each with different capabilities.

Types of Baggage Sortation Systems. There are four types of baggage sortation systems²²:

- **Centralized sortation (localized to terminal):** A centralized sortation BHS gathers all input bags, originating and transfer, into one location and then sorts the bags to the flight’s designation. These systems usually employ automated tag readers (ATRs) for automated scanning and universal encoding consoles (UECs) for manual encoding if the automated scans fail. A single centralized sortation system, while offering flexibility, will however be at a disadvantage when trying to maintain operations during system modifications, expansions, or upgrades.
- **Decentralized sortation (localized to gates):** A decentralized baggage sortation system sorts the bags at two or more locations, or the actual flight sortation is performed at or near the individual airplane gates. These systems usually employ ATRs for automated scanning and UECs

²¹TSA PGDS Version 5, Section 3.1.5, 2015

²²ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.1.3, 2010

for manual sortation if the automated scans fail. Bags will need to be identified with an ATR when multiple make-up carousels are used.

- **Common-use sortation system:** A common-use sortation system incorporates all the carriers' bags into one common sortation and delivery system to process and sort the bags by carrier destination. A major benefit of this system is that any future additions, removals, or modifications are simplified because all inputs feed into one single sortation and delivery system. Another major benefit is that if carriers are operating with sporadic departure times, all carriers' schedules can be combined to maximize the use of the sortation system. A single sortation system will however be at a disadvantage when trying to maintain operations during system modifications, expansions, or upgrades.
- **Manual sortation:** A manual sortation system does not employ ATRs or UECs. The baggage sortation takes place in the baggage make-up area with airline personnel manually sorting each individual bag and placing it in the appropriate cart. In this arrangement, common make-up devices can be shared by multiple carriers if required. Bags will need to be identified with an ATR when multiple make-up carousels are used. This legacy type of system is more labor-intensive, and appropriate for smaller, low-volume airports. It would generally not be feasible at larger PANYNJ airports.

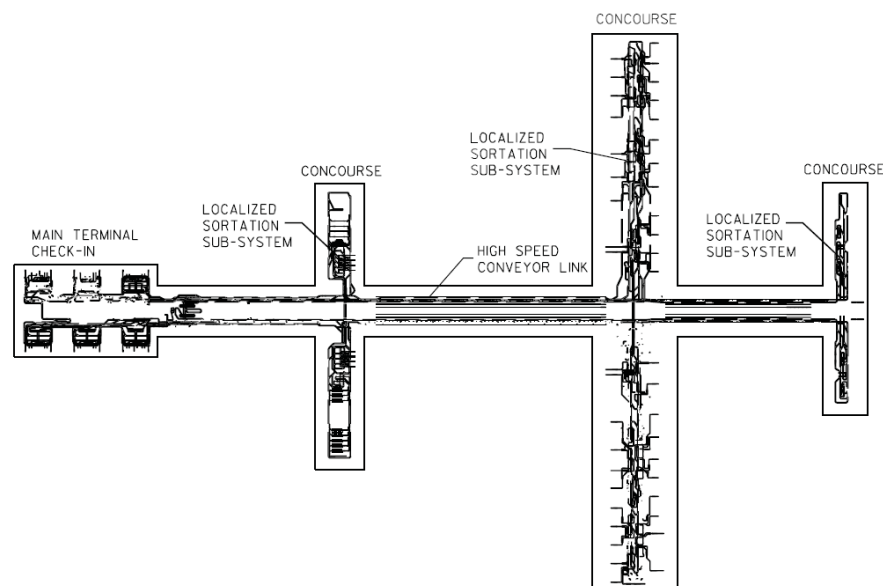


Figure 30: Decentralized sortation baggage handling system²³

²³ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design

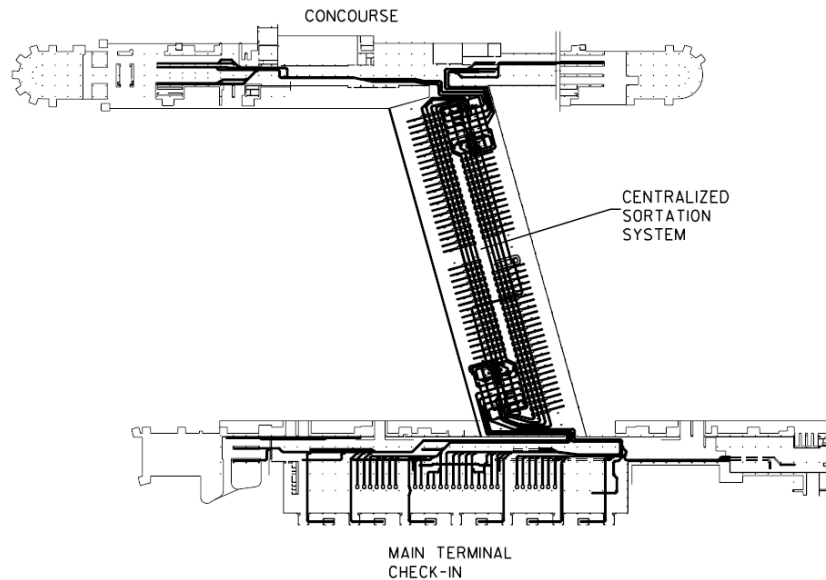


Figure 31: Centralized sortation baggage handling system²⁴

e. Early Bag Storage (EBS)

Early Bag Storage (EBS) is utilized in some facilities when a large volume of originating or transfer bags show up at the airport terminal much earlier than flight departure time, and the airlines do not have an economical method of handling or storing these bags within the outbound baggage system. Large volumes of passengers may show up early at the airport due to factors beyond their control, e.g., being part of a cruise or other organized tour. At busy airports without an EBS, passengers are typically not allowed to check bags more than three or four hours before scheduled time of departure, because the outbound BHS does not have buffer storage to accept the sheer volume of bags. The EBS is typically located near the outbound baggage system and will feed bags back into the BHS for sortation and delivery. It can be loaded by either (1) a dedicated transfer load belt for early transfer bags or (2) a diversion from the outbound sortation system for early originating bags. The bags stored in this facility usually have more than 120 minutes before departure²⁵.

f. Make-Up

Outbound baggage makeup facilities are used by the airlines for storage, sortation, and loading of checked baggage onto baggage carts for delivery to departing aircraft. These facilities are located downstream of TSA baggage screening systems and are used for all originating passenger baggage and connecting passenger baggage not otherwise delivered directly between aircraft for domestic-to-domestic or domestic-to international connections. Baggage transferred between international flights and subsequent connecting flights is required to be screened before being loaded onto the next aircraft, as it has been brought out of the sterile area and had passenger contact. Outbound baggage makeup requirements define the amount of space needed to accommodate the types and number of baggage

²⁴ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.1.3

²⁵ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.1.3

makeup devices and operational, vehicular, and staff support areas required to support terminal activity.

1. Make-Up Devices

Make-up device types include circulating sloped-plate (“carousel”) and flat-plate (“racetrack”) units, straight-line conveyors with indexing operations (“laterals”), and fixed chutes fed by overhead tilt-tray conveyors – all of which have implications on handler operations. Presentation length, which equates to the number of carts staged around a device for a flight during baggage makeup, and bag cart/tug circulation lanes represent the largest components of the space requirement and determine the dimensional criteria.



Figure 32: Sloped-Plate Bag Make-up Device²⁶

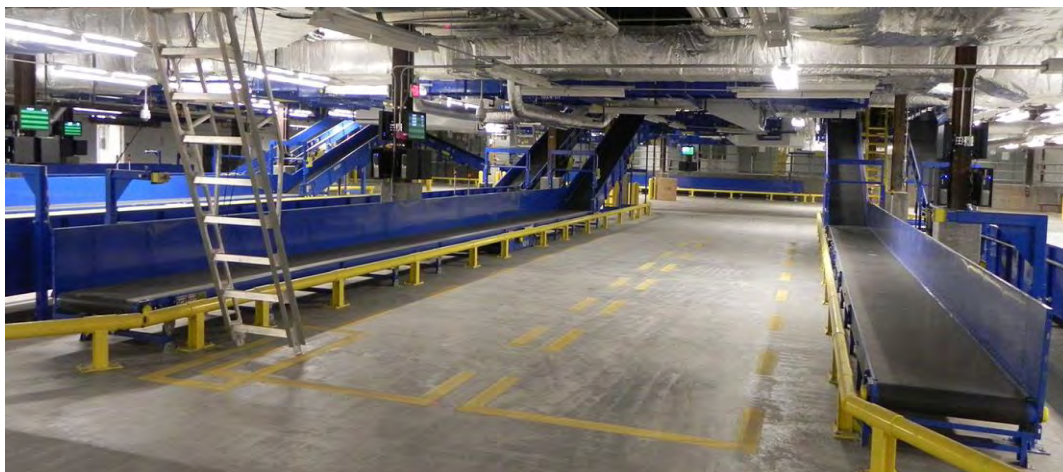


Figure 33: Straight-Line Bag Make-up Device²⁷

²⁶ Unified supply Co.

²⁷ Clark Construction Group

2. Make-Up Rooms

Make-up rooms are typically located at the apron level, but can also be below grade with ramped vehicle access. They can be fully enclosed or without side walls, depending on climate. In the New York / New Jersey area, due to cold winters, the rooms should be fully enclosed. In addition to the make-up devices, associated work areas, and vehicle circulation, these rooms may contain areas for additional carts (as a form of EBS), and other vehicle parking, which may include electric charging capabilities.

The principal elements determining the size and arrangement of outbound baggage makeup areas are:

- Type of makeup device.
- Bag cart/tug staging and loading zones and circulation aisles and lanes.
- Control rooms and power cabinets. The BHS control room contains the essential components to monitor and operate the BHS properly and optimally. This room typically needs 400 square feet to accommodate all the systems required. Verify with BHS designer.
- Miscellaneous spaces for staff, such as locker rooms, break rooms, and restrooms.
- Baggage handling system maintenance room: this type of room is required to maintain, build, or repair conveyor parts to assist with the proper upkeep of the BHS. Special consideration of size and location of the maintenance room/area is required depending on the complexity and magnitude of the BHS. The recommended size of this room would range between 300 and 800 square feet, including space for spare parts. Verify with BHS designer.

Figures below show different examples of circulation spaces between make-up carousels, including double side and single side piers.

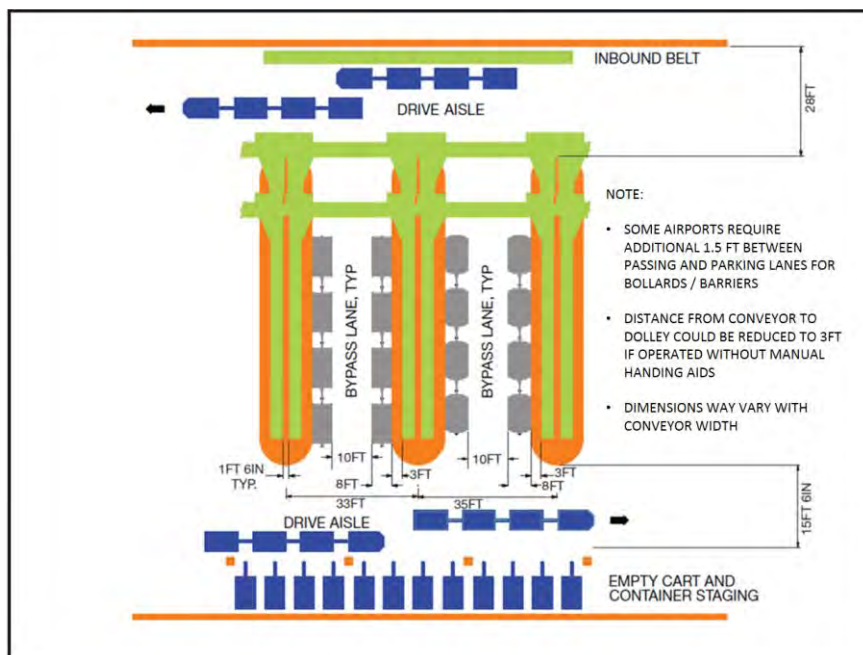


Figure 34: Space allocation for drive aisle/drive-through tug circulation²⁸

²⁸ Graphics from ACRP 25, dimensions from Arup

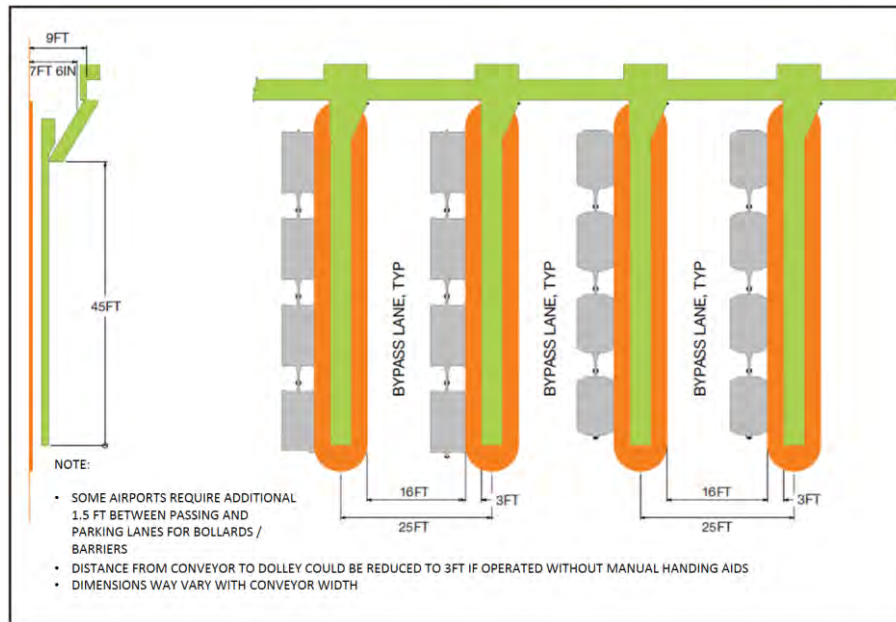


Figure 35: Sort pier spacing (single-sided piers with bypass lane, one mainline)²⁹

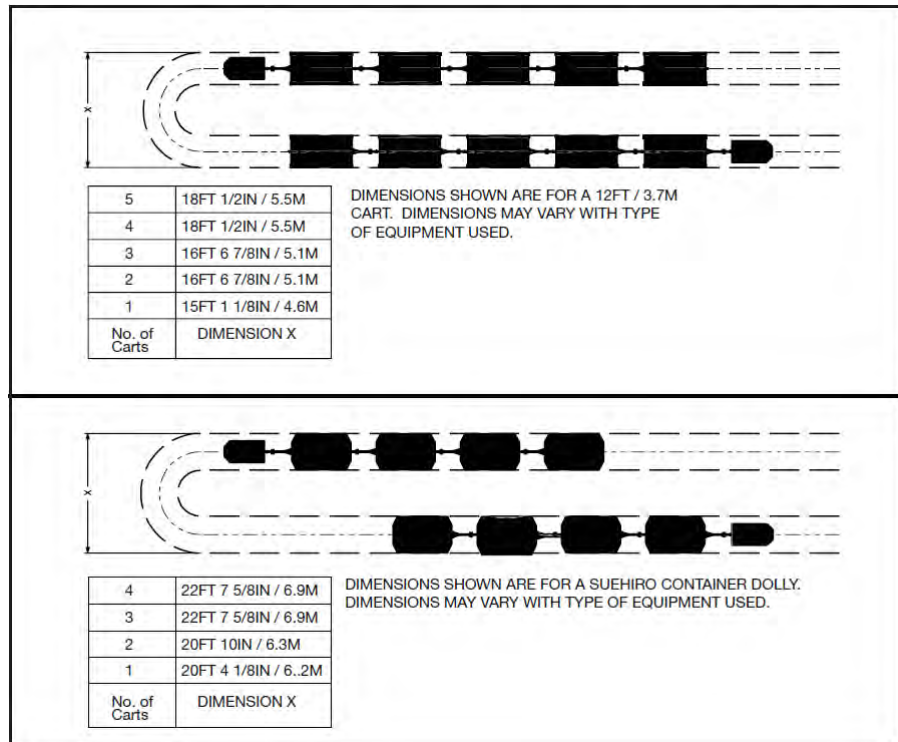


Figure 36: Turning radius for tug and cart³⁰

²⁹ Graphics from ACRP 25, dimensions from Arup

³⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design

Although discussed separately in the Guidelines, offload areas for inbound (arriving) baggage are sometimes collocated with outbound baggage makeup areas.

g. Oversized Baggage

Out-of-gauge (OOG), also known as “out-of-spec” (OOS), or most commonly “oversize” (OS), baggage, is baggage and other checked items that are either too large, or of an irregular shape or lacking rigidity (such as sports gear, golf clubs, bikes, wheelchairs, medical equipment, garment bags, etc.) that would be likely to be mishandled and/or damaged by the automated BHS; are too large to fit on the conveyor belts or makeup units; or might cause jams in the system.

The terminal designer must provide special check-in desks or bag drop stations for oversize bags, which must be clearly marked as such. The number of oversize bag drop stations should be based on demand characteristics of the passengers typically using the facility. The oversize bag check should be provided with wider conveyor belt, having few or no turns along its length, to convey the oversized items to the TSA Level 3 screening. The BHS designer should specify the appropriate width, slope, and turning radii of the oversize bag conveyor belts. Alternatively, the oversize items may be manually transferred to the TSA; however, conveyors are preferred.

After TSA screening, provide a dedicated oversize belt system designed to handle conveyable pieces of luggage, and a manual delivery operational methodology for non-conveyable items like bikes, surfboards, etc., to the secured non-public side of the bag makeup room³¹³². For the transfer from TSA screening to makeup, it is again preferable to use conveyors to the extent practicable rather than manual delivery.

3. Passenger Security Screening Checkpoints (SSCP)

The TSA is responsible for screening all ticketed passengers and their carry-on baggage at security screening checkpoints prior to passengers entering secure gate boarding areas.

The physical characteristics of a terminal, passenger characteristics, and even seasonal changes affect screening lane throughput. The TSA issued a Checkpoint Design Guide (CDG) is a “living” document that is updated when the TSA adopts new technologies and policies. The CDG is adaptable to each unique airport and airport terminal building for reconfiguring existing checkpoints to meet current design guidelines, or locating and sizing new checkpoint(s) at an airport.

a. Travel Document Check (TDC)

Travel document check (TDC) staffed positions are required at the entrance to the SSCP lanes. The TSA officer reviews each passenger’s ID and boarding pass, and scans the boarding pass to verify they are checked in on an upcoming flight. The required number and configuration of TDC positions should be based on their processing speed as well as the configuration of the general queues and SSCP lanes. TDCs are located at the end of the general SSCP queue, where passengers transition to a mini queue for a

³¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.1.2, 2010

³² IATA ADRM 10th Edit, Section 3.4.19.2, 2017

particular SSCP lane. In addition to reviewing the passenger's ID and boarding pass, the TDC officer sometimes directs passengers which lane to use.

b. Queuing

An appropriate space allocation should be made on the non-sterile (public) side of the checkpoint for passenger queuing. This space should include room for tables near the screening equipment, for preparing their belongings for screening³³.

c. Screening Lanes

1. Passenger Screening

The walk-through metal detector (WTMD) is used for passenger screening. It is an archway used to detect concealed metallic items and/or contraband³⁴.

The Advanced Imaging Technology (AIT) provides an additional element of passenger screening by being able to detect a broad spectrum of materials concealed in or under a passenger's clothing³⁵.

2. Carry-on Bag Screening

Carry-on bag screening is mandatory at a SSCP and is accomplished by deploying advanced technology (AT) equipment. Generally, this equipment has the following components³⁶:

- Loading Table/Entrance Roller
- Queuing Conveyor & Hood (Vendor Specific)
- Scanning Belt & Dome
- High Speed Conveyor (HSC) & Hood
- Extension Rollers
- Exit Roller with Bag Stop
- Manual Diverter Roller (MDR)
- Alternate Viewing Station (AVS)

Transportation Security Officers (TSOs) are staffed dynamically at the carry-on bag screening units where one or two screeners can perform the functions listed below:

- Review bag images on the monitors
- Remove alarmed bags from the alarm bag cutout or from the MDR
- Place empty bins on the bin carts

Refer to Part 2, Section h for calculations for the number of screening lanes, and dimensional guidelines and standards.

³³ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.1.2, 2014

³⁴ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.7, 2014

³⁵ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.8, 2014

³⁶ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.5, 2014

Airports are currently implementing the Automated Screening Lanes (ASL) which strengthens security, increases operational efficiency and improves passenger experience. Due to its new configuration, multiple passengers can divest their belongings simultaneously. Another difference with the conventional screening lanes is that the passengers place all their belongings into bins (each of which has a unique Radio Frequency Identification (RFID) for positive tracking) and push the bins onto the automated belt. A camera photographs all the bins before entering X-ray. If a bin contains an alarm item, it will be diverted to a secured belt for additional screening. The recomposure station provides space for several bins, allowing several passengers to collect their belongings at the same time. At the end of the recomposure line, bins are placed on an elevator which leads to a conveyor that returns them to the divestiture station automatically.

Due to the additional equipment, ASL requires more space in the security screening zone than the conventional screening lanes. However, each lane processes 30% or more passengers per hour than a traditional lane.

d. Trusted Traveler (TSA PreCheck, Clear)

Trusted traveler systems allow passengers to voluntarily register, subject themselves to a criminal background check, and pay a fee to gain status as a trusted traveler. Once this status is attained, they are subject to less stringent requirements at the SSCP, allowing for a streamlined process. This may include not having to remove shoes and belts, and not having to remove laptops and liquids from carry-on bags.

Airports who recognize trusted travelers should create a strategy for the accommodation of trusted travelers as part of the development proposal. This can be done by setting aside a few lanes at a security checkpoint, or providing an entirely separate checkpoint for trusted travelers. The lanes for trusted travelers run faster than traditional screening lanes.

e. VIP Screening

Some airlines or terminals may wish to provide separate VIP screening areas for politicians, diplomats, celebrities, other public figures, or highest-level premium passengers. These VIP SSCP lanes are often separated from the traditional SSCP lanes to maintain the privacy of the person. It is up to the airport officials' and/or airlines' decision to have separate private screening areas for VIP passengers or alongside other traditional screening lanes.

f. Known Crewmember (KCM)

Known Crewmembers (KCMs) include uniformed pilots and flight attendants who are reporting for flight duty. They have airline credentials often including biometric verification. KCMs may be admitted to the secure side via separate passageways independent of the SSCP where their credentials are checked by a screener, or they may utilize Trusted Traveler SSCP lanes. If using SSCP lanes, their numbers should be added to the total peak hour demand for passenger SSCP lanes.

g. Secondary Search

Following the initial steps of security screening at the checkpoint (X-rays for carry-on baggage, walkthrough metal detector or body scanner for passengers), certain passengers and/or bags are

identified by the TSA for secondary searches. Secondary search areas are provided at the end of each lane. These are comprised of a baggage inspection table and pat-down area.

h. Private Screening

A private room or booth must be provided for personal searches of passengers requesting privacy for pat-downs, or at the TSA's discretion.

i. Recomposure

The recomposure area is the area after the screening where passengers can retrieve their screened bags and restore their composure. Egress seating after the checkpoint is used for passengers to sit down and compose themselves with their personal belongings after completing the screening process. The screening experience is greatly improved if passengers can sit down to put their shoes and jackets on.³⁷

In addition to the minimal recomposure areas provided in the standard TSA lanes, designers are encouraged to provide additional recomposure areas, including adequate space and comfortable furniture such as cushioned benches, chairs, and tables. For most passengers, the TSA checkpoint is by far the single most stressful part of the passenger experience, and a well-planned recomposure area can alleviate much of this stress. The recomposure area should provide passengers a dignified and comfortable place to put back on their shoes, belts, other clothes, and re-pack their carry-on bags. It should include visual cues for intuitive wayfinding to retail concessions and gates.

Providing an ample and pleasant recomposure area has been shown to provide two tangible benefits:

- Improved lane throughput performance (passengers per lane per hour), because when all passengers have a welcoming place to go for recomposure, they tend to go there quickly, which eliminates the bottleneck of passengers attempting to recompose at the roller-beds immediately at the output end of the x-ray machines. When passengers attempt to recompose here, they can back up the x-ray output as well as block the queue of passengers attempting to access their cleared bags from the roller-bed.
- Measurably happier passengers. The de-stressing power of a good recomposure area can improve customer service ratings, and increase retail spending rates.

4. Post-Security Area / Concourse

Preboarding areas addressed in these Guidelines refer to terminal components located post-security screening checkpoints that are principally used by passengers prior to boarding aircraft.

- Departure lounges (holdrooms) for passengers waiting to board aircraft, including seating and standing areas, airline service counter and gate check podium, and egress aisle from the boarding gate.
- Concessions, including food/beverage, retail, news/gifts, and services.
- Public corridors and restrooms.

³⁷ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.13, 2014

a. Circulation

General public circulation includes the horizontal and vertical circulation elements of all of the corridors and other architectural spaces, which tie the public functional elements of the terminal together. The list below shows the considerations when planning for circulation space:

- Primary circulation pathways
- Non-public circulation pathways
- Moving walkways
- Elevators
- Escalators
- Stairs
- Ramps
- Automated People Mover (APM) Systems

Passenger journeys should be as straightforward as possible with clear sightlines to approaching decision points. Simple direct routes are preferred, with adequate width for passengers to move freely. Walking speeds vary considerably so ample space is required for individuals and small clusters of people to pass each other. Passengers with Reduced Mobility (PRM) should also be provided with ample circulation space and with rest areas at appropriate intervals. The circulation route also needs to provide ample space for electric vehicles (passenger electric carts, etc.) to move freely, back and forth without inconveniencing or endangering passengers on foot³⁸.

Changes in direction should be avoided wherever possible. Wherever unavoidable, they should be as shallow as possible with ample maneuvering space for all passengers and, where provided, electric vehicles.

b. Holdrooms

A gate holdroom is where departing passengers wait for and ultimately board flights. The following are primary components that comprise a gate holdroom³⁹:

- Preboarding waiting area – designated space where passengers wait to board a flight. Area includes seating and standing areas for passengers.
- Agent gate podium and queuing - area where passengers queue and ultimately communicate with airline representatives regarding flight information, make last minute changes to reservations and/or seating assignments, receive upgrades, and may gate-check bags. For flights out of the US, agents review passport and visa information.
- Boarding/egress corridor - designated area near the gate that is used for queuing of passengers to board the aircraft, and for passenger egressing from the aircraft when it arrives at the gate; individual airlines have differing boarding and egress procedures. Main circulation corridors and concessions are outside of the holdroom area and passengers should not queue or wait in these

³⁸ IATA ADRM 10th Edition, Section 3.4.10.1, 2017

³⁹ FAA AC 150/5360-13A, Section 6.4.4, 2016 (Draft)

areas to access their holdroom. Maintaining sufficient clearance in the main circulation corridors is necessary to access emergency exits in case of an emergency event.

Holdroom requirements are based on the assumption that each individual holdroom serves an individual gate. Minor reductions in holdroom requirements may be allowable when there is a legitimate opportunity for passengers to use an adjacent holdroom. An adjacent holdroom is defined as one with a seating area contiguous with the seating area of the gate in question, where passengers can see the podium and hear announcements from the gate in question. Contiguous seating areas are those that are not separated by concessions, circulation corridors, or other obstructions.

It is desirable to have natural light through windows and or skylights, concessions within a reasonable walking distance, and a view of the apron and in particular the aircraft associated with the holdroom.

c. Restrooms

Refer to Part 1, Section 7.

d. Concessions

Concessions development, at PANYNJ Airports, aspires to achieve a world class level of service for all short term, intermediate, and long-term development. Terminal concessions programs will be planned at a level of quality above the current operations of such concession programs at PANYNJ Airports and to develop and operate at a premier first-class concession program. A “premier first-class” concession program is one that consistently performs above the average of airports of similar size and a similar passenger profile on industry-recognized surveys, including the Port Authority-sponsored surveys, which contain evaluations or ratings of passenger terminal concession programs, or specific components thereof, of the same type or class. The criteria set forth in this section establishes a minimum performance bench mark.

Providing passengers with a variety of high-quality retail, food and beverage and personal service concessions are important. Departing passengers often perceive a higher quality travel experience if they have diverse opportunities to shop, eat or receive personal services while waiting for their departing flight. As in-flight food services continue to be reduced, preflight access to food and beverage offerings is becoming increasingly important. Arriving passengers may also seek opportunities to purchase duty-free products or gifts before leaving the terminal⁴⁰.

Revenues that flow from concessions sales can provide significant income.

Airport concessions are an important component in terminal space programs. The following are some of the types of concessions to be considered when developing concession space program requirements⁴¹:

- News/gift: Newspapers and magazines; Convenience items and sundries
- Specialty retail: apparel, souvenirs, gifts, sunglasses, jewelry, personal care/health products, entertainment products (movies, music, others), and prepackaged food and wines.

⁴⁰ IATA ADRM 10th Edition, Section 3.4.14.1.1, 2017

⁴¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter III, Section 9.3.5, 2010

- Food and beverage: Food courts and other self-service units, full-service restaurants, cocktail lounges and bars, coffee stand and vending machines.
- Duty-free/Duty-paid shops
- Services: massage, spa, entertainment (arcades, movie rentals, others), pay-per-use passenger lounges, business centers, currency exchange, luggage storage and wrapping, hair salon, barber, medical services, shoe shine and post office.
- Advertising
- Online and social media driven commerce

ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, provides more detailed explanations and best practices for developing a concession program.

e. Airline Customer Service

Airline information and ticketing desks should be provided within close proximity to all holdrooms. Passengers can be supplied with information regarding delayed or cancelled flights, and can be issued revised tickets. Additional troubleshooting services can also be carried out. Bag drop or bag processing facilities can be provided where applicable⁴².

Where airlines have a large and/or hubbing operation, they may provide a separate bank of service counters not associated with a particular gate, which serves passengers who wish to re-book for earlier or later flights, missed connections, etc.

f. Premium Lounges

Airlines provide club facilities based on their individual criteria for level of passenger activity, type of market (business vs. leisure), the number of club members in a given airport market area, and so forth. The size of these clubs can vary significantly and, at hub locations, can be quite large. These areas include exclusive-use membership clubs run by individual airlines (American's Admirals Club, Delta's Crown Room, United's Red Carpet Lounge, etc.), international premium class lounges, and special services facilities⁴³.

1. Common Use

Terminal operators or other non-airline entities may wish to provide common use premium lounges, which can be pay-per-use or have usage agreements with major airlines that do not provide a premium lounge at that airport. Although previously rare, these are becoming more commonplace, especially in terminals with many airlines but no dominant airline.

g. Nursing Rooms (Lactation/Wellness Rooms)

It is a growing trend to provide additional amenities for passengers, such as mother nurseries, changing rooms, and family rooms, although it is not addressed in local or national building codes. These

⁴² IATA ADRM 10th Edition, Section 3.4.11.13.2, 2017

⁴³ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11.4, 2010

amenities are needed for caregivers traveling with young children and babies as well as nursing mothers who need a private space.

h. Water Filling Stations

Water filling stations provide access to drinking water for passengers so that they can stay hydrated throughout their stay at the airport and on their flight. Since security rules were tightened several years ago, passengers are not allowed to take liquids, including water, through the security check. Providing multiple water filling stations for passengers to refill their water containers post-security helps to improve the travel experience at airports.

i. Children's Play Areas

Child play areas are important in serving families, and should be provided at strategic locations throughout the secure area. These areas may be located near toilet facilities that include "baby changing" and other family-focused facilities to enhance convenience⁴⁴.

j. Pet Relief Areas

Provision should be made for a well-maintained animal service area (included but not limited to guide dogs and other assistance dogs) used by people with reduced mobility. The route to this area must be signed, with level access, and be well lit. Assistance from staff should be available upon request. Appropriate relief areas should be available, where practical, both landside and airside⁴⁵.

5. International Arrivals

Refer to Airport Design Guidelines by U.S. Customs and Border Protection (CBP) for latest updates. Passengers arriving on international flights are required by the Department of Homeland Security (DHS) to be screened and cleared at the Customs and Border Protection (CBP) Federal Inspection Services (FIS) facility for immigration and customs processing prior to gaining entry into the United States. CBP can also use Preclearance operations that stations CBP law enforcement personnel overseas to inspect travelers prior to boarding U.S.-bound flights. Through Preclearance, CBP Officers conduct the same immigration, customs, and agriculture inspections of international air travelers typically performed upon arrival in the United States, before departure from foreign airports.

There are two separate procedures once passengers arrive to the FIS facility; Immigration, which assesses the passenger's ability to enter the United States, and Customs, which assesses the suitability to enter the United States for any items, such as baggage and monetary instruments that may be transported by the passenger. Within the Customs inspection, a separate inspection may be performed by the US Department of Agriculture (USDA) as part of their Animal and Plant Health Inspection Service (APHIS).

For many aspects of the design of the international arrivals hall, specifications will be found in the CBP FIS Facility Planning and Design manual. This manual should be considered as a controlling document, and any local standards or desires from a specific air carrier must be evaluated with regard to any

⁴⁴ IATA ADRM 10th Edition, Section 3.4.11.13.2, 2017

⁴⁵ IATA ADRM 10th Edition, Section 3.4.15.5.6, 2017

potential conflicts with the official CBP guidance. In all cases, deviations from the CBP manual must receive CBP approval before any physical work begins.

a. Sterile Corridor

Arriving international passengers must be kept separate from other passengers, visitors, or unauthorized airline employees until they have cleared all FIS inspections. Therefore, a separate corridor system from the aircraft gate to primary inspection is required. The corridors should be sized for single-direction passenger flow. Depending on the distance from gate to primary inspection, moving walkways or APMs may be appropriate. Because departing passengers can use the same gates as international arrivals, control doors and monitoring of the corridor system is required to prevent mixing of arriving and departing passengers⁴⁶.

Passengers with special needs may be met by airline or contract staff to be escorted through the various processes. All non-CBP staff working in the FIS must be approved by CBP to enter the screening area. The FIS is not a security-sterile environment and personnel with access to the FIS must be TSA-screened before entering the secure departures area of the terminal.

b. International In-Transit Lounge for Passengers Not Entering the US

All passengers boarding flights bound for the United States must have documentation showing their ability to present for entry through the guise of a US Passport, US Permanent Resident card, US Immigrant or Non-Immigrant Visa, or a passport from a country with a Visa Waiver agreement. All passengers are inspected for entry upon first arrival in the United States and must be granted admission, even passengers who have no intention of leaving airport property and are only in the United States for an onward flight leaving the US. Transit visas are somewhat rare, with only 21,080 issued in FY 2016 out of over 10 million total non-immigrant visas.

In the event that direct airside transit is restored, this requirement will be revisited.

c. Immigration (Conventional Option)

Primary Inspection: Passengers have passport identification checked, and declare checked baggage items.

The passengers' documents are examined by a CBP officer, an automated background check is performed, and an interview takes place to determine the passenger's motivation for travel to the United States and suitability for admission. If the officer believes that more information or documentation is required beyond what can be established at this interview, he or she will refer the passenger to secondary screening. The officer will also ask questions to determine if the passenger must be mandatorily referred to either Customs or Agricultural screening that is more extensive than what will be encountered during the standard processing flow. If the officer decides the passenger is suitable for admission, he or she will be directed onwards, to baggage claim or the FIS exit.

The number of booths required for primary inspection is typically prescribed by the CBP based on the design hour passenger volume and, as such, consideration of dynamic issues will not usually impact that

⁴⁶ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.1, 2010

aspect of the facility. However, while agencies may specify minimum queue depths, they may be insufficient depending on the likely distribution of peak hour passengers amongst flights and the relative timing of those flights. Examining demand in a smaller time frame, 15 or 30 minutes, is often helpful in understanding the maximum length of queue to be accommodated. One other key area to consider in arrivals facilities is the impact of off-time (i.e., early or late) flights. In addition to a base analysis, if off-time data is available, a number of sensitivity tests should be performed to fully understand the dynamics of the facility⁴⁷.

CBP periodically updates standards and procedures, refer to ACRP Report 61 and Customs and Border Protection (CBP) FIS Facility Planning and Design for further design considerations for immigration. The latter document is a confidential document and may be obtained through CBP.

d. Immigration (Automated Primary Option)

The CBP Global Entry program is the current manifestation of an expedited screening program for passengers who frequently travel internationally. Stemming from the Global Entry program, conventional ~~un~~staffed primary inspection booths are being replaced by kiosks for passengers to complete the primary inspection process.

Passengers at these kiosks scan their identity documents, answer basic questions, and are algorithmically passed or referred to a conventional primary inspection booth. The passengers who have been passed then present themselves to a CBP agent for an interview that is shorter and less space-intensive than the standard practice. Because the interaction is shorter, fewer agents are required to process the passengers. At this point, the agent can either clear the passenger to proceed to baggage claim and the Customs part of the inspection, can refer the passenger back to a standard primary inspection booth, or refer the passenger to secondary screening. These latter two examples should be considered rare, as the majority of the criteria for referrals have been pre-determined at the kiosk.

The implication for terminal planning is that expedited screening increases processing throughput at primary inspection and reduces the area required to hold passengers waiting for immigration.

e. International Bag Claim System

Upon flight arrival, airline personnel remove bags or unit load devices containing checked bags from the aircraft's cargo holds. These bags are carted to unload areas where they are manually transferred onto flat sections of conventional conveyors that transport bags to the international baggage claim areas.

There are three types of baggage claim devices: sloped plate carousels, flat plate racetracks, and simple claim shelves:

⁴⁷ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.2, 2010



Figure 37: Sloped Plate Baggage Claim

Sloped plate carousels are typically used when the inbound baggage unload area is on a different floor or otherwise remote from baggage claim. Carousels can be fed by conventional conveyors connecting from the ceiling or from the floor, and can hold more bags because the conveyor feeds allow presentation along the entire perimeter length of the device. Additional capacity is gained because bags can also stack along the slope. Carousels can be fed from two separate sets of unload conveyors, which allows two baggage train carts to be unloaded simultaneously.



Figure 38: Flat Plate Baggage Claim

Flat plate racetracks are typically used when the inbound baggage unload area is on the same floor as baggage claim and is able to directly feed baggage claim, typically through the demising wall separating the Secure Identification Display Area (SIDA) from baggage claim. Flat plate racetracks can be configured in various shapes (“T,” “U,” or “L”) to provide the necessary presentation length and, when active, the conveyor plates recirculate between the SIDA and the baggage claim space through wall openings equipped with fire/security shutters.

Simple claim shelves typically can be used for low activity terminals and for delivery of oversized/odd-sized checked items. Shelf units are not mechanized; items are delivered through an opening in the SIDA demising wall, which is equipped with fire/security shutters.

Baggage claim for international flights is located in the CBP FIS facilities, downstream of document check (passport control), and is part of the sterile area.

After primary inspection, passengers proceed to international baggage claim. The approach in sizing a baggage claim for an FIS is similar to that of a domestic baggage claim. However, the time a claim unit is in use is typically longer for two reasons⁴⁸:

- Checked baggage ratios and the percentage of passengers with checked bags are typically higher than for domestic flights, thus requiring more time to unload. All passengers entering the United States must also have CBP baggage inspection at the first point of entry. Connecting passengers then re-check bags to their final destination.
- Because passengers must clear the CBP primary area before entering the baggage claim area, bags may be on the claim unit before passengers are present. This delay can require a claim unit with greater capacity for baggage storage than is required for domestic flights. Thus, an international claim unit may be sized more for baggage storage than for active claim frontage, although both aspects should be considered. If sufficient storage isn't available (or passengers are delayed at the CBP primary area longer than anticipated), airline employees may have to unload bags from the claim unit and place them on the floor or shelves for passengers to pick up.

1. Oversized Baggage

Facilities should also be provided for odd-sized or oversized baggage, such as golf clubs, skis, and packages that are too large to fit on the baggage claim units or may cause jams on feed conveyors.

f. Airline Baggage Service Office

Baggage service offices (BSO) include both passenger service counters and waiting areas, as well as storage for late or unclaimed bags. Full baggage offices are typically required only by airlines with sufficient activity to warrant staffing. Other airlines often will request baggage lock-up areas to store late or unclaimed baggage and will handle passenger claims at their ATO counters⁴⁹.

g. Baggage Carts

Baggage carts, also known as "trolleys", are provided as an amenity to passengers so they may wheel large heavy baggage around the airport terminal and nearby ground transport facilities. They are normally limited to landside areas where checked baggage is handled by the passenger, e.g. for departing passengers, from curbside, parking garage, or transit station to the check-in hall; and for arriving passengers, from baggage claim to curbside, parking garage, or transit station; although in some airports, a small provision of baggage carts is located within the airside areas, close to the concessions.

1. Design Considerations

- Terminal facilities should be designed with large, clear paths so that the cart trains can be maneuvered through.

⁴⁸ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.3, 2010

⁴⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11.2, 2010

- Baggage cart origin stations should be placed along these wide paths.
- Terminal building layout should allocate appropriate areas and consider means for collection, storage, return to and replenishment of cart origin stations.
- Terminal building designers should check the cart manufacturer's specifications for appropriate dimensions for the clear paths, including minimum width, and minimum turn radius.

Baggage cart concept of operations including floor plans with baggage cart deployment locations and train paths shall be submitted to the Port Authority for review and approval.

h. Customs

Exit Control: Passengers submit their immigration form and are granted entry into the United States, or are directed with their checked baggage to secondary screening.

This is the final step in the overall entrance examination. Once passengers have been cleared through Customs, they may proceed out the exit door to the landside portion of the terminal, at which point they are free to utilize onward air or ground transportation.

i. Secondary Screening (Public Health, Agriculture, Fish & Wildlife, etc.)

Secondary Screening: Passengers who are selected for secondary screening are directed to Department of Agriculture or Customs screening of checked baggage, or secondary screening of passports and immigration forms.

This will take place in a separate and enclosed section of the FIS facility. The specialized space and equipment requirements for this secondary area are contained in the CBP FIS Facility Planning and Design manual. The APHIS screening typically involves trained dogs sniffing passengers' baggage, and appropriate provisions must be made in back-of-house areas for the requisite animal welfare.

j. FIS Exit Control

Upon attaining all immigration and customs clearances, passenger and their bags are considered "bonded" and allowed to enter the USA. A final document check and exit portal is required. FIS exit is a one-way process, typically with a frosted glass door or other visual methods employed to block continuous view into the screening areas. Staff from either CBP or local services will be placed to prevent entry into the CBP screening area by members of the public from landside through the exit door.

It should be noted that bonded passengers are not security screened. Newly arrived international passengers who will be taking a connecting flight (whether domestic or international) must go through security checkpoints, and their baggage must be screened, similar to originating departing flights.

k. International Recheck (Passenger and Baggage)

International passengers connecting to a domestic or international departing flight must clear all CBP inspections at their first point of arrival in the United States. Thus, after completing all the FIS procedures, connecting / transfer passengers must re-check their baggage. The re-check counters

should be located between the FIS exit and the meeter/greeter lobby so that the connecting passenger does not have to transit the meeter/greeter lobby with bags⁵⁰.

It is optional for airlines to elect to provide this service at the exit from the FIS. Airlines that choose to provide international recheck service may be those with higher customer service standards or with their departure facilities in a different terminal than the FIS. The recheck counters may be dedicated to an airline or in a common-use arrangement, facilitated by a ground handler, or with space time-shared between airlines depending on their intraday peaks.

l. Meeters / Greeter Area

After exiting the FIS, locally terminating passengers enter a meeter/greeter lobby, which will also provide access to ground transportation and other arriving passenger services. The meeter / greeter lobby should have seating for a proportion of the meeters/greeters. However, seating may account for a smaller portion of the area with greeter standees and passenger circulation through the space making up the bulk of the area⁵¹. The number of meeters and greeters is often influenced by the local/regional culture. So, specific information should be sought for each airport project.

m. Concessions

Refer to Part 1, Section 4.

n. Restrooms

Provide restrooms along the sterile corridor, and/or before the queuing areas for CBP processing. Special consideration must be given to the trash collection from these restrooms, because they are frequently used as a disposal area for weapons or contraband that passengers fear might be discovered in the immigration and customs inspection process.

Refer to Part 1, Section 7.

o. General Visitor Information

All airports require some way of providing information to arriving passengers who may not be familiar with the airport or its region. Airports are using every marketing and public relations tool available to build a positive customer service image and make a favorable impression on travelers and visitors as they pass through their facilities. The customer service centers, information counters, and kiosks strategically located in the terminal assist passengers and visitors by addressing their questions, comments, or concerns. The range of services offered at such information centers might include flight, airport, and city information; directions; lost and found; local phone calls; in-terminal paging services; valet and ground transportation coordination; etc. These tools can be simple information displays and counters with local brochures up to staffed counters or customer information centers⁵².

⁵⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.5, 2010

⁵¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.6, 2010

⁵² ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.6 & 3.14.4, 2010

6. Domestic Arrivals

a. Backflow Prevention / Exit Lanes

Arriving passengers exit from the post-secure to the pre-secure area through a hallway or portal that has one-way control, either staffed or automated. This may be located near the SSCP or away from it.

A staffed backflow prevention corridor is comprised of a manageable width and sufficient length to give visual control to the officer on watch, so that he or she can see and prevent approaching persons walking the wrong way, attempting to reach the post-secure side. Supplementing the staff person, there are cameras and motion detectors, which sound an audible and visual alarm if they detect a person walking in the wrong direction.

Automated exit lanes are comprised of a series of automated one-way doors designed to allow passengers to exit the secure side, but not move in the other direction. They are also supplemented by cameras and motion detectors, which sound an audible and visual alarm, and lock the doors if it detects a person walking in the wrong direction.

b. Domestic Arrivals / Baggage Claim Hall

The arrivals hall is a portion of the terminal where public access is unrestricted. This area must accommodate sufficient space for arriving passengers and their meeters/greeters, as well as the required number of baggage claim devices. The arrivals hall also provides areas for ground transportation centers, concessions, restrooms and other amenities to satisfy users' needs and contribute to a satisfying experience while at the airport. Such amenities include city and transportation information, rental car counters, concessions space, seating, and support areas such as restrooms and mechanical spaces⁵³.

It should be noted that although domestic baggage claim facilities typically form part of some arrivals halls at US airports, this is less common in other countries because of concerns about theft and general security. In these terminals, only arriving passengers have access to bag claim, and after they claim their bags, they go through a secure portal into the arrivals hall where the meeters / greeters waiting area is located.

c. Domestic Baggage Claim System

Upon flight arrival, airline personnel remove bags or unit load devices containing checked bags from the aircraft's cargo holds. These bags are carted to unload areas where they are manually transferred onto flat sections of conventional conveyors that transport bags to the domestic baggage claim areas. Domestic baggage claim is typically located in non-secure areas of airport terminals with direct access to the curbside and accessible to meeters/greeters.

Unload areas for inbound (arriving) domestic bags are usually co-located with outbound (departing) baggage makeup areas. For additional information on baggage claim devices refer to Part 1, Section 5. e.

⁵³ IATA ADRM 10th Edition, Section 3.4.13.5, 2017

d. Airline Baggage Service Office

Refer to Part 1, Section 5. f.

e. Baggage Carts

Refer to Part 1, Section 5. g.

f. Meeter / Greeter Area

The arrivals hall provides a short-term waiting area for visitors (meeters and greeters) waiting for arriving passengers. It may be co-located with the baggage claim hall, or between the baggage claim hall and the landside curbs, providing dedicated circulation and waiting areas that should be dimensioned to accommodate the expected flows of passengers and visitors. It should also cater to the use of baggage carts⁵⁴.

Visitors will access the arrivals hall from the landside forecourts. The number of meeters and greeters is often influenced by the local/regional culture. Therefore, specific information should be sought for each airport project.

g. Concessions

Refer to Part 1, Section 4.

h. Restrooms

Refer to Part 1, Section 7.

i. General Visitor Information

Refer to Part 1, Section 5. o.

7. General Public Areas

a. Circulation

Refer to Part 1, Section 4.

b. Conveyance systems

References:

- ACRP Report 25 - Airport Passenger Terminal Planning and Design
- ACRP Report 67 - Airport Passenger Conveyance Systems Planning Guidance
- ACRP Report 117 - Airport Escalators and Moving Walkways
- IATA Airport Development Reference Manual 10th Edition

Passenger conveyance systems are pieces of equipment in airports that help to physically move people such as escalators, elevators, stairs, moving walkways, and passenger assist vehicles/carts. A critical

⁵⁴ IATA ADRM 10th Edition, Section 3.4.13.5.1, 2017

factor affecting passenger circulation at the airport is the capacity of the conveyance systems and their ability to handle passenger demand throughout the day.

Level changes can be achieved through ramps that have gentle gradients and wide enough space to enable Passengers with Reduced Mobility (PRM) and passengers with wheeled baggage and/or children in strollers to move freely and pass each other.

Any change of level that cannot be achieved by gentle ramps must be provided with satisfactory modes of mechanical vertical circulation. People mover systems are critical in moving passengers between terminal buildings and transferring them between their associated concourses and satellite or remote gates. These systems, which aid in the movement of passengers, include moving walkways, APM, escalators, and elevators⁵⁵.

- **Escalators.** Typically, escalators provide the primary means of transport for large numbers of people between floors.
- **Elevators.** Passenger elevators are required for handicapped travelers, passengers with large bags and/or baby strollers, and others who either cannot or will not use escalators or stairs.

Passenger walking distance, ease of use, and the positioning of conveyance systems with regard to passenger flows must be considered when passenger terminal facilities are planned. In all airports, elevators and escalators are used to provide vertical circulation for passengers, while moving walkways, passenger assist vehicles, and wheelchairs are often used to facilitate horizontal movement through airports with longer walking distances.

c. Moving Walkways

A moving walkway is a slow-moving conveyor mechanism that transports people across a horizontal distance, providing an efficient means of traveling horizontally through terminal areas and reducing travel time through terminals for those who choose to walk on the walkway equipment. This system can either be manufactured as a pallet or moving belt style.

1. Walking Distance

Walking distance for departing passengers is defined from security screening checkpoint (SSCP) exit to the farthest gate(s); whereas walking distance for arriving passengers is defined from the farthest gate(s) to immigration control or baggage claim.

A series of moving walkways should be considered in terminals with walking distances over 1,000 feet⁵⁶. This is consistent with the International Air Transport Association (IATA) Airport Development Reference Manual (ADRM), which recommends routes with walking distances of over 300 meters (985 feet) should be augmented with moving walkways.

⁵⁵ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.10.6, 2010

⁵⁶ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.1.5

2. Moving Walkway Width

Depending on the manufacturer, the pallet width (clear width for walking) for an airport moving walkway is 48-56 inches. The overall outside edge-to-outside edge width for the moving walkway ranges from 66-84 inches, and maximum possible lengths vary by manufacturer. Figure 39: Dimensional Example of a moving walkway

represents a typical moving walkway with common dimensional criteria. The width used for planning double moving walkways (e.g., one in each direction) are 12-15 feet, including allowance for a 1-foot buffer between the two walkways⁵⁷.

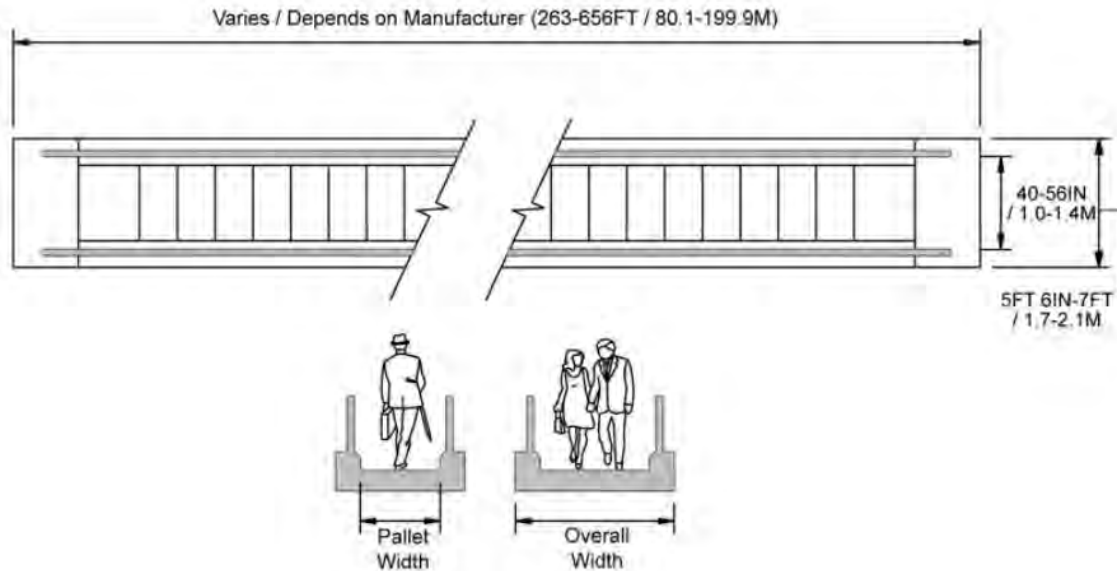


Figure 39: Dimensional Example of a moving walkway⁵⁸

In airport applications, the narrow widths can be problematic, wider pallet widths can allow people to pass one another, even with luggage. Designers should specify the higher width for longer moving walkways, to allow walking passengers to easily pass standing passengers with little to no interference.

3. Angle / Maximum Rise / Maximum Length

The maximum length of a moving walkway ranges from 164 to 656 feet, but a practical maximum length is around 300 feet per unit⁵⁹. Due to emergency egress requirements, moving walkways at Port Authority airports may be no longer than 150 feet.

Certain systems can be constructed with an incline. Moving walkways at Port Authority facilities shall have a maximum inclination angle of 3 degrees for segments within 36 inches of the entry and exit ends, and no more than 12 degrees at any point⁶⁰.

⁵⁷ ACRP 25 Airport Passenger Terminal Planning and Design, Vol 2

⁵⁸ ACRP 25 Airport Passenger Terminal Planning and Design, Volume 2: Spreadsheet Models and User's Guide

⁵⁹ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.1.1.2

⁶⁰ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.1.1.2

4. Entry Clear Area

The absolute minimum clear area in front of the entry zone of moving walkways should be twice the distance between the centerlines of the handrails. This distance should provide sufficient queue space to accommodate passenger surges and, if applicable, designers should consider the effects of other pedestrian cross-traffic passing through the queuing area. Queuing is often generated by peak passenger surges at the walkway entry. As a result, planners must analyze the peak 10 to 15-minute period to account for pedestrian surges on conveyance devices. Assessments of baggage quantities should also be estimated because this will affect space requirements per person and per party. Typical area queues range from 13 square feet per person (sfpp) to as much as 17 sfpp.

5. Landing Clear Area

Minimum clear area at the exit zone of moving walkways should be 30 feet. As a practical planning rule, if multiple moving walkways are operating in succession, this safety zone must be provided independently for each moving walkway. Further, the provision of suitable queuing area at the entrance and the exiting end of moving walkway must consider the effects of all pedestrian traffic passing through the area, whether or not the pedestrians are using the moving walkway system.

6. Concession Location in Relation to Moving Walkways

Planners should carefully consider the arrangement of moving walkways with respect to retail concessions, such that the moving walkways do not bypass concessions, which is inconvenient to passengers who have to double back to patronize the concessions, and may be dissuaded from doing so if the walking distances are long. As indicated in Figure 40, it is preferable to locate concessions either adjacent to a moving walkway or between successive moving walkways.

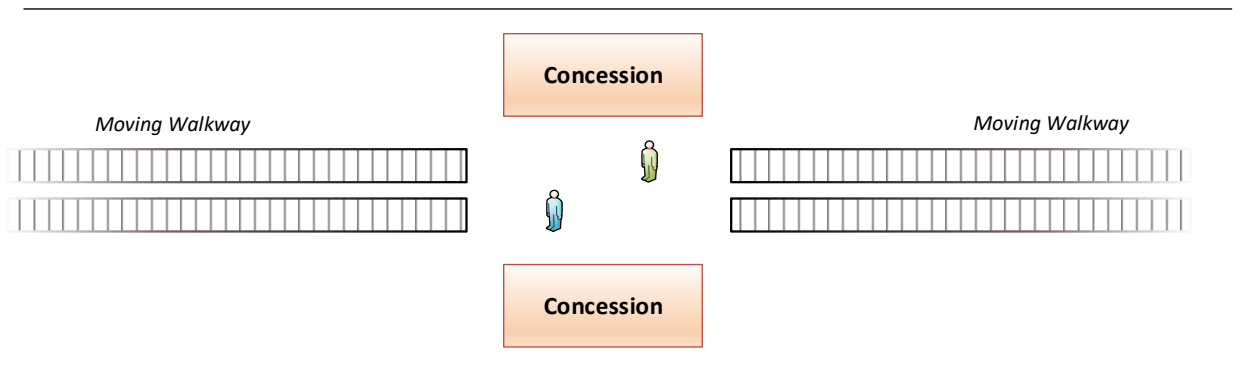


Figure 40: Preferred Arrangement of Moving Walkways and Concessions: Concessions Readily Accessible⁶¹.

7. Safety and Signage

Passengers using a moving walkway may not recognize that they are approaching the end of the walkway where they must transition to walking. Falls can result. Signs and recorded announcements can

⁶¹ Arup

mitigate accidents but cannot eliminate them. Signs and/or announcements should also be used to prohibit passengers in wheelchairs or with baggage carts from using moving walkways⁶².

d. Escalators

Escalators and/or ramps should be provided at all level changes along passenger flow routes. Stairs may also be included as a contingency measure in the event of escalator maintenance or breakdown, or for passengers who prefer them. Escalators are the preferred method for moving most passengers quickly from level to level, but they must be accompanied by elevators to ensure that passengers with reduced mobility (PRM) and passengers with substantial amounts of baggage and/or baby strollers are provided with an equivalent, speedy, and straightforward method of making the level change⁶³.

1. Capacity

Human factors play a large role in escalator capacity with arrival rates and person-to-person spacing influencing the rate at which escalators move people. Based on common practice among airport terminal planners, design capacities are typically estimated at 50 people per minute (ppm) in the down direction and 60 ppm in the up direction if location-specific data is not available⁶⁴.

2. Step Width

Observed passenger behavior on escalators in airports is generally one person on every other step on a 32-inch-wide escalator and one person per step on a 48-inch-wide escalator. At airports which experience a higher percentage of pleasure flying or serve tourist destinations, a 48-inch-wide surface better accommodates baggage⁶⁵.

3. Maximum Rise

The angle of inclination of any escalator shall not exceed a maximum of 30 degrees⁶⁶.

4. Queue Area

The termination points of an escalator must not be in a confined or restricted processing area where “back flow” might occur⁶⁷.

Safe design provisions must include ample space to allow entering and exiting, especially in the space between successive escalators. A minimum of 30 feet of queuing and run-off space, as measured from the escalator comb is preferred, to clear to any obstruction at the top and bottom of each escalator.

⁶² ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.1.3

⁶³ IATA Airport Development Reference Manual 10th Edition, Section 3.4.10.2

⁶⁴ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.1.4

⁶⁵ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.2.1.3

⁶⁶ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.2.1.2

⁶⁷ IATA Airport Development Reference Manual 10th Edition, Section 3.4.8.1

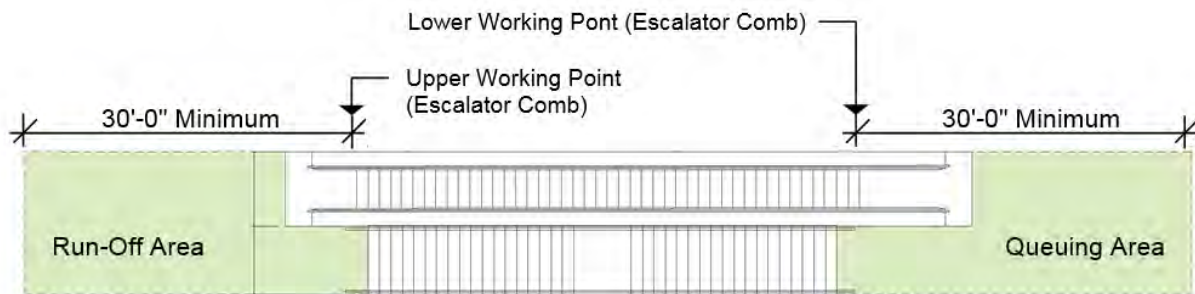


Figure 41: Queuing and Run-off Space for Escalators ⁶⁸

The width of the zone shall be not less than the width between the centerlines of the handrails plus 8 in. The length of the zone Space shall be provided to accommodate all traffic in the safety zone. If multiple escalators are operating in a serial configuration, this safety zone must be provided independently for each escalator (shown in Figure 42)⁶⁹.

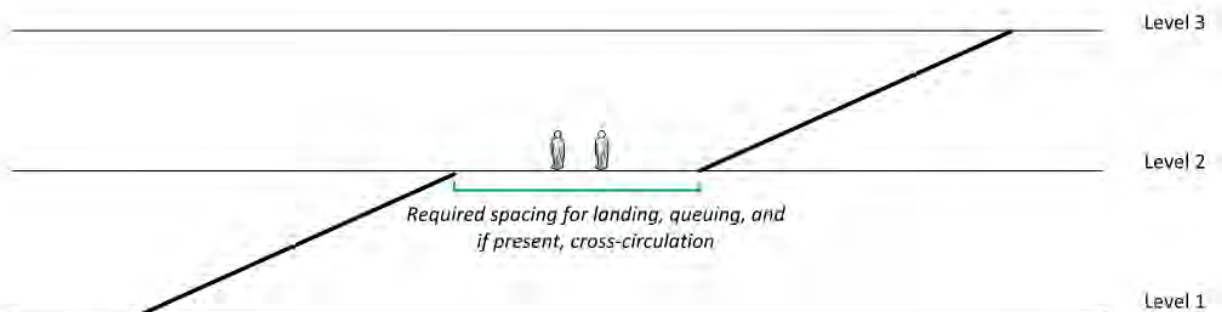


Figure 42: Boarding Area between Successive Escalators.⁷⁰

Further, the provision of a suitable queuing area at the entrance as well as adequate space for exiting must accommodate composite flows of all pedestrians moving through these areas without hindering movements to and from the escalator. Finally, in configurations where escalators cascade sequentially and a landing area is created where people transfer between escalators, ample space must be provided to absorb fluctuating exit and entry flows and cross-flows, if present, between successive escalators to avoid potentially hazardous conditions associated with pedestrian cross-flows at different directions and speeds. To the extent possible, designers should avoid creating arrangements where there will be cross-circulation between successive escalators.

5. Number of Escalators

Escalator boarding rates for passengers going up are higher than for passengers going down. In general, it is believed that passengers slow their boarding rate when going down if the entire escalator is not visible from their point of view.

⁶⁸ Port Authority PATH – Harrison Station Planning Standards

⁶⁹ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.2.1.4

⁷⁰ Arup

As the number of escalators is increased the ability to move more people increases, but the increase is not linear. For example, the addition of a second escalator doubles capacity but may not double throughput. The boarding rate per individual escalator is dependent on the use and placement of the escalator bank. When bulk queues form in front of multiple escalators, the effect of people moving through the larger queuing space and the additional decision time associated with choosing escalators can regulate or meter the flows onto the escalators. This can result in lower boarding rates for multiple, adjacent escalators.

Escalator quantity should be determined by demand and should be able to accommodate waves of arrivals. For instance, if escalators provide terminal access from an automated people mover station, the escalators should be able to clear one trainload of arriving passengers before the next train arrives.

e. Elevators

Elevators shall be conveniently located for all customers and facilitate access for the mobility impaired and the disabled. Elevators shall be provided with a queuing area to permit passengers disembarking the elevator to exit without interference from those waiting. Elevators shall be located so as to not obstruct general passenger circulation or visually obscure other vertical circulation elements along the path.

1. Elevators Use in Relation to Location

The location of the elevators relative to the security checkpoints affects use. Elevators located prior to security points have higher utilization because they carry passengers with a higher number of bags. In contrast, post-security passengers usually have less baggage. The reduction in baggage gives passengers additional alternatives in vertical conveyance choices and may reduce elevator use as a result.

2. Capacity

Elevator capacity depends on several different characteristics, including rated speed, number of stops, cab floor area, dwell times, and passenger demand patterns between levels of the building.

Cab size in an airport environment should be guided by several factors including the required system capacity measured in passengers per peak 15 minutes, specific use, area occupancies, and level of service to be achieved during the 15-minute peak period. Specific uses include janitorial and supplies services, concessions goods, airport employee, airline personnel, public, and traveling passenger conveyance. With respect to passenger conveyance, cab size should be guided by the typical area required by each standee with or without baggage, baggage carts, or wheelchairs. *Figure 43* indicates the typical area required by standees. Typical area occupancy is around 3.5 sf/person for a crowded elevator, not including baggage. With baggage, typical area occupancies may increase to 10 sf/person on average. Recommended cab size for elevators in airports ranges between 40 and 55 square feet, which allows for 4 to 5 persons with baggage, or up to 10-15 persons without baggage⁷¹.

⁷¹ ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 2.3.1.1

When intended for extensive use of passengers with baggage carts, cab configurations often have large door widths and flow-through door configurations (i.e., doors on each side of the cab). These large units are typically ordered as special-order hospital-size elevators with large cab sizes.

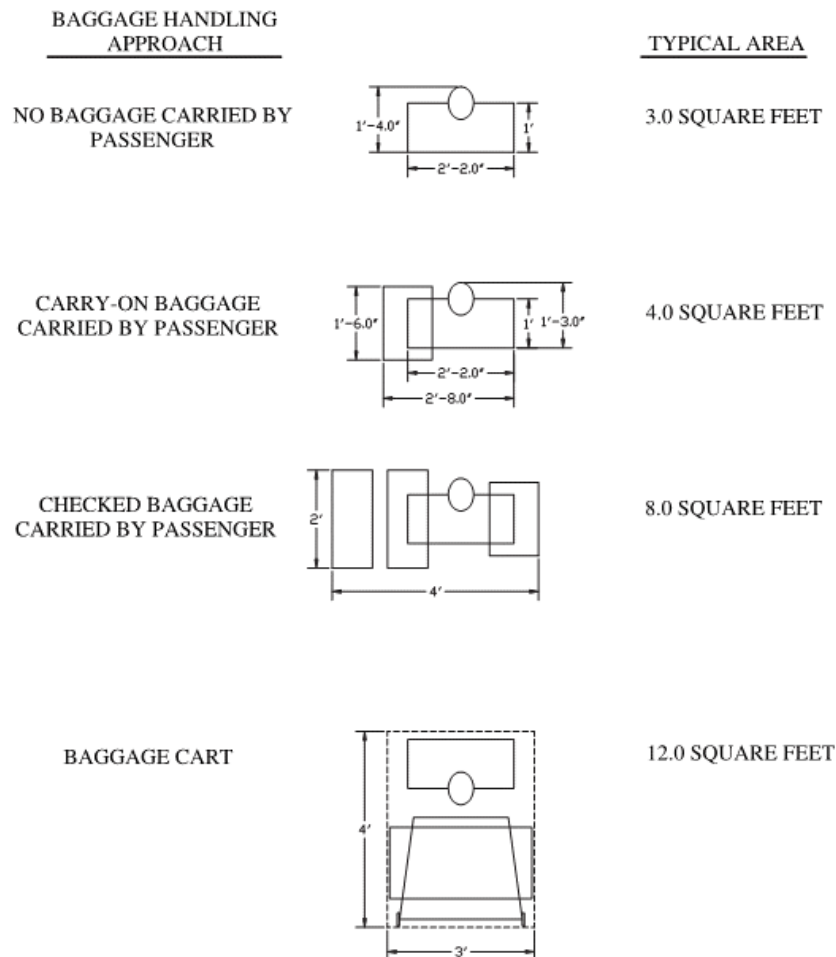


Figure 43: Typical Area Required for Standees⁷²

3. Elevator Boarding Area & Wait Time

The quality of elevator service is normally based on waiting time. Service time of 30 seconds and an average wait time of 1 minute are typical in an airport environment. The service time corresponds to the time it takes to board the elevator and includes door open time, boarding/deboarding time, time to push the elevator button, and door close time. The average wait time is the time a passenger waits for the elevator to arrive, prior to the start of the elevator service time. Boarding areas should provide

⁷² ACRP 67 Airport Passenger Conveyance Systems Planning Guidebook, Section 4.3.3.1

adequate space for queuing passengers. On average, 20 square feet per person (sfpp) should be provided at elevator queuing and boarding areas in an airport environment.

4. Consideration of Using Freight Elevator

For Luggage Processing Units, specially designed units are required for the acceptance of oversized or out-of-gauge (OOG) baggage. These must be located in clearly identified positions within the processing hall. These processing positions have wider baggage belts with a straight feed down to the outbound baggage hall. They usually also have access to a freight elevator or door that will allow large non-conveyable items (Super-OOG) to be placed on a cart and taken to the outbound baggage makeup hall⁷³.

f. Restrooms

Restrooms play an important role in airport facilities for passenger and staff convenience and passenger perceptions regarding their overall experience at an airport. Passengers and staff should be provided with adequate toilet facilities near all main waiting zones and workplaces.

Restroom requirements include the quantity of lavatory fixtures needed to accommodate the expected numbers of people using the restroom facility. Dimensional criteria based on area per fixture and circulation, and spatial guidelines for restroom layout are used to derive the restroom space program.

Refer to Public Terminal Restrooms Appendix for the *PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms*.

g. Concessions

Refer to Part 1, Section 4.

h. Meditation / Prayer / Quiet Room

Considerations should be given to providing quiet space facilities for passengers to rest, pray, or contemplate. Different religions have different facility requirements, these need to be considered carefully in conjunction with the relevant stakeholders during the planning process⁷⁴.

i. Facilities for Passengers/Employees with Disabilities (ADA and Universal Design)

1. Americans for Disabilities Act

Airports shall adhere to the design standards set forth by the Americans with Disabilities Act (ADA). Airport terminals should fully accommodate the needs of passengers with disabilities and provide respective facilities that offer the greatest possible traveling comfort to them. Terminal operator/designers should also provide suitable workplaces to employees with reduced mobility. The guiding principle for airport planners and designers is that persons with reduced mobility should be allowed to exercise self-reliance wherever possible⁷⁵.

⁷³ IATA Airport Development Reference Manual 10th Edition, Section 3.4.11.3.4

⁷⁴ IATA ADRM 10th Edition, Section 3.4.11.13.2, 2017

⁷⁵ IATA ADRM 10th Edition, Section 3.4.5, 2017

Whenever possible, terminal facilities should enable passengers with disabilities to use the same facilities as passengers who do not have reduced mobility. All elevators, concessions, and restrooms in the terminal building must accommodate wheelchair users to meet ADA requirements.

2. Universal Design (Inclusionary Design)

Universal Design integration aims to achieve an equal level of service and increase safe and efficient travel for people, of all ages and abilities, to the greatest extent possible, without any intended or unintended obstacles that limit, segregate, and stigmatize. There are two growing disability markets to serve that primarily include individuals born with disabilities or disabled as younger adults. The second market includes mature individuals with late onset disabilities. ACRP Report 130 and ACRP Report 157 summarize, “The intent of universal design is to create spaces and components that everyone can use, regardless of mobility, age, status in life, ... It is important to consider universal design, especially from the perspective of providing excellent customer service. With our increasing elderly population, for example, accommodation for limited mobility, visual and hearing impairments, and slower movement is no longer just the realm of the accessible.” Planners may wish to refer to the FAA Airport Disability Compliance Program and the New York City Inclusive Design Guidelines.

j. Outdoor Waiting / Seating Areas

To comply with PA Policy and applicable state laws against smoking indoors, certain areas outdoors are designated for smoking. Smoking areas must be a certain distance away from entry doors and HVAC system intakes.

k. First Aid / Emergency

Medical facilities should be provided to staff and passengers for treatment of medical emergencies (first aid), for aircrew medical inspection and for emergencies and rescue. The usefulness and efficiency of any medical emergency and rescue organization on an airport may be greatly enhanced if it is in continuous use dealing with day-to-day medical activities during the normal routine working of the airport⁷⁶.

l. HVAC

Heating, Ventilation, and Air Conditioning (HVAC) are the systems used to provide thermal comfort and ventilation for the terminal building interiors. By providing proper thermal comfort in the terminal, passengers will experience a more pleasant building environment when moving throughout the building.

m. Lighting

Providing the proper lighting in the terminal building ensures passengers and employees can clearly see and find their way throughout the terminal, especially when looking for signage and specific amenities. Proper lighting also ensures a pleasant passenger experience.

⁷⁶ ICAO Doc 9184-AN/902, Airport Planning Manual Second Edition, Part 1, Section 12.3, 1987

n. Public Address / Visual Paging System

Public areas of a terminal and passenger airside facilities, including boarding lounges, should be provisioned with means for paging and mass notification. These systems need to be modular so they can be adapted to new or changing uses in different parts of the airport (passenger halls, retail areas, etc.) and controllable by zone according to the messaging function being performed⁷⁷.

o. Wayfinding & Signage

Signage and wayfinding is an important airport terminal component that facilitates the movement of departing passengers from the airport access roadway (or transit system) through the terminal to the departure lounge; and vice-versa for arriving passengers. However, passenger demographics are diverse, and can include frequent business travelers, first time travelers, international passengers, aging passengers and passengers with disabilities. Therefore, it is important that signage and wayfinding is consistent and reliable throughout the airport, and meets all local and national code compliance standards⁷⁸. All projects at port authority facilities must follow PANYNJ Pedestrian Signage and Wayfinding Standards.

p. Advertising

In-terminal advertising includes traditional static airport advertising displays such as wall posters, backlighted wall displays, wall wraps, and large-format displays.

Other advertising media in airports may include interior and exterior loading bridge wall wraps, ads on luggage cart panels, banners and column wraps, and dynamic displays including flat-panel monitors, video projection systems, and displays with alternating, changeable printed media. The development of light-emitting diode (LED) displays, such as those used as high-definition video walls in sports stadiums, is providing new opportunities to create free-form, custom displays capable of dynamic graphics and video⁷⁹. Advertising programs are subject to review and approval by PA customer service group.

q. Passenger Personal Technology Support

1. Electric Power Outlets

The recent trend, likely to increase in the foreseeable future, is that most passengers carry one or more electronic devices on a flight, including laptop computers, tablets, smartphones, e-readers, and gaming consoles. The convenience of recharging electronic devices at the airport adds to customer satisfaction, allowing passengers a way to stay connected and remain productive while traveling through the airport, as well as charging their devices before a flight which may not offer electric recharging on board.

Providing convenient electrical outlets is a trend that is increasing in popularity at airports and has more recently been recognized by some airlines as a potential LOS enhancement to be associated with their particular airline brand⁸⁰. When insufficient electric recharging is provided, passengers tend to cluster

⁷⁷ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.6, 2010

⁷⁸ FAA AC 150/5360-13A, Section 6.4.4, 2016 (Draft)

⁷⁹ ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, Chapter 2, Section 2.2.5, 2011

⁸⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.6, 2010

around the few available electric outlets, creating unwanted crowding, sitting on the floor, and competition for scarce resources, in hallways or other locations not intended for sitting or waiting.

The recharging outlets at the airport should be located primarily in holdrooms, because that is where passengers spend the most stationary time. Holdrooms shall provide a number of charging receptacles accessible to the public for no less than 50% of the seats available in the holdroom. At least one-half of the receptacles provided must be standard North American 110v outlets with 3-prong (grounded) plugs. USB recharging outlets are recommended in addition to standard outlets. Outlets of both types may be either incorporated into holdroom seating (as an original accessory, or a retrofit), or on standing stations or pylons furnished by a third-party provider (often a technology company), sometimes with advertising and/or charging a fee for use. Providing outlets at holdroom seating is the higher level of service.

2. Wi-Fi

Many airports have added free Wi-Fi high-speed Internet access as an amenity for travelers. Some offer Wi-Fi access throughout the entire airport, while others may limit access to specified areas of the terminal complex or waiting areas. In addition, many airline club lounges offer their own free or fee-based Wi-Fi access⁸¹.

8. Back-of-House Areas

Non-public support facilities comprise a wide variety of tenants and functions, such as employee amenities, operational spaces, and office space for agencies, including Port Authority, Federal Aviation Administration (FAA), Transportation Security Administration (TSA), US Customs and Border Protection (CBP), police, FBI, and Airport Rescue & Firefighting (ARFF). Airline and third-party ground handling contractor support facilities would be also included in this group.

The area provided in the airport for these facilities varies per airport, depending on different factors, such as which specific agencies would occupy the building, and operational layout issues such as the provision of secure vs. non-secure vs. sterile elevators to segregate passengers, staff, goods, and waste.

Considering all these factors, the typical area assigned to non-public supports facilities ranges from 12% to 16% of the total gross terminal building area. Terminal designers can use this number as a starting point for initial space planning exercises, but as soon as possible in the programming phase, actual space requirements should be assessed for each tenant and user.

a. Employee Screening

Employee screening is currently not a TSA mandate. Terminal operators or airlines may elect to screen employees via similar means that passengers are screened, (e.g., walkthrough metal detector and X-ray screening of bags / other possessions.) Employee screening is more commonly implemented at airports / terminals that have experienced some level of employee (“insider”) criminal activity. The TSA may eventually require all employees with airside access to be screened, and so some airports are reserving space for this purpose.

⁸¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.6, 2010

It is recommended that the screening of staff be separated from other screening operations. Screening requirements for staff may differ to those applied to passengers. Additionally, combining the two flows and processes in the same area can be difficult to manage, particularly during peak periods⁸².

b. Airline Spaces

The following list discusses the various types of airline offices that should be considered for office space allocation⁸³:

- Airline Administrative Offices: Airline offices include the Airport (or Airline) Ticket Office (ATO) and other airline administrative spaces. The ATO is usually located immediately behind, or in proximity to, the check-in counter to provide support functions and supplies for the airline staff and equipment handling check-in and ticketing.
- Other offices may include space such as the airline station manager office or a sales office.
- Baggage Service Offices: Refer to Part 1, Section 5.
- Airline Operations Offices: Operations include all support spaces for aircraft servicing and aircraft crew-related support spaces, typically located on the apron level.

At airports with a large number of small domestic, international, and/or charter airlines, many of these carriers may use ground handling services provided by third parties. These third parties may include one or more ground handling companies, or other airlines. Typically, this use of third-party ground handling service providers will reduce the amount of operations space in a terminal; however, ground handler support space must still be provided elsewhere on the airport. It should be noted that some larger airlines will also use third parties at their smaller stations.

Hub airlines, in contrast, may require a significantly larger amount of operations space due to locating some functions at the hub airport that serve smaller spoke airports in the region. These support functions may include space for crew-based (flight deck and/or cabin staff) offices and lounges, aircraft parts storage, larger storage areas for passenger cabin stores, etc.

c. Concessions Storage

Concession storage is typically accommodated in a combination of storage space in or near the concession unit, if space is available, and storage space in lower levels of the terminal adjacent to the truck bays. Concession storage space near the truck bays will hold incoming products and inventory for restaurants and retail stores⁸⁴.

d. Port Authority Spaces

In addition to offices for airport staff, many airports have a communication / incident control center that can often double as a meeting room or for other functions that are required on a more day-to-day basis⁸⁵.

⁸² IATA ADRM 10th Edition, Section 3.4.11.12.3d, 2017

⁸³ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11, 2010

⁸⁴ ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, Chapter 11, Section 11.3, 2011

⁸⁵ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.3, 2010

e. Other Agencies' Offices and Support Spaces

Besides the TSA, Port Authority, and terminal operator, other agencies that may require tenant space in a terminal include various US Customs and Border Protection (CBP) divisions, police, and FAA. The requirements for these agencies vary by airport and terminal.

Although the TSA is responsible for screening passengers and their baggage, TSA officers do not have authority to arrest. For this, a local law enforcement officer (LEO) is required. Typically, there is space for an LEO at the SSCP, but depending on the size of the LEO presence at an airport and any additional duties (such as traffic enforcement), additional office and support spaces may be required⁸⁶.

In association with the baggage inspection control, customs may require offices for their administrative procedures, as well as for interview or search rooms for passengers found in contravention of regulations. Office accommodation for customs in this area should be restricted to the absolute minimum necessary for application of baggage inspection; supporting administrative offices, rest rooms, etc., should be provided elsewhere in the building⁸⁷.

f. Other Tenants' Offices and Support Spaces

Maintenance, janitorial, and storage space includes the building maintenance functions that are required to be within the terminal building. In addition to typical janitorial and supplies storage, areas may be required for hoists (cherry-pickers) and other specialized equipment needed to clean and maintain high-ceiling areas or certain types of window walls. Additional maintenance support may also be provided by facilities outside the terminal complex⁸⁸.

g. Ramp Control

The FAA airport traffic control tower (ATCT) does not typically take control of aircraft until they enter the movement area. At smaller airports with lower numbers of gates, aircraft can push back and otherwise maneuver on the terminal ramp with minimal control. At larger airports, especially with the potential for aircraft to simultaneously push back into the same taxiway area, a ramp control tower is typically required. This tower can be staffed by either the airport's operations department or an airline if it controls a large proportion of gates⁸⁹.

h. Vehicle Screening

Vehicles entering airside areas or parking within the terminal security perimeter must be screened to ensure against threats. The prevalence of trucks or other large vehicles bringing deliveries or bulk goods to terminals increases the overall security risks. Standard methods for vehicle screening involve visual inspections of the cargo compartment, inspection of a vehicle's underside with a mirror, and explosive-detecting dogs. Screening may be accomplished at the entrance to the airport or at individual terminal entrances, provided unscreened heavy goods vehicles are not able to access sensitive areas at any time

⁸⁶ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.4, 2010

⁸⁷ ICAO Doc 9184-AN/902, Airport Planning Manual Second Edition, Part 1, Section 9.5.19, 1987

⁸⁸ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.2, 2010

⁸⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11, 2010

prior to screening. This screening area should be located at least 300' away from the terminal and with a guard post and control point.

With respect to vehicles, the NYPD recommends screening for High Tier buildings at direct entry points as well as at the entrances to underground parking areas and loading docks. Effective vehicle screening requires an adequate number of well-lit vehicle entrances to accommodate peak flows of vehicular traffic and to provide sufficient visibility of vehicles at the true perimeter. The NYPD recommends that security personnel at High Tier buildings ensure that vehicle access points are securely locked when not operational, illuminated during off-hours, and inspected periodically by a roving patrol. Additionally, barrier systems should be put in place to thwart any attempt to "rush" the checkpoint⁹⁰.

The NYPD recommends that owners of High Tier buildings provide for off-site screening of vehicles; when no such design is feasible, building owners should create hardened on-site areas sufficiently removed from critical facilities and occupied spaces. Because underground parking areas and loading docks may create significant vulnerabilities based on their proximity to the base of a building, owners of High Tier buildings should harden them as much as possible, and design them to both limit damage to adjacent areas and vent explosive forces outward.

i. Loading Docks

Receiving areas and loading docks can serve both terminal maintenance and concessions. It is generally recommended that loading docks should be provided for concession deliveries to avoid clogging the terminal curbs with delivery vehicles. When loading docks are used for concession receiving, provisions may need to be made for security screening of food and retail merchandise before it can be moved to a secure area of the terminal⁹¹.

j. Incoming Goods Screening

Any goods entering in the airport are subject to x-ray screening before been accepted for storage.

Security screening checkpoints may be located at the airport security perimeter, at the truck bays to screen inbound concession goods, or further downstream in the terminal building. To best accommodate the size of typical loads associated with terminal retail products, an oversized x-ray machine is required⁹².

k. Trash and Recycling

Trash compactors are also typically co-located with loading docks, and multiple compactors may be required depending on the volume and types of trash generated in the terminal⁹³.

⁹⁰ NYPD Engineering Security Protective Design for High Risk Buildings, Chapter 5: Guidelines on Access Control, Screening & Monitoring, 2009

⁹¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.3, 2010

⁹² ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, Chapter 11, Section 11.1.3, 2011

⁹³ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.3, 2010

I. Building Services (MEP)

This area of the plan includes all the utility support areas for the terminal and concourses. Recent trends in computer systems, telecommunications, and other building-related systems have increased the demand for these areas within the terminal building. Some of these areas can be accommodated in the airline operations area whereas common-use systems need to be located in the airport-controlled areas. Plumbing is also a difficult system to remove and or relocate within a terminal facility. Thus, areas such as restrooms should be located in areas that are less likely to require future relocation if possible⁹⁴.

m. Flood Control Resiliency

Flooding occurs when normally dry land becomes inundated with water. Sources of the water may be the result of natural bodies of water overflowing their banks, rapid accumulation of runoff or surface water, hurricane-caused storm surges or earthquake-caused tsunamis, or erosion of a shoreline. The following are recommendations gathered from best practices in dealing with storm effects at other major US airports.

1. Reference Documents

- *FAA AC 150/5200-31C – Airport Emergency Plan*
- *FAA AC 150/5210-22 - Airport Certification Manual (ACM)*
- *ACRP Report 65 - Guidebook for Airport Irregular Operations (IROPS) Contingency Planning*
- *ACRP Report 81 - Winter Design Storm Factor Determination for Airports*
- *ACRP Report 93 - Operational and Business Continuity Planning for Prolonged Airport Disruptions*
- *ACRP Report 112 - Airport Terminal Incident Response Planning*
- *ACRP Report 123 - A Guidebook for Airport Winter Operations*
- *ACRP Report 147 - Climate Change Adaptation Planning: Risk Assessment for Airports*
- *ACRP Report 160 - Addressing Significant Weather Impacts on Airports*

2. Communications

PANYNJ shall conduct a daily general briefing of airport operations officials with representatives of airlines and a roster of state and federal agencies to share information that might affect that day's airport operations: everything from the weather to runway maintenance. PANYNJ should serve as the ultimate authority with the lead PANYNJ director leading the meetings. Each of the terminal operators at each respective airport should have its own manager who reports to the lead PANYNJ director.

After the general meeting, an additional severe weather forecast briefing (if needed) and Crisis Management meeting should be conducted to review detailed weather report and communicate with the airlines about status of their flights. A significant component of the Crisis Management meeting involves understanding how airline partners are planning for severe weather events. The airports should

⁹⁴ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.1, 2010

have an established plan that outlines planning priorities, which is dynamic to accommodate information from airlines, the FAA, the National Weather Service (NWS), and others stake holders.

Each Crisis Management meeting should arrive at an agreed airport status. (e.g., terminals must operate up until 12 hours before storm hits) that all parties would work to and start mobilizing their responsibilities. Crisis Management meetings should include a detailed review of the resources available to all affected parties, and assessment made of the ability of the contingency plan to be delivered. To support this, PANYNJ and airport partners should have a joint, pre-arranged plan for deploying their staff resources in the quantities required for threshold conditions that would trigger the cancellation or postponement of flights.

Each Crisis Management meeting should end with an agreed summary of actions which should be shared amongst participants.

- This provides time for the airlines to cancel flights and communicate with passengers when the final flights will be departing, reducing the number of people at the airport by the time the storm hits. At that point, the airport starts securing movable items, setting up temporary flood barriers, tying down outside equipment, ensuring generators are safe and operational, and sending out final flights.
- Staffing for a storm should have two teams of staff switch back and forth on 12-hour shifts. The severe weather event requires ride-out teams and recovery teams. The ride-out teams are expected to arrive on-site prior to a flood event occurring and should be prepared to stay through the duration of the event until relieved by recovery team(s). The recovery teams are expected to arrive on-site as soon as is reasonably practicable following a flood event occurring and should be prepared to address immediate recovery activities on-site, such as removal of excess water, clean-up, and restoration of airport operations.
- Staff are notified of which group they are in ahead of time to give them time to handle any needs at home before coming into work. Additionally, the airport provides food, fuel, showers, and places to sleep for staff providing their services during events. Staff are encouraged to bring other amenities they might need to be comfortable to ensure that they can be ready and able to work when their shift begins.
 - Supply food and potable water, stored on site, for each employee and passenger stationed at the airport for at minimum 3 days after the flood.
 - All parties should be suitably represented at Crisis Management meetings and should ensure their representatives are fully informed.
 - The Airport's Crisis Management rostering should ensure that there is always available a member of the airport executive management team, with extensive, significant and relevant operational experience; and the PANYNJ director should seek to establish contact with their equivalents in key external stakeholders impacted by a crisis.

3. Operational Procedures

This section contains a listing of the functional annexes that would be required in the preparation of a hazard-specific appendix for floods. It also identifies the unique and/or regulatory planning considerations that should be used by the Airport Emergency Plan (AEP) planning team.

i. Direction and Control.

The extent of the initial response will depend on warning time, which varies with the cause and the source of the flooding. Intense storms may produce a flood in a few hours or even minutes for upstream

locations, while areas downstream may have from 12 hours to several weeks to prepare. Flash floods occur within six hours of the beginning of heavy rainfall. The AEPs of airports downstream of a heavy flood source should, in coordination with the local emergency management agencies' Emergency Operations Plan (EOPs), address the following planning considerations in one or more appendices to a Direction and Control Annex:

ii. Flood Control

Preparation to control flooding should include:

1. Coordination with AEP planning staff during disaster or disaster threat situations to facilitate expeditious notifications and exchange of information.
2. Mapping of areas likely to be flooded.
3. Identification of potential locations for the placement of temporary flood defenses and the inclusion of this information on the appropriate maps.
4. Arrangements for a labor force to perform flood fighting tasks associated with building a flood defense (i.e., fill and place sand bags to prevent flooding).
5. Temporary flood defenses should be completely deployed 4 hours prior to a heavy rainfall event, 6 hours prior to a potential flash flood event, and 12 hours prior to a hurricane event. It will be up to the terminal operator to decide how to meet these deployment requirements (i.e., amount of labor needed, storage locations for the flood defenses, duration required to deploy, etc.).
6. Temporary flood defenses should be completely deployed 4 hours prior to a heavy rainfall event, 6 hours prior to a potential flash flood event, and 12 hours prior to a hurricane event. It will be up to the terminal operator to decide how to meet these deployment requirements (i.e., amount of labor needed, storage locations for the flood defenses, duration required to deploy, etc.).
7. While there are several types of flood defenses, it is up to the terminal operator to decide how the flood defenses will maintain critical building systems and defer others not deemed critical to terminal operations.
8. A Hurricane Response Schedule shall follow an earlier set of emergency response actions for hurricane response. The schedule establishes phases for the approaching hurricane, describes the activities to be completed during each phase, and establishes some priorities for actions to be taken.

iii. Continuity of Operations

Address the relocation, as necessary, of key operations, resources, vital records, and equipment to assure continuation of services and to prevent damage and loss.

Passenger and aircraft operations of the terminal shall terminate with the initiation of flood mitigation measures as described above, because the mitigation elements will physically interfere with normal circulation.

iv. Before the Event

Develop a facility inspection Standard Operational Procedures (SOP) that is specific to potential flood damage. This is something that can be used by terminal employees as a preparatory inspection process, such as checking and testing flood pumps, checking levees and dikes, inspecting flood control devices, etc.

Develop a list of terminal facilities which are in low lying areas and potentially subject to flooding, including the any electrical equipment, access points (doors, windows, garbage chutes, BHS/ventilation openings, underground facilities, etc.). The equipment and systems listed in Table 5 are considered critical and shall be considered for priority for floodproofing.

Terminal operators must hold twice-annual on- and off-season flood-specific training programs, deployment drills, and operational exercises. This ensures that new and current employees are up to date with any operational procedures that may have changed from the previous training.

Check the availability of emergency generators to maintain the operation of critical terminal facilities during and after the event.

System	Critical Equipment/Systems
Electrical	Substations, Transformers, Switchgear, Service and Distribution Panels, Emergency Panels, Cable Terminations and Splices, Emergency Generators, Stock and Parts Storage, Meter Centers
Water and Plumbing	Domestic/Fire Water Pumps and Controls, Sump Pump Non-Submersible Motors and Controls, Plumbing Systems (lavatories, showers, toilets), Ejector and Grinder Pumps, Water Heaters, Pipe Insulation
Mechanical	Air Intake and Exhaust Vents/Louvers, Air Conditioning Units and Condensers, Chilled Water Systems, Pumps, Ventilation Units, Boilers, Unit Heaters, Distribution Duct Work
Telecommunications	Telephone Switches, Network Interface Devices, IDF Closets, Data/Computer Centers/Rooms, Dispatch Rooms, Emergency Communications Centers, Public Announcement System Control Rooms, Radio Systems (incl. personal radio storage areas), Surveillance Systems, Access Control Systems
Emergency and Fire	Fire Alarm Master Boxes, Emergency Operations Centers, Emergency Supplies (medical, food/water, cots/blankets), Emergency Vehicles and Specialized Equipment (medical, fire, rescue, law enforcement)
Hazardous Materials	Waste Oil, Fuel Storage Tanks, Chemical Supplies
Other*	Records Storage, Office Space, Parking Garages

* Floodproofing recommended but not required for tenants and third party leases/developments.

Table 5. Critical Infrastructure Subject to Immediate Floodproofing Standards⁹⁵

⁹⁵ Massachusetts Port Authority - Floodproofing Design Guide

v. After the Event (Recovery)

The recovery effort will be dependent upon the severity of the flooding; the amount of damage; facilities, equipment, and systems impacted; and the availability of resources. Recovery efforts should involve:

- Arrangements for a labor force to dissemble the temporary flood defenses when suitable (i.e., when water levels reach a certain point where it would not leak into areas the flood defense is preventing water from entering).
- As with other emergencies, consider the formation of a Situation Analysis Team consisting of representatives from appropriate airport organizations, functional areas, tenants, etc., that:
 - Ensures periodic damage assessments are conducted.
 - Prepares an Incident Action Plan, to include long- and short-term considerations for:
 - Final damage assessment (written, pictorial, including video).
 - Safety issues (e.g., downed power lines, unsafe drinking water, etc.).
 - Sanitary issues.
 - Public information announcements.
 - Facility repair.
 - Supply inventory and restoration.
 - Cost documentation.
 - Economic impact.
 - Documentation of actions taken.
 - Personnel utilization by time on duty.
 - Critical Incident Stress Debriefing requirements.
 - Equipment utilization documentation.
 - Overall cleanup activities.
 - Air Operations Area (AOA) inspections.
- Issuance appropriate Notices to Airmen (NOTAMs).
- Critique of the overall operation and apply lessons learned to planning and training programs.

4. Temporary Flood Defenses

Given the dynamics of global climate change and the costs of designing for a worst-case scenario, it is generally accepted in the industry that complete flood-proofing of airports is not feasible. Therefore, many airport operators seek to increase the resilience level of the airport to flooding and other disasters, ensuring rapid recovery and restoration of services.

Temporary flood barriers are systems that are brought to a site to provide a flood defense for a limited period. They are then removed until required again. They have no fixed foundation other than the natural ground on which they are based (with perhaps minor modifications to ensure proper stability or performance of the temporary barriers). No type of temporary barrier is universally deployable in all situations, and generally they cannot withstand large wave action. All leak to a certain extent and therefore need to be accompanied by pumps.

5. PANYNJ Review and Proposals

The terminal developer must submit an emergency and flood operations plan to the Port Authority for review and approval that shows how the terminal operator will respond before, during and after the disaster event. Table 6 describes the requirements of the floodproofing design process. This process shall be followed for new construction and additions, substantial repair or improvement projects, or dedicated floodproofing projects. The intent of this process is to identify floodproofing-related issues early in the design process to ensure that the proposed floodproofing strategies to be used are adequate and that operational, maintenance and storage requirements are clearly understood by all parties responsible for implementing them.

Design Stage	Design Flood Parameters and Calculations	Floodproofing Design Narrative and Drawings	Floodproofing Calculations	Flood Operations Plan	Floodproofing Inspection and Maintenance Plan
Schematic Design/ Pre-Design	Identify FEMA Flood Insurance Rate Map (FIRM) information and PANYNJ DFE ⁹⁶	Identify proposed strategies and performance objectives to be achieved by design	Conduct facility condition assessment and/or site assessment	Identify parties responsible for facility flood emergency response	Identify parties responsible for facility inspection and maintenance
30% Design	Preliminary design load assumptions and calculations	Identifies specific measures to achieve performance objectives; Review for code compliance, update narrative	Engineering report with structural calculations demonstrating floodproofed facility can withstand design loads	Outreach to parties responsible for implementing active floodproofing measures; Prepare draft plan	Outreach to parties responsible for inspection and maintenance of floodproofing measures; Prepare draft plan
90% Design	Update	Update narrative and drawings	Update structural calculations	Update draft plan	Update draft plan
Final Design	Finalize	Finalize narrative and drawings. Complete FEMA NFIP floodproofing certificate for non-residential structures signed/ submitted. For new construction with lowest floor elevated above base floor elevation or DFE, complete FEMA NFIP elevation certificate, signed and submitted	Finalize	Final plan and approval memo	Final plan and approval memo

Table 6: Floodproofing Design Implementation Process⁹⁷

⁹⁶ The design flood elevation (DFE) corresponds to the maximum level of water that an engineered structure has been designed to resist, being a foundational input for the calculation of design flood loads, which then set the parameters for structural design. DFEs are also used as a vertical threshold above which the lowest floor of the lowest enclosed area, important utilities, life safety systems, and other critical equipment must be elevated. If elevation above the DFE is not feasible, floodproofing critical areas below the DFE may be permitted. The DFE will be defined by the maximum water elevation with a 0.2% annual probability of exceedance in 2030 plus 3 feet of freeboard. This translates to an elevation of 13.7 feet for existing terminal facilities and 17.0 feet for new terminal facilities.

⁹⁷ Massachusetts Port Authority - Floodproofing Design Guide

n. Triturator

At the end of each flight, the aircraft restroom wastewater or “blue water” is vacuumed into tanker trucks to be disposed in sewage treatment. Experience has shown that this wastewater often contains objects that are accidentally or intentionally flushed by passengers, which are not acceptable for local sewage treatment facilities. Therefore, from the tanker truck, the entire contents must pass through a special grinder known as a triturator, which grinds the contents into small enough pieces that can safely enter the sewage treatment facility.

o. IT/Communications Rooms and Facilities

IT design in the terminal is no longer limited to point-to-point copper wire connections; the immense opportunities available in fiber optics and computerized local area network/wide area network (LAN/WAN) implementation can now be optimized by the early inclusion of IT professionals in the planning and design process⁹⁸.

In addition to security, specifications for networked terminal facilities should address requirements for bandwidth (wired and wireless), availability, uninterruptible power supply (UPS), and emergency power backup.

⁹⁸ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 4.2, 2010

Part 2 - Planning and Design Methodology

1. Scope

The objective of this section is to support the planning and design team in identifying the optimal requirements for the terminal facilities (key rooms, areas, processing elements, etc.), to supplement the forecast and proposed airside design. The planning and design process entails collecting data and information on existing conditions as well as airport specific passenger behavioral characteristics (see Section 3). This information must be analyzed with appropriate demand levels for various terminal functionalities. The demand levels are derived from forecast, the Design Day Flight Schedules (DDFS) and other parameters (see Section 4).

The terminal building shall be designed in accordance with the following codes and standards found in Section 2 below.

All terminal facilities should be planned to achieve the level of service defined in the sections below in order to ensure a terminal design that provides high level comfortable and seamless passenger experience. Section 5 presents the Port Authority's standard methodology and criteria for planning to be followed by developers and planners when designing passenger and baggage processes inside a terminal building. Port Authority's standards are based on the latest IATA ADRM guidelines, except for international immigration. For that particular element of the terminal, appropriate references to planning documents published by U.S. Customs and Border Protection (CBP) are provided in Section 5.

In addition to the analytical methodology presented in the following sections, the Port Authority recommends that simulation of the entire passenger processing environment within the terminal building (departure, arrival and transfer flows) is performed at a planning/design stage, in order to confirm the appropriate program requirements. Simulation analysis should be used to identify potential bottlenecks and crossflows, as well as to assess additional design and layout specific issues that may not be reflected in the analytical method. However, simulation results shall not be used to reduce capacity and space requirements calculated through the analytical method described in this document.

2. References

a. Federal Aviation Administration (FAA) Advisory Circulars (AC) and Orders

1. AC 150/5220-21C: Aircraft Boarding Equipment
2. AC 150/5300-13A: Airport Design
3. AC 150/5360-13: Planning and Design Guidelines for Airport Terminal Facilities
4. FAA Federal Aviation Regulations Part 107 – airport security
5. FAA – Federal Aviation Regulations (FARS 14 CFR)
6. Applicable FAA Advisory Circulars

b. Airport Cooperative Research Program (ACRP)

1. ACRP Report 25, Volume 1: Airport Passenger Terminal Planning and Design
2. ACRP Report 96 - Apron Planning and Design
3. ACRP Report 161 - Guidelines for Improving Airport Services for International Customers

- c. International Civil Aviation Organization (ICAO)
 - 1. ICAO Aerodrome Design Manual
 - 2. ICAO Annex 14, Volume I: Aerodrome Design and Operations
- d. International Air Transport Association (IATA)
 - 1. IATA Airport Development Reference Manual
- e. Port Authority of New York and New Jersey (PANYNJ) Standards
 - 1. PANYNJ Engineering Department Civil Design Guidelines
 - 2. PANYNJ Standards and Guidelines for Port Authority Technology
 - 3. PANYNJ Sustainable Design Building Guidelines, August 15, 2007
 - 4. PANYNJ Sustainable Infrastructure Guidelines, March 23, 2011
 - 5. PANYNJ Tenant Alteration Procedures and Standards Guide, December 20, 2013
 - 6. PANYNJ Tenant Construction Review Manual
 - 7. PANYNJ Pedestrian Signing & Wayfinding
 - 8. PANYNJ Traffic Engineering Design Guidelines
 - 9. PANYNJ Traffic Signal Design and Drawing Preparation Guidelines
- f. Transportation Security Administration (TSA)
 - 1. Planning Guidelines and Design Standards for Checked Baggage Inspection Systems (PGDS), Version 5.0 (2015)
 - 2. Checkpoint Design Guide, Revision 5.1 (2014)
- g. Airports Council International (ACI)
 - 1. Apron Markings and Signs Handbook, Third Edition, 2017
- h. United States Customs and Border Protection
 - 1. Airport Technical Design Standards (2017)
- i. National Safe Skies Alliance
 - 1. PARAS 0004 - Recommended Security Guidelines for Airport Planning, Design, and Construction 2017
- j. American Association of State Highway and Transportation Officials (AASHTO)
 - 1. AASHTO: A Policy on Geometric Design of Highways and Streets
 - 2. AASHTO: Roadside Design Guide
- k. American Society of Mechanical Engineers (ASME)
 - 1. ASME A17.1: Safety Code for Elevators and Escalators
 - 2. ASME B20.1 Safety Standards for Conveyors and Related Equipment and all addenda

- l. Americans with Disabilities Act (ADA), 2012 (or latest)
 - 1. Title III (28 CFR Part 36) ADA – ADOPTED July 1, 1994 (Updated September 15, 2010)
 - 2. Americans with Disabilities Act Accessibility Guidelines (ADAAG)
 - i. ADAAG published in 28 CFR Part 36 Federal Register
 - ii. ADAAG for Titles I (Employees) and III (Public Accommodation)
- m. Architectural & Transportation Barriers Compliance Board (ATBCB)
- n. BOCA National Building Code
- o. Green Building Council (USGBC)
 - 1. Leadership in Energy and Environmental Design (LEED) New Construction Version 4.0
- p. Highway Capacity Manual (2010)
- q. Illumination Engineering Society of North America (IESNA)
 - 1. IES Handbook 10th Ed.
 - 2. IES RP-8-00 Roadway Lighting
- r. International Building Code (IBC)
- s. International Fire Code (IFC), 2010
- t. National Fire Protection Association (NFPA)
 - 1. NFPA 101: Life Safety Code, 2006
 - 2. NFPA 407: Standard for Aircraft Fuel Servicing
 - 3. NFPA 415: Standard on Airport Terminal Buildings, Fueling Ramp Drainage, and Loading Walkways
- u. Occupational Safety and Health Administration (OSHA)
- v. Earthquake provisions as required by local code
- w. All applicable federal, state and local codes

The following codes are applicable to projects in New York City only:

- a. New York City Building Code (NYC BC)
- b. New York City Fire Code (NYCFC), 2008
- c. NYSDEC SWPPP (6YNCRR-750)
- d. NYSDEC Storm Water Management Design Manual

The following codes are applicable to projects in New York State only:

- a. New York State Department of Transportation
- b. NYSDOT Highway Design Manual (HDM)
- c. New York State SWPPP (6YNCRR-750)
- d. New York State Storm Water Management Design Manual

The following codes are applicable to projects in the State of New Jersey only:

- a. International Building Code (IBC), New Jersey edition, 2009, or latest adopted edition
- b. International Fire Code, (IFC) New Jersey Edition 2006
- c. New Jersey Uniform Fire Code NJAC 5:70

3. Data Collection Program

Refer to Demand Section 4.

4. Assessing Passengers Demand

The methodology for assessing the passenger demand to guide the terminal design should be based on a combination of the design MAAP and the Design Day Flight Schedule (DDFS). The methodology for assessing the MAAP and preparing the DDFS is as described in Section I – Demand. These demand levels are then adjusted to reflect parameters including, but not limited to, passenger arrival curves at the frontage, upstream processing rates, downstream processing rate etc.

5. Planning Considerations and Conceptual Design Criteria

a. Automated Processors

Airports and airlines are increasingly incorporating new types of passenger processing technology, resulting in a passenger experience that is more personalized. These technologies usually result in less overall processing and wait times and require less time per passenger from airline staff.

b. Use of Technology

Technological advances have been changing the travel experience. As increasingly empowered passengers seek new ways to take control of and customize their own travel experiences, airports, often working in collaboration with airlines, have embraced intelligent innovations. Technology and constant innovation are shaping air travel as we know it. A few of the growing list of technology objectives and uses that are enabling the transformation of the airport experience and influencing customer satisfaction are discussed in the following.

1. Improve airport efficiency.

Self-service technologies such as online check-in; mobile boarding passes; self-tagging of baggage and bag drop; radio-frequency identification (RFID) bag tags; automated gates; automated passport control (APC) kiosks, the Automated Passport smartphone app; clearing security using technology and biometrics; and common-use technology could maximize the use of airport terminal space and provide flexibility to serve passengers.

2. Ease navigation

Dynamic signage and digital wayfinding; flight information displays (FIDS) and baggage information displays (BIDS); mobile apps; airport websites; and Global Positioning System (GPS) technology that communicate directions via the customer's smart phones; and operational alerts indicating delays and congestion along the customer's way.

3. Reduce waiting times

Using technology to monitor waiting times and length of queues, that alerts management to open additional stations when wait time standards are approached; advising customers of waiting time at the queues; notifying passengers of checkpoints with the shortest queues; enabling passengers to make reservations online to clear the security checkpoint; and using biometric data to expedite processing.

4. Provide flight, baggage, concessions, and other information

Automated airport alerts, airport apps, and social media; digital wayfinding; website and social media promotions; virtual assistants; remote customer service representatives using robotics or interactive kiosks; and customer relationship management systems.

5. Facilitate terminal planning and operations

Passenger flow applications and automated dashboards.

6. Solicit customer feedback

Engaging in a two-way dialogue with customers through social media, websites, and customer relationship management systems.

7. Streamline and simplify the customer experience

Apps to order food online that is delivered to the gate or picked up in the terminal to take on the plane; and automated parking assistance, including entry and payment options as well as online parking reservations.⁹⁹

c. Planning considerations for some processors that will move from manned to automated systems

1. Check-in processors: traditional check-in, baggage drop-off and self-service kiosks

New technologies can improve managing existing terminal capacity and expansion without building more infrastructure. Current trends in the check-in process are moving from traditionally staffed to more self-service counters and remote online check-in.

Self-service counters and other forms of electronic check-in (whether via Internet, off-site locations, mobile devices, etc.) have effects on the size and configuration of the check-in lobby. When planning the ticket lobby processing elements and spaces, designers should consult with constituent airlines to assess their current and future plans for passenger processing, and the check-in and bag check processing mode splits they expect passengers to utilize.

Based on the processing mode splits, the designer should calculate requirements for each type of processing element. In some cases, although airline staffing levels generally decrease, the ticket lobby area requirements could increase with additional technology. Proposals to provide relatively less

⁹⁹ ACRP Report 157, Improving the Airport Customer Experience, Chapter III, Section 3.4.6, 2016

processing infrastructure at the terminal due to high utilization of remote check-in, must provide definitive evidence of high levels of remote check-in, to be acceptable to the PANYNJ.

Technological advances in the check-in process can also have potential capacity effects on down-stream processes such as security, if the amount of time required for earlier processes is reduced and passengers find that they can show up at the terminal closer to departure time. Showing up later at the airport but processing more quickly through the check-in process places a more peaked demand on the down-stream processes such as security screening¹⁰⁰.

New apps are available providing remote baggage check as a premium service, where passengers will be able to choose with the phone, tablet, etc. the time slot for the airline or third-party baggage handling company to collect baggage to be checked at their house or hotel on the day of, or one day before travel, to the airport, transporting the baggage as an agent of the airline. This process is expected to be limited to a relatively small number of premium passengers willing to pay the extra fees, and therefore should not factor into any reduction in baggage system infrastructure at the terminal.

Remote check-in and bag check at major downtown transit centers is provided in some international cities. Downtown remote check-in solutions could address capacity constraints in terminals, improve passenger experience, improve accessibility and mobility, and encourage public transport usage, improving air quality.¹⁰¹ If downtown check-in and bag check are ever provided at a large scale at the Port Authority airports, that could provide a legitimate reason to allow a reduction in check-in and bag check facilities at the airports, in amounts to be determined.

2. Boarding pass and ID check before security screening

For centralized security facilities, IATA recommends boarding pass check facilities be designed based on fully automated self-service access gates or equivalent technology to reduce the number of manual processes required throughout the passenger journey¹⁰².

In the 2017 Checkpoint Innovation Supplemental Guidelines, TSA has indicated that Travel Document Check (TDC) can be replaced with Biometric Authentication Technology (BAT) electronic gates in the near future.

Automated access gates can be combined with a manned access gate for passengers needing assistance. The following aspects need to be considered for a manned access gate: additional floor space; a swinging or sliding door accessible for wheelchairs; and a sterile area exit for passengers wanting to go back landside. As with other technologies, the result of implementation of this system is likely to be a moderate increase in required area, along with a decrease in staffing.

¹⁰⁰ ACRP Report 25, Airport Passenger Terminal and Design, Volume I, Appendix G, Issues and Trends

¹⁰¹ City Check-In as Future of UK Aviation Design, Opinion Piece March 2018, Airportr.

¹⁰² IATA ADRM 10th Edit, Section 3.4.11.15

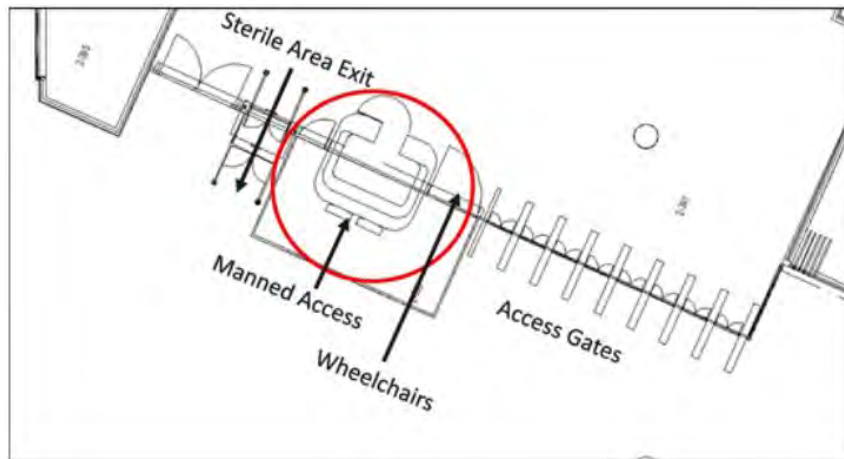


Figure 44: Combination of Automatic Access Gates and Manned Gates¹⁰³

3. Security screening

New security screening checkpoints are incorporating automated screening lanes and automated tray return systems. Automated tray return systems are recommended where possible, to reduce manual handling (by both staff and passengers) and to ensure a constant supply of trays to the passengers. While this facilitates enhanced overall productivity and increased passenger satisfaction, tray return systems occupy more space than conventional X-ray roller beds and also require additional technical support.

4. Immigration

Automated Immigration / Border Clearance solutions can reduce the overall space needed to perform this function. New technologies such as machine-readable passports, biometric data capture and processing as well as the resultant database links and encryption requirements are now being implemented around the world as more stringent immigration checks are required. Terminal planners should give consideration to the growing demand these technologies place on the airport IT systems.¹⁰⁴ While the primary screening (Immigration) area may decrease with the expedited process, the secondary screening (Customs) area will likely need to increase due to additional processing and queuing. Terminal designers should consult with the US Customs and Border Protection for current screening protocols and design guidelines.

d. Passenger Check-in and Bag Check - Methodology

Passenger check-in requirements define the amount of space needed to accommodate the types and numbers of check-in positions (baggage drop, self-service kiosks, and curbside) and queuing areas required to support terminal activity.

Performance criteria are applied to activity (demand) levels to determine the required number of check-in positions. Dimensional criteria based on level of service criteria and operating requirements are then

¹⁰³ ADRM 10th Edition

¹⁰⁴ ADRM 10th Edition, Section 3.4.13.2.3, 2017

applied to the required number of check-in positions and the number of passengers in transaction waiting areas (queue) to derive the initial space program.

For detailed planning, separate analyses would have to be conducted for each airline operating in the terminal, and differences in operating parameters and passenger characteristics among the airlines would have to be considered. Individual airline requirements should be aggregated according to rules for terminal facility use (exclusive, preferential, or shared) to formulate the overall program requirement for check-in facilities.

The program of requirements at a minimum, should identify and account for the following parameters:

- Counter operations and rules for use (counter availability and close-out time, use/lease basis, check-in options)
- Processing rates
- Passenger check-in options and class of service
- Planning schedule analyses by airline
- Passenger behavior (show-up time at terminal ahead of flight departure time, check-in option preference, number of bags checked, and group size)
- Level of service criteria (time and space)

Check-in demand is analyzed using level of service standards that address performance in terms of the time passengers wait for processing and the space allotted each waiting passenger.

1. Off-site check-in

Guidance on design of off-site check-in and bag check is not provided here, because it is by definition not part of the airport terminal site. However, there are limits to the reduction of on-site check-in and bag check facilities provided in the terminal that may be assumed when accounting for off-site check-in as a percentage of the total peak departure demand for requirements analysis purposes.

If terminal designers wish to reduce on-airport check-in and/or baggage check facility requirements based on an assumption that a substantial portion of the peak-hour passengers would be checking in and/or checking bags off-site, the proposed percentage reduction should be submitted to the Port Authority for review and approval before starting any analysis.

2. Curbside Counters

Curbside check-in is an option offered at many airport terminals and is dimensionally similar to standard check-in counters. Curbside check-in facility planning and design should comply with Americans with Disabilities Act (ADA) and Federal Emergency Management Agency (FEMA) regulations for terminal façade fortification. These guidelines relate to:

- Curbside counter includes agent work area, counter, and baggage scale
- Transaction/circulation aisle, queue area, curbside circulation with bollards
- Bollards to curb edge
- Interval between bollards

Dimensional guidelines for curbside check-in, as well as ADA and FEMA bollards design guidelines, are illustrated below.

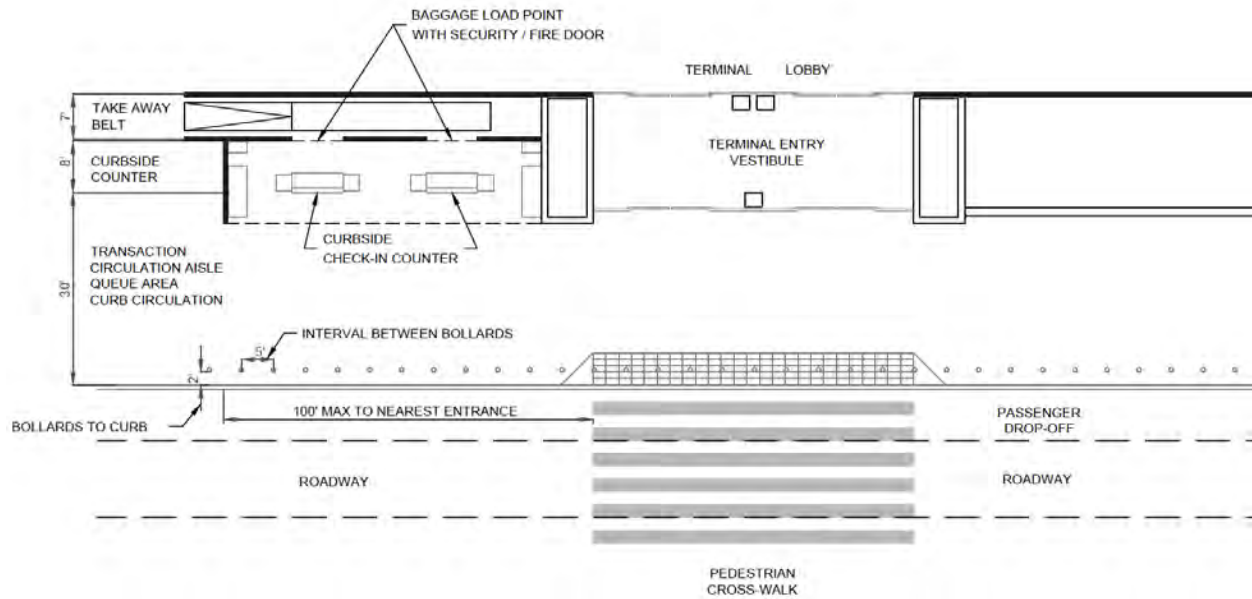


Figure 45: Minimum PA Standards for Terminal Frontage and Curbside Counters ¹⁰⁵

The following layouts depict PA minimum standards for other typical configurations of curbside counters:

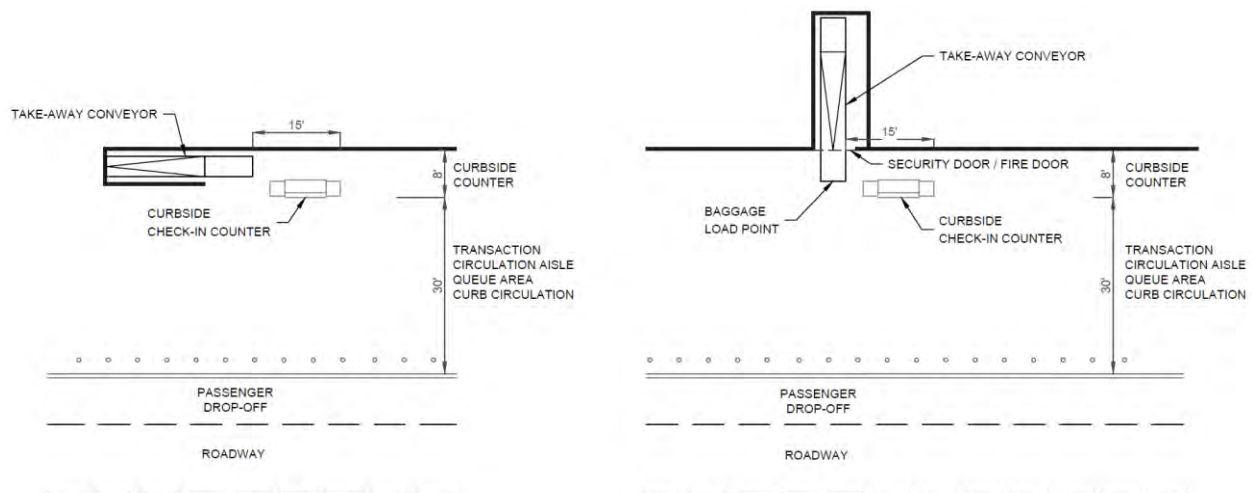


Figure 46: Minimum PA Standards for other configurations of Curbside Counters ¹⁰⁶

¹⁰⁵ Source: Port Authority of New York and New Jersey

¹⁰⁶ Source: Port Authority of New York and New Jersey

3. Departures / Check-in Hall

To develop check-in hall space requirements, key information is required in order to make accurate assessments. Each airport and airline situation is different, but there are common variables which influence spatial requirements for the check-in hall¹⁰⁷.

- Airport environment – are check-in hall facilities (ticket counters or kiosks) for common use or preferential use; is there a single dominant hub airline or are there multiple airlines?
- Patrons and passengers – factors such as the ratio between originating and connecting passengers, the characteristics and requirements of passengers who check-in and drop-off baggage (e.g., elite airline passengers or passengers requiring assistance, the number of well-wishers who see passengers off, earliness arrival profiles, etc.).
- Processing rates objectives – acceptable processing rates, allowable wait times, maximum queuing lengths, etc. to meet established level of service parameters; objectives need to be balanced against facility and equipment capacities.
- Airline processes – the unique characteristics, equipment, processes, and special requirements of individual airline check-in and bag-drop policies.
- Passenger volumes – estimated passenger volumes, typically expressed in peak hour numbers, based on forecasted activity levels.

When designing the overall area and configuration of the departures hall, the designer must provide the required number of passenger processing elements (kiosks, bag drops, counters, etc.) within a reasonably sized space with adequate circulation and emergency egress. The frontage of the building must provide adequate length and doorways to interface with the departures curbside. Immediately inside the doorways, adequate space must be provided between doorways and fixed objects or queuing zones, to provide visual access for intuitive wayfinding to check-in areas, and cross-circulation.

Working within the constraints of available width and depth of the terminal building site, the designer should configure the kiosks, ticket counters, and bag drops in the departures hall in such a manner that different types of passengers using different modes can find and access each mode easily and without getting in each other's way; usually with 20 feet circulation space between built elements and/or queuing zones. When ticket counters are configured in parallel "islands" arranged perpendicular to the front wall, clear distance between counters should be calculated, to allow for minimum 8-foot transaction / circulation aisle, adequate queuing zones based on demand in front of each counter, and 25 feet minimum clear circulation between queuing zones. More space is generally needed when serving international flights where passengers tend to have more, and larger, checked bags.

The walls and fixed elements of the departures hall should be configured so that the passenger's overall circulation path from curbside, through various check-in and bag check modes, and to the security screening checkpoint (SSCP) will be as direct and intuitive as possible, with minimal back-tracking or cross-circulation.

¹⁰⁷ FAA AC 150/5360-13A, Section 6.4.1, 2016 (Draft)

4. Check-in Counters - Processing Elements Calculation

The type and number of counter positions required are usually determined in consultation with each airline or handling agency according to its staffing criteria and company standards for processing passengers and baggage. Individual airport variables that influence the number of positions include one or more of the following¹⁰⁸:

- Design hour enplanements.
- Contact ratio
- Passenger arrival distribution patterns
- Average process time for each type of counter activity.
- Service goals of an individual airline for specific types of counter positions.

The required footprint for initial processing (check-in) facilities and associated queuing areas depends on their geometrical configuration. Queuing patterns will usually follow the airline's service frontage area. The depth of the queue depends on the waiting time policy and queue management strategy.¹⁰⁹

Sizing of the passenger processing hall depends on the number of passengers using the facility during the peak period, the proportion of premium passengers, the processing rate, the space provision per person as well as the maximum queuing time.¹¹⁰

The Port Authority requires that the number of required processors be calculated based on the maximum waiting times provided in Table 6. For the calculation of waiting area requirement, sufficient area to accommodate passengers' waiting time of 30 minutes must be provided, regardless of the target maximum waiting time.

All assumptions related to the percentages of passengers using a specific check-in mode must be documented and approved by the Port Authority. In addition, certain processors may be used by airport employees and must therefore be designed to accommodate that additional demand.

The Port Authority requires the use of IATA ADRM 10 methodology, taking into account the additional requirements stated above and in Table 6, for the calculation of number of processors, waiting areas, and total areas.

Flexible designs that allow for the future expansion of certain functions and contraction of others are necessary to ensure that the terminal building can adapt to future and unforeseen changes in technology and passenger behaviors.

i. Traditional Counters

Step 1: Calculate the approximate number of desks using the following equations:

$$CD_v = (PHP * PK * (1 - P_i - P_f) * CR * PT_v / 60) / (30 + MQT_v)$$

$$CD_j = (PHP * PK * P_j * CR * PT_j / 60) / (30 + MQT_j)$$

¹⁰⁸ ICAO Doc 9184-AN/902, Airport Planning Manual Second Edition, Part 1, Section 9.4.10, 1987

¹⁰⁹ IATA ADRM 10th Edition, Section 3.4.11.6, 2017

¹¹⁰ Refer to 109

$$CD_f = (PHP * PK * P_f * CR * PT_f / 60) / (30 + MQT_f)$$

The peak 30-minute factor is usually derived from the design day flight schedules (DDFS).

$CD_{(Y/J/f)}$	=	Approximate Number of Check-in Desks for Economy/Business/First Class Passengers
PHP	=	Originating Peak Hour Passengers
PK	=	Peak 30-minute Factor (in % of PHP)
Cf	=	Correction Factor for Demand Variability (see reference table)
$P_{(J/f)}$	=	Proportion of Business/First Class Passengers (in % of PHP)
CR	=	Ratio of Passengers Using Traditional Check-in Facilities
$PT_{(Y/J/f)}$	=	Process Time per Passenger at Check-in Desks for Economy/Business/First Class Passengers (in seconds)
$MQT_{(Y/J/f)}$	=	Maximum Queuing Time for Economy/Business/First Class Passengers (in minutes)
A	=	Area Required for the Check-in Desks Facility
CD	=	Total Number of Check-in Desks
CDd	=	Depth of the Check-in Process Area (in feet), including a courtesy distance between desks and queue. Refer to Figure 47, Figure 48, and Figure 49 for PA minimum standards.
CDw	=	Width of One Check-in Desk (in feet). Obtained from typical dimensions
QMAX	=	Maximum Number of Passengers Waiting in Queue at Check-in Desks
SP	=	Space per Person (in sq ft)
W	=	Corridor Width (in feet)*

* The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

Table 7: Traditional counter calculation inputs¹¹¹

The maximum waiting times (MQT) summarized in the table below are to be used for the calculation of required traditional check-in counters.

Port Authority Criteria	
WAITING TIME STANDARDS FOR PROCESSING FACILITIES Not To Exceed (Minutes)	
Standard Counters	
Economy Class (MQT_y)	10 min
Premium Counters	
Business Class (MQT_j)	3 min
First Class (MQT_f)	3 min

Table 8: PA Maximum waiting times for traditional counters calculation

¹¹¹ IATA ADRM 10th Edition

These maximum waiting times should be used to determine the number of required processors (traditional counters) but not for the calculation of space requirements, including sizing of queue areas. The Port Authority requires that queue area be designed to accommodate a 30-minute queue time (see Step 3).

Step 2: Adjust requirements to account for variability in passenger arrival distribution within the peak period and in processing time using the following equation:

$$CD = CD_Y * Cf + CD_I * Cf + CDf * Cf$$

Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)	
For MQT	CF
3, and less	1.22
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 9: Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)¹¹²

The smaller the MQT, the greater the variability in demand over the 30-minute period analysis. The correction factor (CF) will apply to each desk type.

Step 3: Calculate the maximum number of passengers in the queue using the following equation:

Step 3a. Calculate the number of economy OR business OR first class passengers in the queue by looking at the individual Peak 30-minute demand for that particular segment, as used in Step 1.

$$QMAX = 0.495 * \text{Peak 30-min (corresponding to a 30-minute MQT)}$$

All queue areas at traditional counters should be able to accommodate the numbers of passengers waiting up to 30 minutes in queue to account for demand surges occurring during peak periods and fluctuations in staffing. When designing a queue area at a processing facility, the planner should choose either a single or snake queue layout. The typical width of a queue should be between 4.6 and 5.2 feet.

Step 4: Calculate the area required for the passenger processing element of the departures hall using the following equation:

$$A = (CD * CDd * CDw) + QMAX * SP + (CD * CDw * W)$$

Remember that the passenger processing hall is composed of the process area ($CD * CDd * CDw$), plus the queuing area ($QMAX * SP$), plus a circulation area ($CD * CDw * W$).

¹¹² IATA ADRM 10th Edition

The minimum space per person standards (SP) presented in the table below should be used for the calculation of space requirements for traditional counters:

Port Authority Standard	
SPACE STANDARDS FOR QUEUE AREAS (sf/pax)* - MINIMUM	
Domestic Flights	16.1
International Flights	19.4

*Considering a queue width of 4.5 to 5.0 feet.¹¹³

Table 10: Space standards for queue areas

ii. Self-Service Kiosks

Step 1: Calculate the approximate number of self-service kiosks using the following equation:

$$SSi = (PHP * PK * SSR * PT / 60) / (30 + MQT)$$

SSi	=	Approximate Number of Self-Service Kiosks
PHP	=	Originating Peak Hour Passengers
Cf	=	Correction Factor for Demand Variability (see reference table)
PK	=	Peak 30-minute Factor (in % of PHP)
SSR	=	Ratio of Passengers Using Self-Service Kiosks
PT	=	Process Time per Passenger at Self-Service Kiosk (in seconds)
MQT	=	Maximum Queuing Time (in minutes)
A	=	Area Required for the Self-Service Kiosks
SS	=	Total Number of Self-Service Kiosks
SSa	=	Area Occupied by a Single Self-Service Kiosk. (obtained from typical dimensions)
AA	=	Adjustment Area for a Single Self-Service Kiosk (to account for additional area needed for layout-obtained from typical dimensions)
QMAX	=	Maximum Number of Passengers Waiting in Queue
SP	=	Space per Person (in sq ft)
CAF	=	Circulation Area Factor (in %)

Table 11: Self-service kiosks calculation inputs¹¹⁴

The maximum waiting times (MQT) summarized in the table below are to be used for the calculation of required traditional check-in counters.

¹¹³ IATA ADRM 10th Edition

¹¹⁴ IATA ADRM 10th Edition

Some kiosks do not provide capability to check bags or print bag tags. They are usually clearly labeled “Check-in Only, No Checked Bags” or similar. They may be able to print boarding passes only.

Port Authority Standard	
WAITING TIME STANDARDS FOR PROCESSING FACILITIES Not To Exceed (Minutes)	
Check-in Only	
Economy Class	1 min
First / Business Class	1 min
Check-in, Baggage Check, Weighing, and Tag	
Economy Class	2 min
First / Business Class	2 min

Table 12: PA Maximum waiting times for self-service kiosks calculation

These maximum waiting times should be used to determine the number of required processors (traditional counters) but not for the calculation of space requirements, including sizing of queue areas. The Port Authority requires that queue area be designed to accommodate a 10-minute queue time (see Step 3).

Step 2: Adjust requirements to account for variability in passenger arrival distribution within the peak period and in processing time using the following equation:

$$SS = SS_i * C_f$$

Where:

Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)	
For MQT	CF
3, and less	1.22
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 13: Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)¹¹⁵

The smaller the MQT, the greater the variability in demand over the 30-minute period analysis.

Step 3: Calculate the maximum number of passengers in queue using the following equation:

$$Q_{MAX} = 0.289 * \text{Peak 30-min (corresponding to a 10-minute MQT)}$$

Step 4: Calculate the area required for the self-service process using the following equation:

$$A = [(SS * SS_a * AA) + (Q_{MAX} * SP)] * (1 + CAF)$$

¹¹⁵ IATA ADRM 10th Edition

The minimum space per person standards (SP) presented in the table below should be used for the calculation of space requirements for self-service counters:

Port Authority Standard	
SPACE STANDARDS FOR QUEUE AREAS (sf/pax)* - MINIMUM	
Domestic Flights	16.1
International Flights	19.4

*Considering a queue width of 4.5 to 5.0 feet.¹¹⁶

Table 14: Space standards for queue areas

It must be noted that the adjustment factor applies only to the equipment (kiosk) footprint. Since the equipment is relatively small, it cannot be aligned like traditional desks. Space is needed around it to allow passengers to make their transaction in a comfortable way. The adjustment factor (AA) depends on the layout and configuration of the kiosks.

The circulation area factor (CAF) is introduced to provide additional space for circulating through and around this processing area.

iii. Baggage Drop Induction Points

Step 1: Calculate the approximate number of baggage drop positions using the following equations:

$$BD_v = (PHP * PK * (1 - P_j - P_f) * (1 - CR) * PT_v / 60) / (30 + MQT_v)$$

$$BD_j = (PHP * PK * P_j * (1 - CR) * PT_j / 60) / (30 + MQT_j)$$

$$BD_f = (PHP * PK * P_f * (1 - CR) * PT_f / 60) / (30 + MQT_f)$$

¹¹⁶ IATA ADRM 10th Edition

BD _(Y/J/f)	=	Approximate Number of Baggage Drop Positions for Economy/Business/First Class Passengers
PHP	=	Originating Peak Hour Passengers
Cf	=	Correction Factor for Demand Variability (see reference table)
PK	=	Peak 30-minute Factor (in % of PHP)
P _(J/f)	=	Proportion of Business/First Class Passengers (in % of PHP)
CR	=	Ratio of Passengers Using Traditional Check-in Facilities
PT _(Y/J/f)	=	Process Time per Passenger at Baggage Drop for Economy/Business/First Class (in seconds)
MQT _(Y/J/f)	=	Maximum Queuing Time for Economy/Business/First Class Passengers (in minutes)
A	=	Area Required for the Baggage Drop Facility
BD	=	Total Number of Baggage Drop Positions
BDd	=	Depth of the Baggage Drop Process Area (in feet), including a courtesy distance between desks and queue. Obtained from typical dimensions.
BDw	=	Width of One Baggage Drop Position (in feet). Obtained from typical dimensions
QMAX	=	Maximum Number of Passengers Waiting in Queue at Baggage Drop
SP	=	Space per Person (in sq ft)
W	=	Corridor Width (in feet).*

* The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

Table 15: Baggage drop calculation inputs¹¹⁷

The maximum waiting times (MQT) summarized in the following table are to be used for the calculation of required baggage drops.

Port Authority Standard	
WAITING TIME STANDARDS FOR PROCESSING FACILITIES Not to Exceed (Minutes)	
Standard Counters	
Economy Class (MQT _Y)	3 min
Premium Counters	
Business Class (MQT _J)	2 min
First Class (MQT _f)	2 min

Table 16: PA Maximum waiting times for baggage drop inductions points calculation

These maximum waiting times should be used to determine the number of required processors (traditional counters) but not for the calculation of space requirements, including sizing of queue areas. The Port Authority requires that queue area be designed to accommodate a 10-minute queue time (see Step 3).

¹¹⁷ IATA ADRM 10th Edition

Step 2: Adjust requirements to account for variability in passenger arrival distribution within the peak period and in processing time using the following equation:

$$BD = BD_v * Cf + BD_d * Cf + BD_f * Cf$$

Where:

Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)	
For MQT	CF
3, and less	1.22
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 17: Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)¹¹⁸

The smaller the MQT, the greater the variability in demand over the 30-minute period analysis. The correction factor will apply to each desk type.

Step 3: Calculate the maximum number of passengers in queue using the following equation:

$$QMAX = 0.289 * \text{Peak 30-min (corresponding to a 10-minute MQT)}$$

Step 3a, b or c: Calculate the number of economy OR business OR first-class passengers in the queue by looking at the individual Peak 30-minute Factor for that particular segment, as used in Step 1.

Note: Calculate the number of economy, business and first class passengers in the queue by looking at the individual Peak 30-Minute Factor for that segment and then add the segments together to calculate the total.

Step 4: Calculate the area required for the baggage drop facility using the following equation:

$$A = (BD * BD_d * BD_w) + QMAX * SP + (BD * BD_w * W)$$

The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

The minimum space per person standards (SP) presented in the table below should be used for the calculation of space requirements for baggage-drop counters:

¹¹⁸ IATA ADRM 10th Edition

Port Authority Standard	
SPACE STANDARDS FOR QUEUE AREAS (sf/pax)* - MINIMUM	
Domestic Flights	16.1
International Flights	19.4

*Considering a queue width of 4.5 to 5.0 feet.

Table 18: Space standards for queue areas¹¹⁹

e. Dimensional Criteria

1. Traditional Counters

The dimensional guidelines for the most common airline agent check-in position modules are approximately 380 square feet for domestic counter positions, 420 square feet for international counter positions, and 460 square feet for international counters with automated take-away conveyors. A single module consists of:

- Agent counter and baggage scale
- Agent work area, including the baggage take-away conveyor
- Transaction/circulation aisle separating the baggage drop from the queue area
- Queue area
- Main circulation corridor

¹¹⁹ IATA ADRM 10th Edition

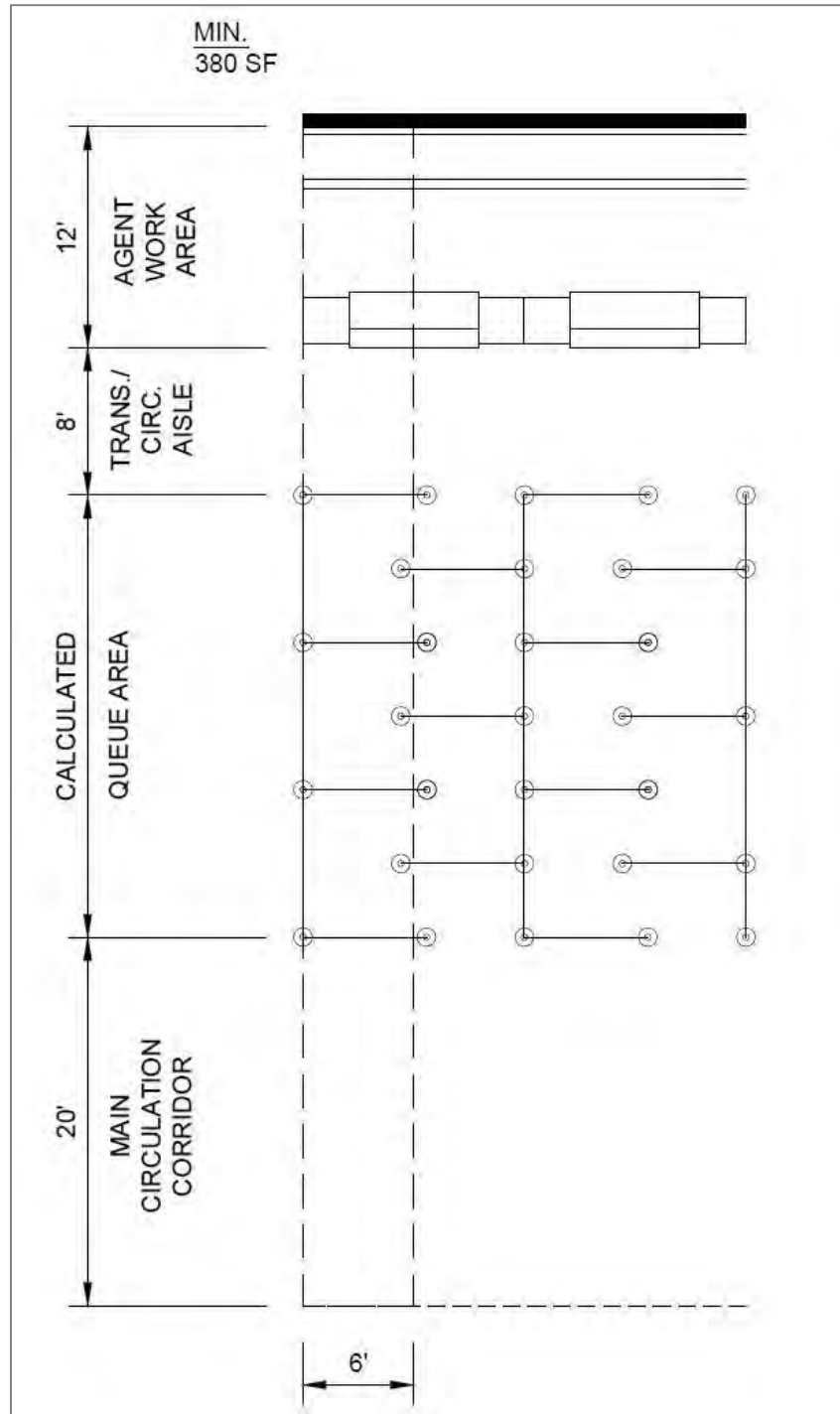


Figure 47: Typical Layout for Standard Domestic Check-in Counters

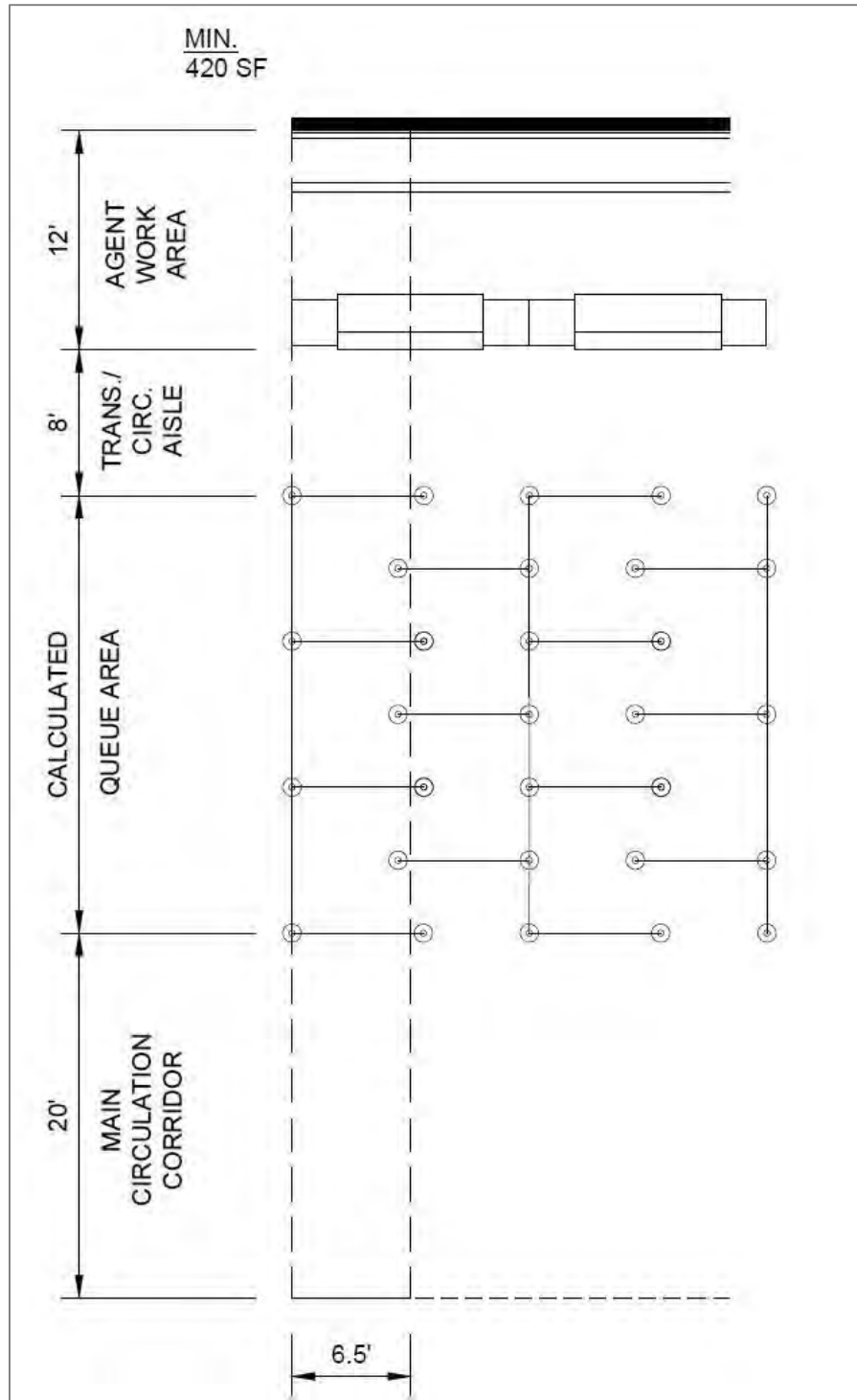


Figure 48: Typical Layout for Standard International Check-in Counters

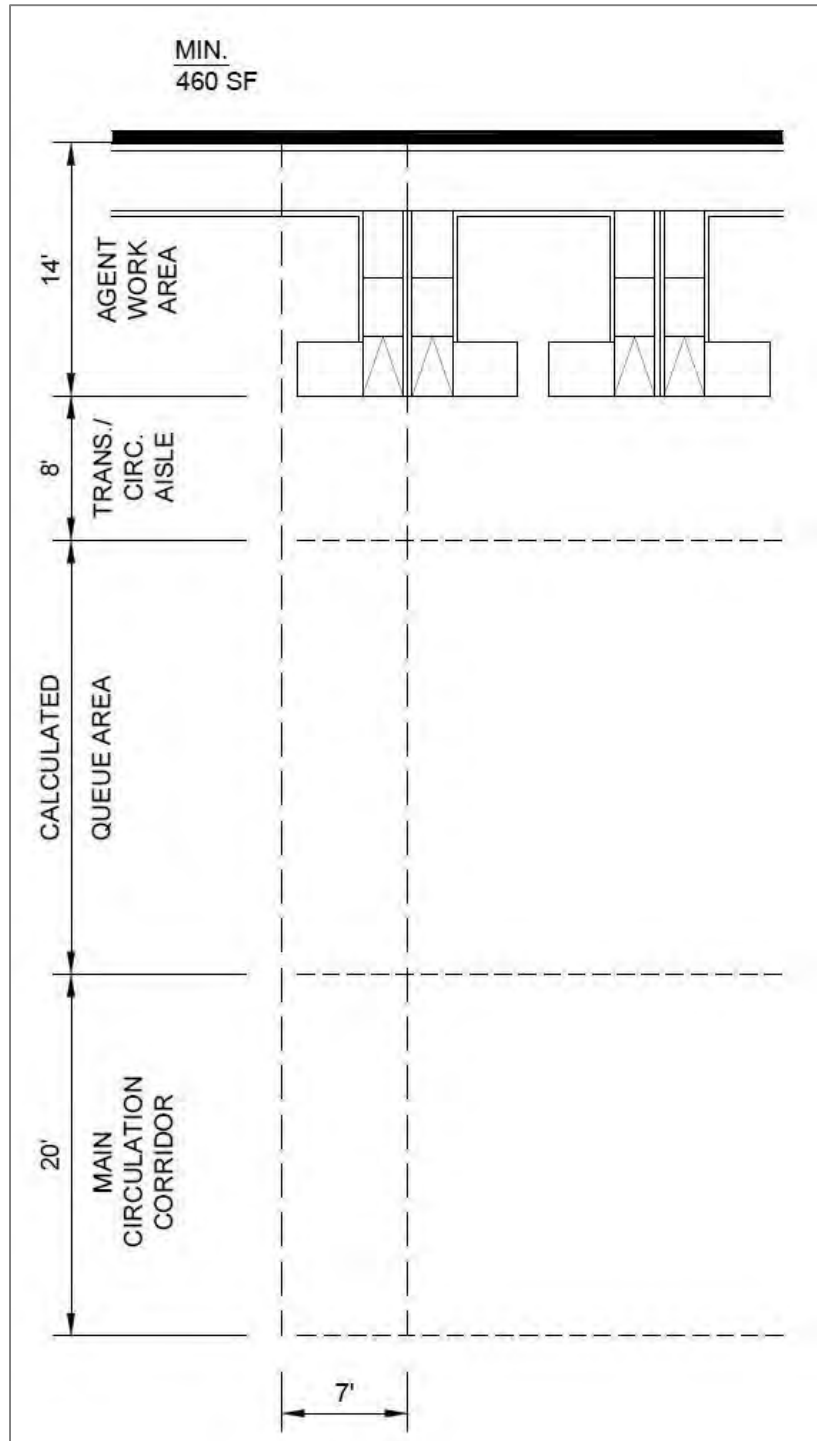


Figure 49: Typical Layout for International Check-in Counters with Automated Take-Away belt

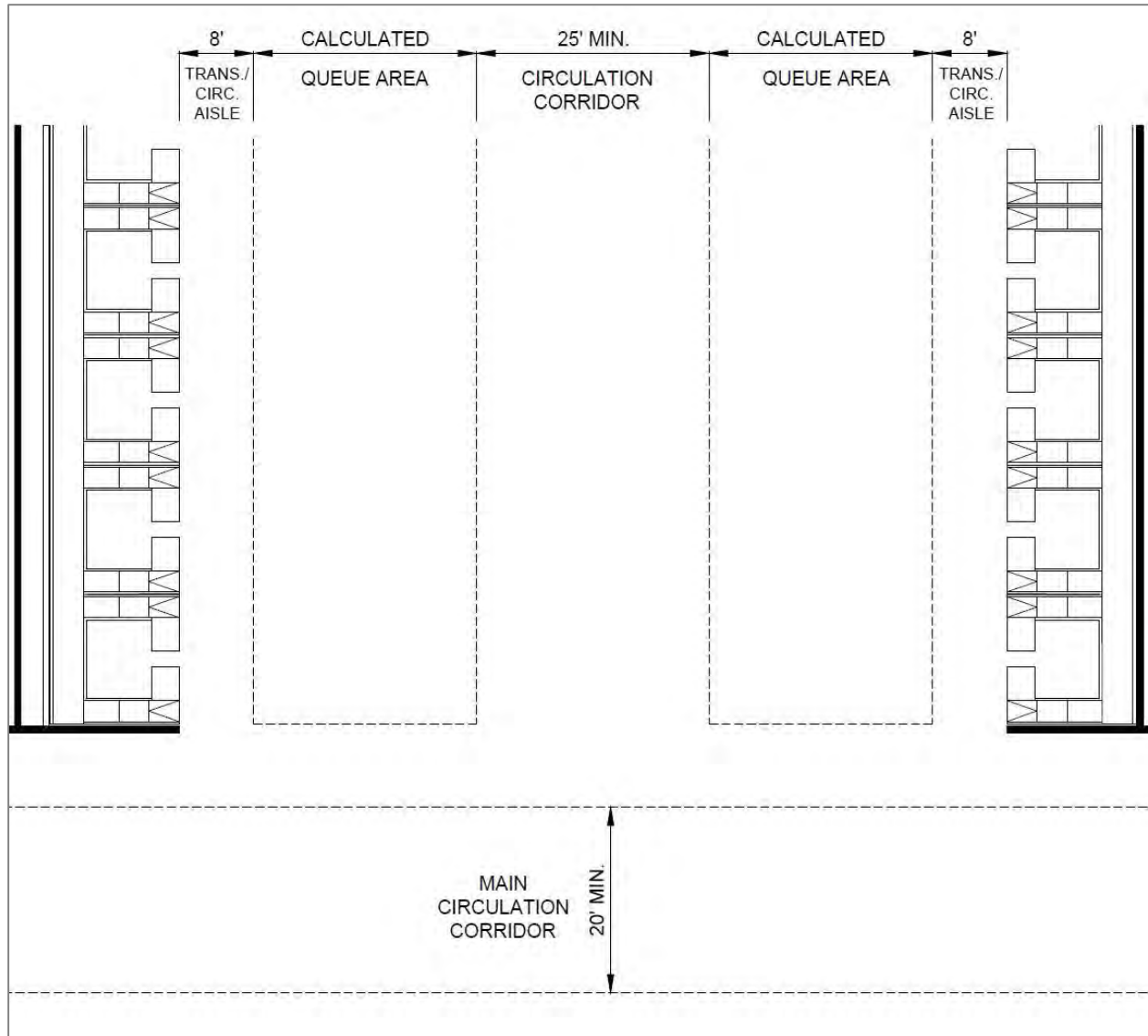


Figure 50: Typical Layout for Standard International Check-in Counters (configured in parallel islands)

2. Self-Service Kiosks

[Section under development]

3. Oversize baggage

Facilities should also be provided for odd-sized or oversized baggage, such as golf clubs, skis, and packages that are too large to fit on the baggage claim units or may cause jams on feed conveyors.

f. Outbound Baggage Handling System (BHS)

1. Processing Elements Calculation - Methodology

i. Baggage screening demand

The methodology in determining baggage screening demand shall use the latest version of the TSA's Planning Guidelines and Design Standards for Checked Baggage Inspection Systems (PGDS) Chapter 5 for guidance. The document captures TSA's requirements for a CBIS project from the beginning stages of design through commissioning of the system. The scope of the design is to be discussed on a case-by-case basis between the project sponsor and TSA. All other design standards in conjunction with TSA's PGDS will follow the industry's best practice.

The estimation of oversized baggage demand as a percentage of overall baggage should be checked against historical data of each terminal. Provide a means of conveying oversized baggage from the departures hall to the CBIS. This could be via special oversize belts, or manual conveyance, depending on demand levels and building configuration.

ii. Take-Away & Collector Belts

Main lines taking bags away from the EDS machine shall be capable of transporting bags equal to or greater than the capacity of the non-redundant EDS machines¹²⁰.

2. EDS Equipment Requirements¹²¹

The following key steps must be completed to determine EDS equipment requirements:

- Group airlines into screening zones or a common screening area
- Project design year baggage demand for each screening zone
- Surge design year baggage demand for each screening zone
- Select CBIS type and EDS equipment type (a list of system types, including EDS equipment types and their throughputs)

EDS equipment requirements shall be based on surged flows obtained by multiplying the design year design day checked baggage flow by a zone-specific surge factor* for each 10-minute bin. The use of a surge factor is recommended to capture the intrinsic variance of baggage demand and to ensure that equipment requirements are not undersized. For mini in-line systems the application of a surge factor may not be required. This will be at TSA's discretion. The following formula shall be used to calculate the surge factor:

$$SF = \frac{x + 2 \sqrt{x}}{x}$$

Where:

SF = Surge Factor

x = 10-minute baggage flow

¹²⁰ TSA PGDS Version 5, Section 7.2.1.1, 2015

¹²¹ TSA PGDS Version 5, Section 6.1.1, 2015

To calculate EDS equipment requirements, the surged peak 10-minute design year baggage flow is first converted to surged peak-hour design year baggage flow and then divided by the EDS machine throughput (95% throughput)

$$N_{EDS} = \frac{\text{SurgedPeak10Minute Flow} \times 6}{\text{Throughput}_{EDS}}$$

N_{EDS} = Number of EDS machines

Throughput_{EDS} = Number of EDS screened bags per hour

i. On Screen Resolution (OSR) Station Requirements¹²²

For certain system types, OSR can be centralized and remotely located.

The degree of centralization can also vary from totally centralized OSR systems that serve the entire airport to OSR systems dedicated to each CBIS. If the system type supports a remotely located OSR system, several considerations should guide the selection of the appropriate degree of system centralization, including TSA staffing, space requirements, and information technology (IT) infrastructure requirements.

Thus, to select the best OSR system type and location, it is recommended that OSR options be evaluated by assessing OSR staffing needs, capital costs of IT infrastructure and building modifications, and O&M costs associated with each option.

The number of OSR stations to be installed shall be derived based on the total non-redundant EDS capacity. The size of the OSR Room in terms of space allocation shall be based on the number of OSR stations derived based on the total EDS capacity including redundant units.

The number of OSR stations (N_{OSR}) required shall be calculated as follows:

$$N_{OSR} = \frac{N_{EDS} \times \text{Throughput}_{EDS} \times FA_{EDS}}{\text{Throughput}_{OSR}}$$

$N_{EDS} \times \text{Throughput}_{EDS}$ = Sum of total EDS capacity (throughput) for all EDS machines connected to the remote OSR system

FA_{EDS} = EDS false alarm rate for the EDS equipment selected

Throughput_{OSR} = 3600 / Screening Processing Time_{OSR}

Where:

Screening Processing Time_{OSR} = Average screening time that the OSR operator needs for each bag

ii. Baggage Inspection Table Requirements¹²³

BITs are accommodated in CBRAs. In general, an ETD machine is shared between two TSOs because the amount of time the ETD machine is used during the total screening process for a bag is relatively short. Thus, the ratio of BITs to ETD equipment is typically 2:1.

¹²² TSA PGDS Version 5, Section 6.1.3, 2015

¹²³ TSA PGDS Version 5, Section 6.1.4, 2015

The number of BIT stations to be installed shall be derived based on the total non-redundant EDS capacity. The size of the CBRA in terms of space allocation shall be based on the number of BIT stations derived based on the total EDS capacity.

$$N_{BIT} = N_{Alarmed/OOG} + N_{ETD \text{ Protocol OS}}$$

$N_{Alarmed/OOG} = N_{Alarmed/OOG \text{ Domestic}} + N_{Alarmed/OOG \text{ International}}$ and round to the next whole integer value

$$N_{Alarmed/OOG \text{ Domestic}} = \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ Domestic} \times [FA_{EDS} \times (1 - CR_{OSR}) + RL_{IT} + EDS_{Error}]}{\text{Throughput}_{\text{Directed Search Domestic Rate}}} + \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ Domestic OOG}}{\text{Throughput}_{ETD \text{ Protocol Domestic OOG Rate}}}$$

$$N_{Alarmed/OOG \text{ International}} = \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ International} \times [FA_{EDS} \times (1 - CR_{OSR}) + RL_{IT} + EDS_{Error}]}{\text{Throughput}_{\text{Directed Search International Rate}}} + \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ International OOG}}{\text{Throughput}_{ETD \text{ Protocol International OOG Rate}}}$$

$N_{ETD \text{ Protocol OS}} = N_{ETD \text{ Protocol Domestic}} + N_{ETD \text{ Protocol International}}$ and round to the next whole integer value

$$N_{ETD \text{ Protocol Domestic}} = \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ Domestic OS}}{\text{Throughput}_{ETD \text{ Protocol Domestic OS Rate}}}$$

$$N_{ETD \text{ Protocol International}} = \frac{N_{EDS} \times \text{Throughput}_{EDS} \times \% \text{ International OS}}{\text{Throughput}_{ETD \text{ Protocol International OS Rate}}}$$

Where:

N_{EDS} = the total quantity of EDS machines (non-redundant for determining equipment to be actually installed; including redundant for determining space allocation)

Throughput_{EDS} = the rate of the EDS equipment selected

$\% \text{ Domestic OOG}$ = the expected percentage of Domestic Out of Gauge baggage

$\% \text{ International OOG}$ = the expected percentage of International Out of Gauge baggage

$\% \text{ Domestic OS}$ = the expected percentage of Domestic Oversize baggage

$\% \text{ International OS}$ = the expected percentage of International Oversize baggage

EDS_{Error} = the expected EDS error rate percentage (typically 1%)

N_{BIT} = the minimum quantity of baggage inspection tables that are required in the CBRA

$N_{\text{Directed Search}}$ = quantity of baggage inspection tables that are allotted for the directed search of Domestic and International baggage

$N_{\text{Directed Search Domestic}}$ = quantity of baggage inspection tables that are allotted for the directed search of Domestic baggage

$N_{\text{Directed Search International}}$ = quantity of baggage inspection tables that are allotted for the directed search of International baggage

CR_{OSR} = OSR clear rate

RL_{IT} = the percentage of the bags sent through the EDS machines that are anticipated to be “Lost in Tracking” (i.e., to become “Unknowns”; typically, 2%)

Throughput Directed Search Domestic Rate = the capability of the TSO to process Domestic baggage expressed as a bags per hour rate per TSO

Throughput Directed Search International Rate = the capability of the TSO to process International baggage expressed as a bags per hour rate per TSO

N ETD Protocol OS/OOG = the quantity of baggage inspection tables that are allotted for the ETD protocol search of Out of Gauge and Oversize baggage for both Domestic and International passengers

N ETD Protocol Domestic = the quantity of baggage inspection tables that are allotted for the ETD protocol search of Out of Gauge and Oversize baggage for Domestic passengers

N ETD Protocol International = the quantity of baggage inspection table that are allotted for the ETD protocol search of Out of Gauge and Oversize baggage for International passengers

Throughput ETD Protocol Domestic OS/OOG Rate = the capability of the TSO to process Domestic Oversize and Out of Gauge baggage expressed as a bags per hour rate per TSO

Throughput ETD Protocol International OS/OOG Rate = the capability of the TSO to process International Oversize and Out of Gauge baggage expressed as a bags per hour rate per TSO

FA_{EDS} = EDS false alarm rate for the EDS equipment selected

iii. ETD Machine Requirements¹²⁴

The ratio of BITs to ETD equipment is typically 2 to 1.

$N_{ETDMachines} = N_{BIT} / 2$ (Round up to the next ETD)

3. Checked Baggage Resolution Area (CBRA)

i. CBRA Layout and Equipment¹²⁵

The CBRA layout shall be designed to optimize TSO utilization, minimize bag lifting, and reduce equipment costs. A centralized CBRA can optimize TSO utilization and equipment cost reduction.

- Incorporate a Re-Insert Line (RL) connected to the end of the Alarm Line (AL) and omit the RL queue side guard to ease bag placement during manual reinsertion
- Enable transport of OOG bags via the AL and leave via the Clear Line (CL)
- Enable transport of oversized bags via a dedicated conveyor line
- Ensure that bags arriving on the AL are centered or closer to the Baggage Inspection Table (BIT) side (not to the conveyor side guard)
- Define Transportation Security Officer (TSO) access path to the oversized bag area

ii. CBRA Physical Requirements

The quantitative sizing of the room should be based on the number of queues and workstations required to adequately meet the screening demands of the CRBA.

iii. Make-up

Baggage make-up includes manual or automated make-up units, the cart/container staging areas, and baggage tug/cart (baggage train) maneuvering lanes. The type of system selected for a terminal depends

¹²⁴ TSA PGDS Version 5, Section 6.1.5, 2015

¹²⁵ TSA PGDS Version 5, Section 9.2.1, 2015

on several factors including the number of airlines, the terminal configuration, operating policies (common use, exclusive use), and size of the terminal complex¹²⁶.

The Baggage Make-Up model estimates the make-up requirement based on the total Equivalent Aircraft (EQA) [1 EQA = 145 seats] of gates in use, the average number of departures per nominal gate (not normalized to EQA) in the make-up period, and the likely number of staged carts/containers required per EQA. The EQA value can be linked to the Gate Demand model, but can also be entered manually¹²⁷.

Although checked baggage ratios are a consideration, especially when designing more complicated automated sortation systems, these ratios generally affect the total number of baggage carts in use rather than the size of the make-up area. The number of carts/containers per flight staged at any one time, however, is generally based on the size of the aircraft. For most terminals, one cart or container is typically staged for each 50 to 75 seats of aircraft capacity; this would be equivalent to approximately two to three carts/containers per EQA. A cart is usually assumed to have the capacity for 40 to 50 bags. The number of staged carts/containers can also vary based on individual airline policies for pre-sorting baggage at the spoke airport for more efficient transfer at the hub.

iv. Make-Up Devices

Outbound baggage makeup requirements define the amount of space needed to accommodate the types and number of baggage makeup devices (laterals, chutes, or carousels) and operational, vehicular, and staff support areas required to support terminal activity. Presentation length, which equates to the number of carts staged around a device for a flight during baggage makeup, and bag cart/tug circulation lanes represent the largest components of the space requirement and determine the dimensional criteria. Baggage makeup for a flight usually begins at the time agents at check-in counters begin to accept bags for a flight departure and ends when the flight is closed out.

Information used to develop outbound baggage makeup requirements include:

- Operating parameters
 - Rules for use: flight sector, duration for baggage makeup by flight sector and aircraft type, close out time, use/lease basis, transfer bag handling
 - Baggage system equipment
- Demand basis
 - Planning schedule analyses by airline to determine aircraft or reasonable equivalent aircraft for baggage make-up.
 - Number and rate of checked bags per flight received from upstream processes.
- Dimensional criteria (space template)

The total number of make-up positions (MUPs) is dependent number of flights in build at any one time and allocations per flight type (ADG-III - 3 to 4; ADG-V - 5 to 6). The assumption used for MUP allocations assumption needs to be defined on airport by airport basis. An EBS can also reduce MUP demand by reducing make-up opening time but must be sized accordingly.

¹²⁶ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.12.1, 2010

¹²⁷ ACRP Report 25, Vol 2, Airport Passenger Terminal Planning and Design, Baggage Make-up Model, 2010

- Makeup device presentation length
 - Cart staging
 - Sortation area (loading aisle and cart/container staging area)
- Tug bypass lane

ACRP 25, Volume 2 provides the methodology followed to determine the make-up area required.

	A	B	C	D	E	F	G	H	I
1	Baggage Make Up								
2									
3	RETURN TO TABLE OF CONTENTS		Go To User's Guide				Input Data Values		
4							Calculated Values		
5							Linked or Predetermined Values		
6									
7	BAGGAGE MAKE UP SPACE REQUIREMENTS								
8	EQA (In Use)	User Specified Input		30.0	30	linked to Gate Demand			
9	Expected # of departures per Gate (within 2-4 hour staging period)				1.3				
10	Staged carts/containers per EQA				2	range: 2 - 3 per EQA			
11	Area required per cart/container (sq. ft)				600				
12	Make Up Area (sq. ft)						46,800		
13									
14	Additional Allowance for Baggage Train Circulation				10%		4,700		
15	Total Make Up Area (sq. ft)						51,500		
16									
17	ALTERNATE RATIO METHOD								
18	EQA (In Use)				30				
19	Actual Average Area per EQA (sq. ft)				1800	1500 - 2200 sq. ft			
20	Total Make Up Area (sq. ft)						54,000		
21									
22									
23									
24									
25									
26									
27									
28									
29									

Figure 51: Sample calculation screen

g. Oversized Baggage

The estimation of oversized baggage demand as a percentage of overall baggage should be checked against historical data of each terminal. Provide a means of conveying oversized baggage from the departures hall to the CBIS. This could be via special oversize belts, or manual conveyance, depending on demand levels and building configuration.

1. Dimensional Criteria

i. Take-Away & Collector Belts:

The following passage, from TSA PGDS, discusses design considerations for conveyor belt speeds and slopes.

ii. Tail-to-Head Bag Spacing Requirement¹²⁸

The space between bags as measured from the trailing edge of leading bag to the leading edge of the trailing bag, or “tail-to-head spacing” shall be no less than 12 inches as bags enter the EDS machine. The speed of the queue belt immediately before and after the EDS machine shall match the speed of the internal belt of the EDS.

iii. Gradual Conveyor Speed Transitions¹²⁹

The transitions in conveyor belt speeds between any two consecutive conveyor belts should not exceed 30 feet per minute or a 50% difference of belt speeds, whichever is less, so as not to affect the stability, orientation, or spacing of bags while still maintaining accurate bag tracking.

CBIS designers must match adjacent conveyor speeds at the juncture between BHS and EDS conveyors at both the entrance and exit of the EDS.

iv. Avoidance of Steep Conveyor Slopes¹³⁰

The CBIS should be designed with incline and decline angles no greater than 18 degrees in non-tracking zones (i.e., zones where bags are not positively tracked) and no greater than 12 degrees in tracking zones (i.e., zones where bags are positively tracked).

2. Checked Baggage Resolution Area (CBRA)

i. CBRA Layout and Equipment¹³¹

The CBRA layout shall be designed to optimize TSO utilization, minimize bag lifting, and reduce equipment costs. A centralized CBRA can optimize TSO utilization and equipment cost reduction.

- Incorporate a Re-Insert Line (RL) connected to the end of the Alarm Line (AL) and omit the RL queue side guard to ease bag placement during manual reinsertion
- Enable transport of OOG bags via the AL and leave via the Clear Line (CL)
- Enable transport of oversized bags via a dedicated conveyor line
- Ensure that bags arriving on the AL are centered or closer to the Baggage Inspection Table (BIT) side (not to the conveyor side guard)
- Define Transportation Security Officer (TSO) access path to the oversized bag area

ii. CBRA Physical Requirements

The quantitative sizing of the room should be based on the number of queues and workstations required to adequately meet the screening demands of the CBRA.

¹²⁸ TSA PGDS Version 5, Section 7.2.1.2, 2015

¹²⁹ TSA PGDS Version 5, Section 7.2.6.2.1, 2015

¹³⁰ TSA PGDS Version 5, Section 7.2.6.2.2, 2015

¹³¹ TSA PGDS Version 5, Section 9.2.1, 2015

iii. CBRA Layout and Equipment ¹³²

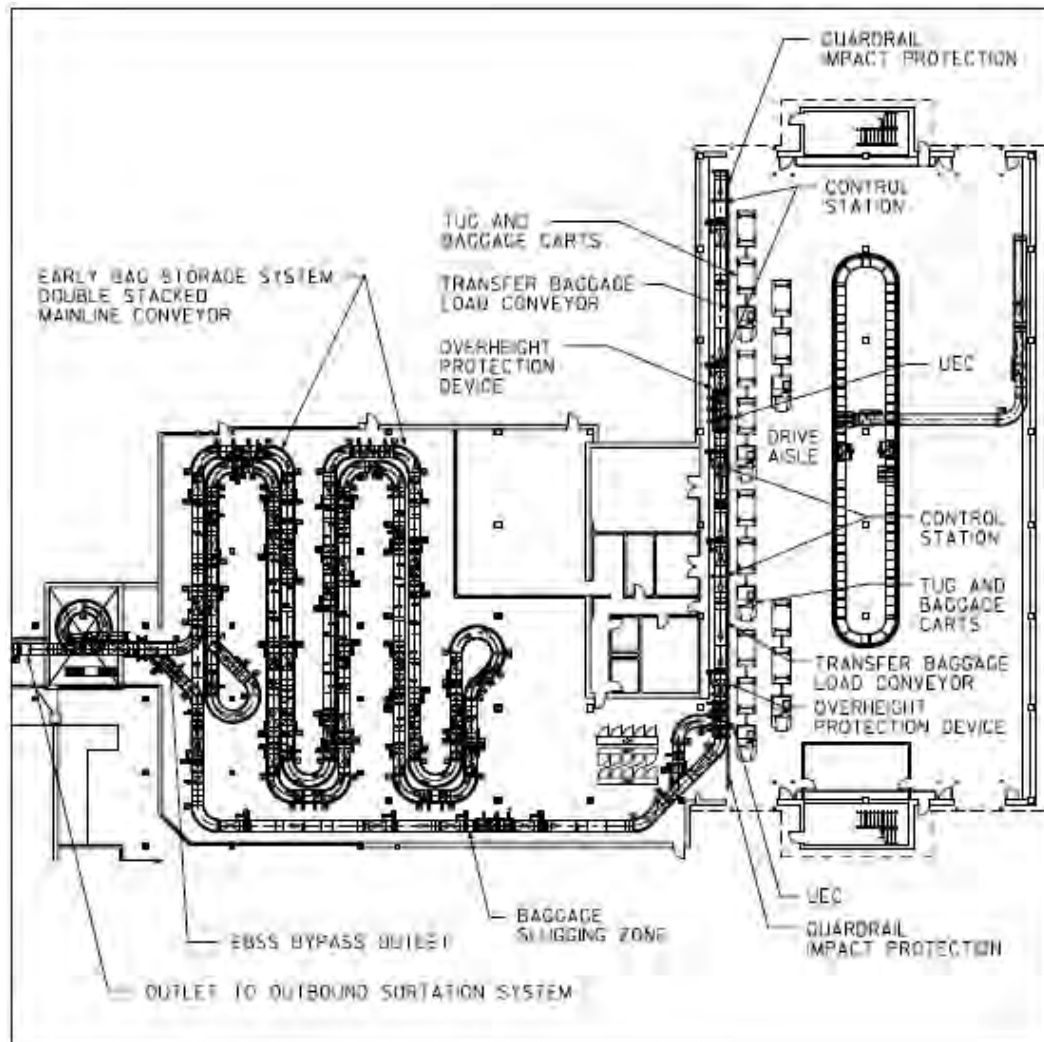
The following passage from TSA PGDS, discusses design considerations for TSA equipment sizing when designing the layout of CBRA.

The Baggage Inspection Table (BIT) is where TSOs perform baggage security screening protocols. The BITs shall be aligned with the AL and designed to provide a 30-inch by 60-inch minimum work surface with 30-inches of height.

The Baggage Removal Point (BRP) is the queue conveyor adjacent to the BIT from which bags are removed and transferred to the BIT. The BRP shall be 48 inches long and designed to a 32-inch height.

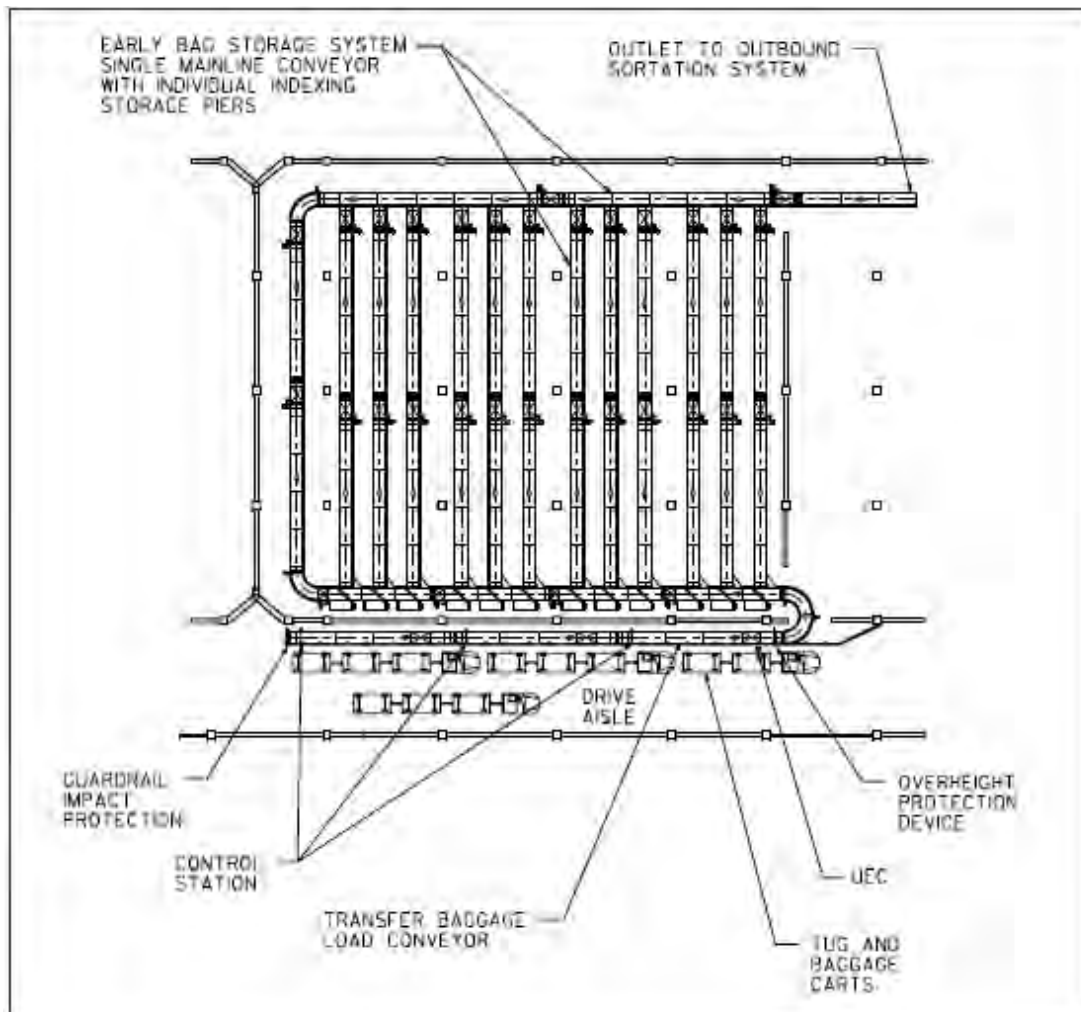
¹³² TSA PGDS Version 5, Section 9.2.1, 2015

3. Early Baggage Storage (EBS)



Source: Star Systems, LLC—A subsidiary of Five Star Airport Alliance

Figure 52: Typical EBSS with double-stacked mainline conveyor and two load points



Source: Star Systems, LLC—A subsidiary of Five Star Airport

Figure 53: Typical EBSS with single mainline conveyor and one load point

4. Make-Up Room

The size of the baggage make-up area will vary depending on the type of make-up units (index belts, re-circulating make-up units, sort piers, etc.) and whether the systems are exclusive or common use for typical configurations and dimensions. For preliminary planning purposes, the area per staged cart/container typically varies from 600 square feet/cart for individual airline make-up areas with re-circulating make-up units to 300 square feet/cart for larger pier make-up areas. In addition to the area for baggage make-up and bag claim off-loading, most terminals need additional lanes and other common-use maneuvering areas that link the inbound and outbound baggage handling areas to the apron. For programming, a 10% to 15% allowance of all baggage handling areas will generally be sufficient for tug circulation in a two-level terminal, provided the terminal configuration is reasonably efficient¹³³.

¹³³ ACRP Report 25, Vol 2, Airport Passenger Terminal Planning and Design, Baggage Make-up Model, 2010

Minimum floor-to-floor head clearances should be maintained in baggage handling facilities for tug cart circulation, conveyors, and other building systems' equipment rights-of-way. These minimum clearance recommendations, which indicates:

- Tug cart clearance from the finish floor to the underside of a fixed structure element or conveyor belt system
- Baggage conveyance line clearances from the bottom of the structure to the bottom of the conveyor belt
- GSE requirements (e.g., tug charging, ULD storage, cart parking)
- Roadway design (e.g., number of lanes, lane width, turning radius)

The alternative ratio method uses a general rule-of-thumb approach based on the average makeup area in relation to total EQA. Generally, 1,500 to 2,200 square feet per EQA of overall make-up area is the range at airports that have been studied.

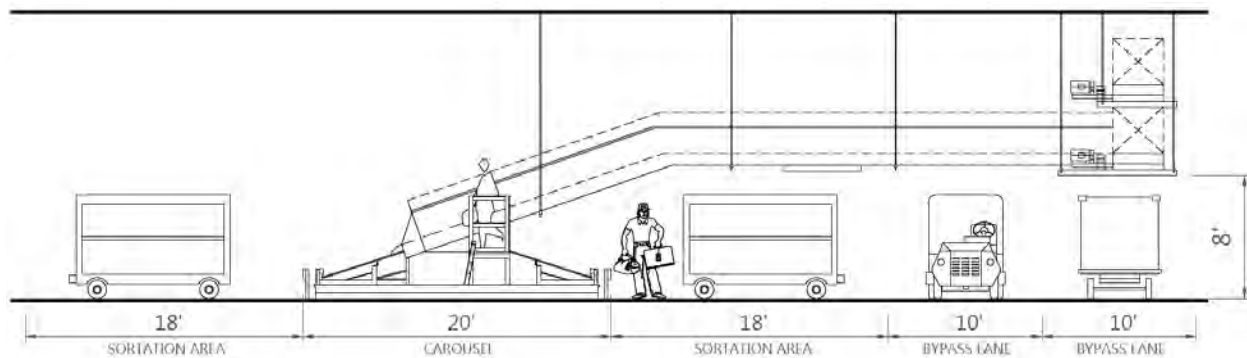


Figure 54: Schematic of baggage induction system ¹³⁴

¹³⁴ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, 2010

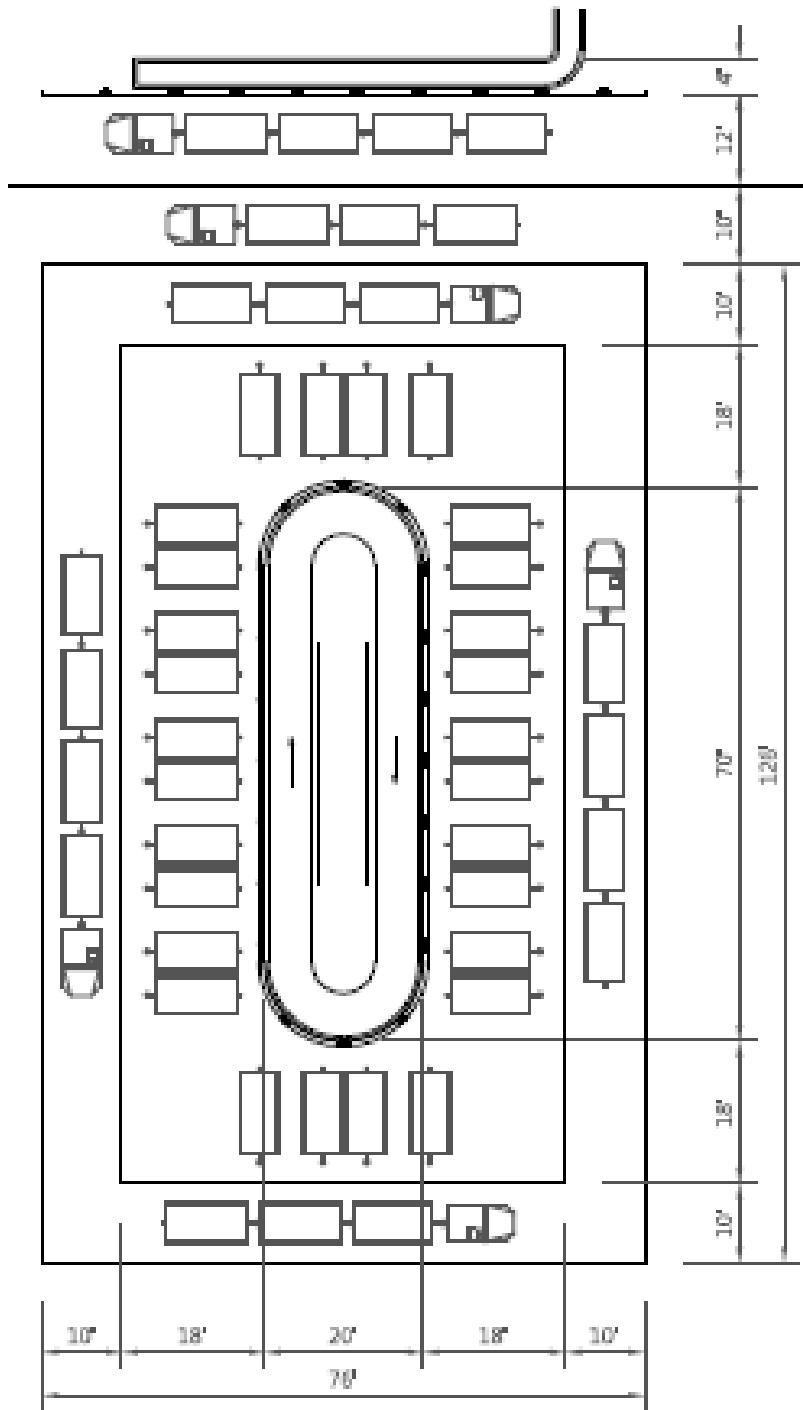


Figure 55: Outbound bag make-up benchmark with perpendicular staging ¹³⁵

¹³⁵ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, 2010

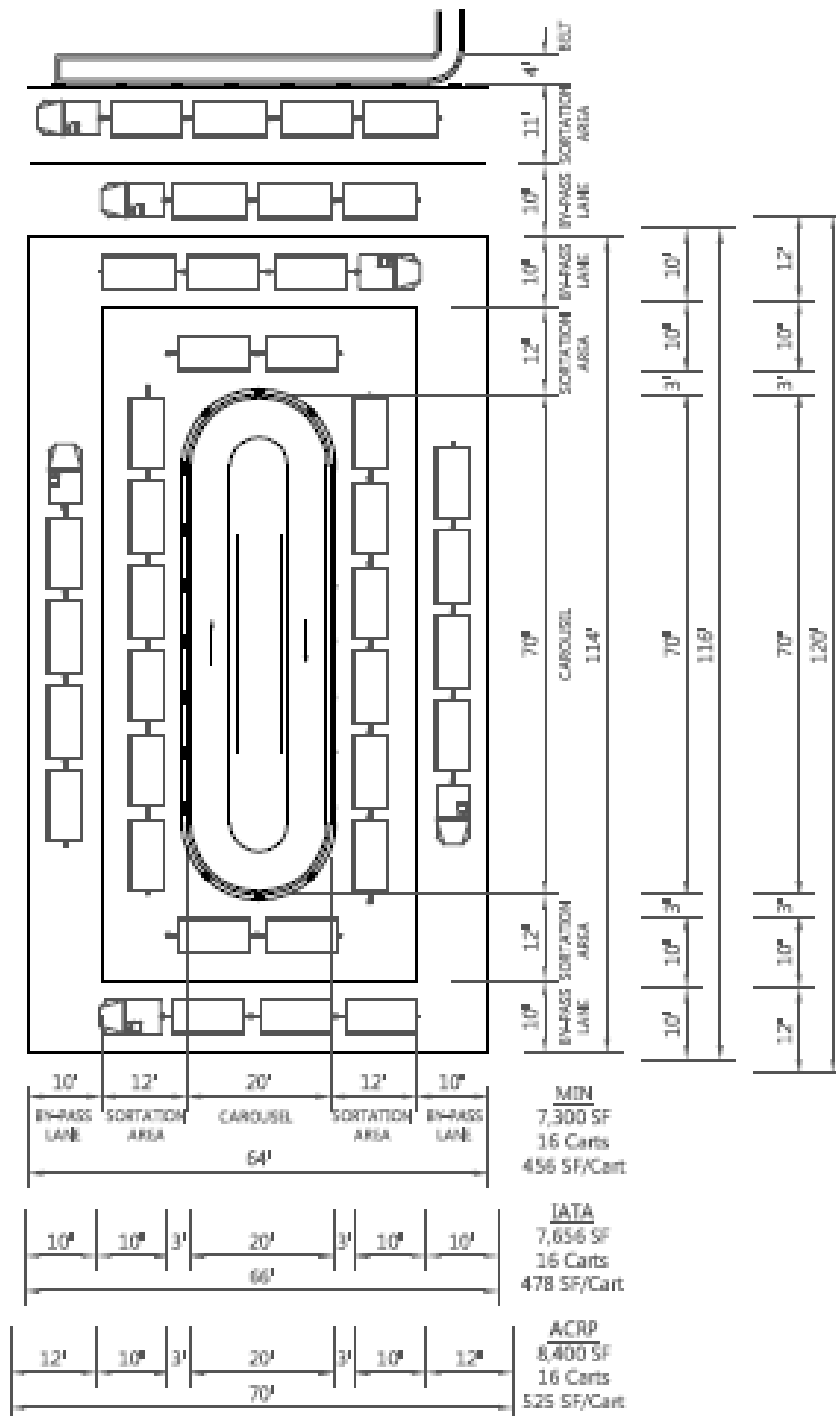


Figure 56: Outbound bag make-up benchmark with parallel staging¹³⁶

¹³⁶ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, 2010

h. Passenger Security Screening Checkpoints (SSCP)

Checkpoint requirements define the number of travel document checkers (TDC), number of checkpoint lanes, and amount of queue area required to support terminal activity. A checkpoint lane consists of a single or paired advanced imaging technology (AIT) and magnetometer, x-ray unit with attached divest and recompose rollers and tables, manual search stations, and benches. A supervisor station is used to monitor each checkpoint area.

Critical information necessary for calculating checkpoint requirements includes:

- Operating parameters
 - Staffing and operating hours
 - Utilization (general versus program lanes)
 - Processing rates
- Demand basis reflecting upstream processors
- Level of service criteria
- Dimensional criteria (space template)

The Port Authority requires that the number of required processors be calculated based on the maximum waiting times provided in this document. For the calculation of waiting area requirement, sufficient area to accommodate passengers' waiting time of 30 minutes must be provided.

All assumptions related to the percentages of passengers using a specific check-in mode must be documented and approved by the Port Authority. In addition, certain processors may be used by airport employees and must therefore be designed to accommodate that additional demand.

The Port Authority requires the use of IATA ADRM 10 methodology, taking into account the additional requirements stated above, for the calculation of number of processors, waiting areas, and total areas.

Flexible designs that allow for the future expansion of certain functions and contraction of others are necessary to ensure that the terminal building can adapt to future and unforeseen changes in technology and passenger behaviors.

1. Screening Lanes Requirements - Methodology

To assess the required numbers of standard and trusted traveler lanes, the designer must account for the total peak hour demand, percentage of passengers who are in a trusted traveler program (at the time of this writing, varies from 15% - 30% depending on airport), and the lane processing speed of each lane type.

Lane processing speeds vary considerably per airport, and are dependent on many factors, local and national. Designers should consult with local TSA, and perform site surveys if possible, to establish a realistic lane speed for design purposes. At this time of this writing, lane speeds observed at several large airports in the US ranged from 120-180 pax/hr. for standard lanes, and 150-250 pax/hr. for trusted traveler lanes.

Step 1: Calculate the demand from the previous processor.

The demand includes that from:

- The processing desks (CD);
- The self-service kiosks; and
- Those who by-passed the processing desks using web/mobile processing.

Use the following formula: $PK_{30MIN} = (CD * 60 / PT_{CD} * 30) + (BD * 60 / PT_{BD} * 30) + (PHP * PK * (1 - (CR + BR)))$

PK _{30MIN}	=	Throughput 30-minute Demand
CD	=	Number of Service Desks Open
PTCD	=	Process Time for Service at Desks (in seconds)
Cf	=	Correction Factor for Demand Variability (see reference table)
BD	=	Number of Baggage Drop Positions Open
PTBD	=	Process Time at Baggage Drop (in seconds)
PHP	=	Originating Peak Hour Passengers
PK	=	Peak 30-minute Factor (in % of PHP)
CR	=	Ratio of Passengers Using Traditional Check-in Facilities
BR	=	Ratio of Passengers Using Baggage Drops
PD	=	Number of Departure Passport Control Desks
PTPD	=	Process Time for Departure Passport Control (in seconds)
SECI	=	Approximate Number of Security Lanes
PTSEC	=	Process Time per Passenger at Security (in seconds) *
MQT	=	Maximum Queuing Time (in minutes)
A	=	Area Required for the Security Checkpoint Facility
SEC	=	Total Number of Security Lanes
SECd	=	Depth of One Security Lane (in feet). Obtained from typical dimensions
SECw	=	Width of One Security Lane (in feet). Obtained from typical dimensions
QMAX	=	Maximum Number of Passengers Waiting in Queue
SP	=	Space per Person (in sq ft)
W	=	Corridor Width Behind Lanes (in feet) **

* The process time at security is rather a throughput time since the lanes may serve multiple passengers at the same time. The process time is the number of passengers served per period of time, translated into seconds/passenger. For example, if a facility can process an average of 40 persons in 20 minutes, the process time is 30 seconds per passenger.

** The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

Table 19: Screening lanes calculation inputs¹³⁷

¹³⁷ IATA ADRM 10th Edition

Step 2: Calculate the approximate number of security lanes using the following equation:

$$SECi = (PK_{30MIN} * PT_{SEC} / 60) / (30 + MQT)$$

The maximum waiting times (MQT) to be used for the screening lanes calculation are summarized in the table below:

Port Authority Standard	
WAITING TIME STANDARDS FOR PROCESSING FACILITIES Not To Exceed (Minutes)	
Economy Class	10 min
Fast-Track and TSA pre-check	5 min

Table 20: Waiting time standards for processing facilities

For security checkpoint, waiting time is defined by time when the passenger is entering the queue until the time of arrival at the divestiture table.

These maximum waiting times should be used to determine the number of required processors (security screening lanes) but not for the calculation of space requirements, including sizing of queue areas. The Port Authority requires that queue area be designed to accommodate a 30-minute queue time (see step 4).

Step 3: Adjust requirements to account for variability in passenger arrival distribution within the peak period and in processing time using the following equation:

$$SEC = SECi * Cf$$

Where:

Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)	
For MQT	CF
3, and less	1.22
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 21: Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)¹³⁸

¹³⁸ IATA ADRM 10th Edition

The smaller the MQT, the greater the variability in demand over the 30-minute period analysis.

Step 4: Calculate the maximum number of passengers in queue using the following formula:

$$Q_{MAX} = 0.495 * \text{Peak 30-min (corresponding to a 30-minute MQT)}$$

Note: When designing a queue area at a security checkpoint facility, the planner should consider a single or snake queue layout. The typical width of a queue at a security checkpoint should be between 4 feet and 4 1/2 feet.

Step 5: Calculate the area required for the security checkpoint using the following equation:

$$A = (\text{SEC} * \text{SECd} * \text{SECw}) + Q_{MAX} * \text{SP} + (\text{SEC} * \text{SECw} * W)$$

The following minimum space per person standards (SP) must be used to calculate the required queuing space for security screening process:

Port Authority Standard	
SPACE STANDARDS FOR QUEUING AREAS (sf/pax) * - MINIMUM	
Economy Class	12.9
Fast-Track and TSA pre-check	12.9

*Considering a queue width of 4.0 feet.

Table 22: Space standards for queue areas

2. Dimensional Criteria

Screening lane pair consisting of the length of each screening lane, including divest tables, x-ray machine, agent work area, recompose tables, AIT body scanner, magnetometer, divest bins, recompose benches.

3. Travel Document Check (TDC):

Per the TSA CDG, travel document check (TDC) staffed positions are required at the entrance to the SSCP lanes. When passengers reach the end of the SSCP general queue, TDC officers inspect each passenger's ID and boarding pass. Designers should follow the CDG for number and configuration of TDC positions. Each TDC position requires a standing podium with a boarding pass scanner and ultraviolet (UV) lamp for illuminating UV watermarks on IDs. Each podium must be provided electrical and data connections. Lighting in the TDC area must be adequate and evenly distributed with no harsh glare, so that TDC officers can clearly view the passengers' faces, IDs, and boarding passes.

4. Queuing

At checkpoints with both regular and PreCheck lanes, provide separate queuing for regular and PreCheck passengers. As part of the incentive for passengers to participate in the PreCheck program, there is an expectation of lower wait times for PreCheck queuing.

Where an airline or terminal operator has overall control over the queuing of a checkpoint, they may wish to provide special queuing for premium passengers. This queue is expected to be substantially shorter than the queue for economy passengers, due to smaller demand population. Because premium passengers may or may not be enrolled in PreCheck, if a checkpoint has both regular and PreCheck

lanes, the premium queue should be positioned between the regular queue and the PreCheck queue, so that premium passengers may be directed by the TDC to either regular or PreCheck lanes.

5. Screening

i. Passenger Screening

Typical configuration with one X-ray unit for each Walk-Through Metal Detector (WTMD) varies from approximately 27 to 31 feet wide for a pair of lanes, depending on the type of baggage X-ray unit used. If a “2 to 1” configuration of two X-rays for one WTMD has been installed, a slightly narrower footprint of approximately 22 to 29 feet can be assumed. Non-standard configurations are also used when physical constraints do not allow a typical line of inspection lanes. Additional width may be associated with ADA accessible lanes¹³⁹.

¹³⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.3.2, 2010

The following figure shows the minimum dimensions for security screening lanes:

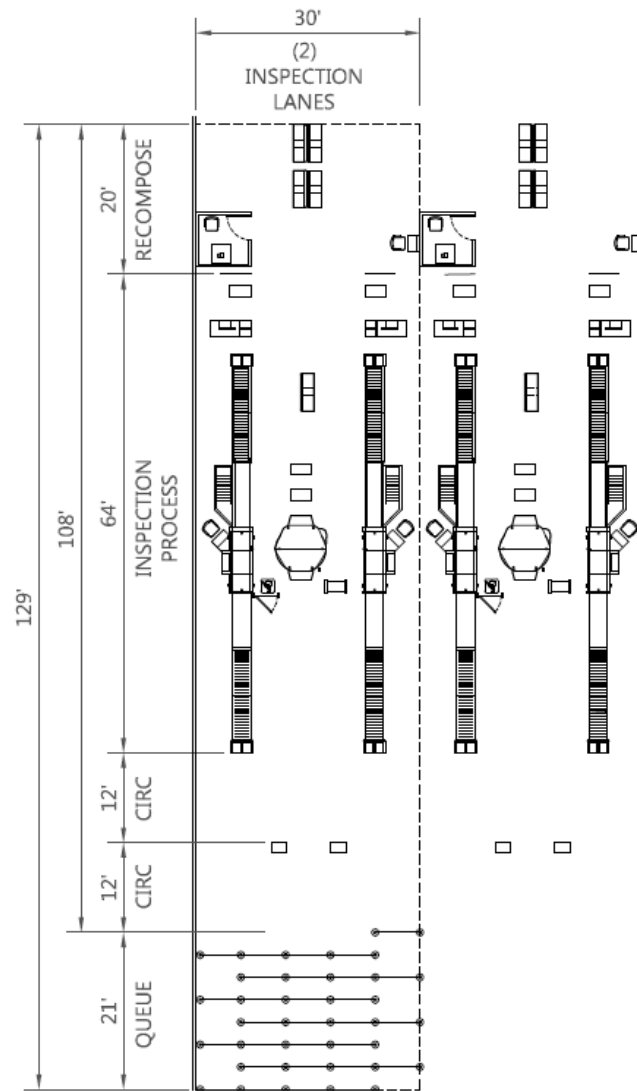


Figure 57: Minimum dimensions for security screening lanes ¹⁴⁰

For additional information on the kind of equipment to use, it is advisable to follow the dimensions shown in the TSA Checkpoint Design Guide Revision 5.1 (2014). This manual provides all the dimensions for the different components of the lanes according to each type of equipment and WTMD.

ii. Carry-on Bag Screening

The length of the SSCP varies depending on a number of factors but is primarily related to the length of the tables placed before the X-ray unit for passengers to unpack laptop computers, take off jackets and shoes, and remove metal objects from pockets. Similarly, the length of roller beds and/or tables, and seats after the SSCP for passengers to put clothing back on and repack bags, can vary. Airports are experimenting with these functions, and standards for these tables are evolving. The length for an SSCP

¹⁴⁰ Source: TSA guidelines

can vary from 57 to 68 feet. The variability in both SSCP width and length is a function of the type of baggage X-ray unit, the type of passenger holding and/or wandering stations, and other screening equipment¹⁴¹.

The dimensional guideline for a checkpoint lane pair with AIT and magnetometer is approximately 3,870 square feet. The dimensional guidelines for an expanded checkpoint lane pair with AIT and magnetometer can range from 4,680 square feet to 5,670 square feet.

Refer to Part 2, Section h.

Regarding Automatic Screening Lanes, TSA Innovation and Concept Supplemental Information 1-2010 v.1 provides layouts and dimensions of different examples of ASL.

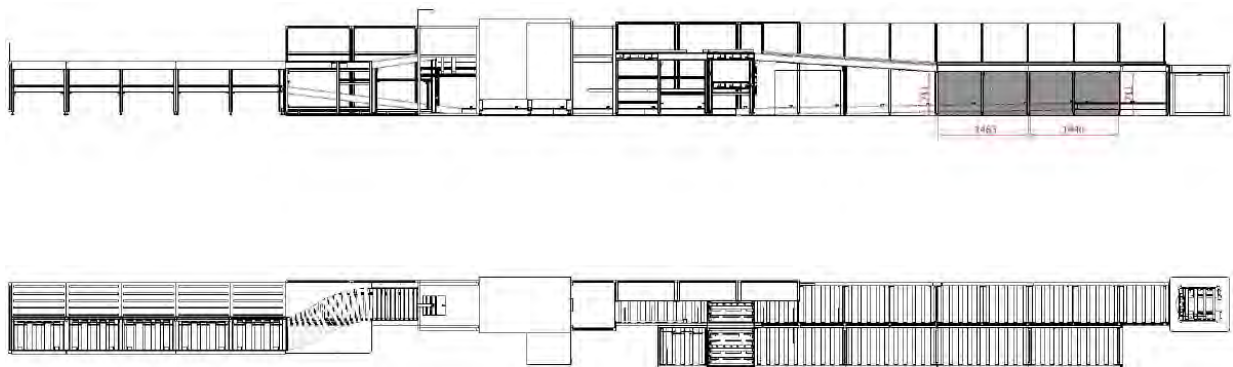


Figure 58: ASL Example – SmartView MacDonald Humphrey LTD

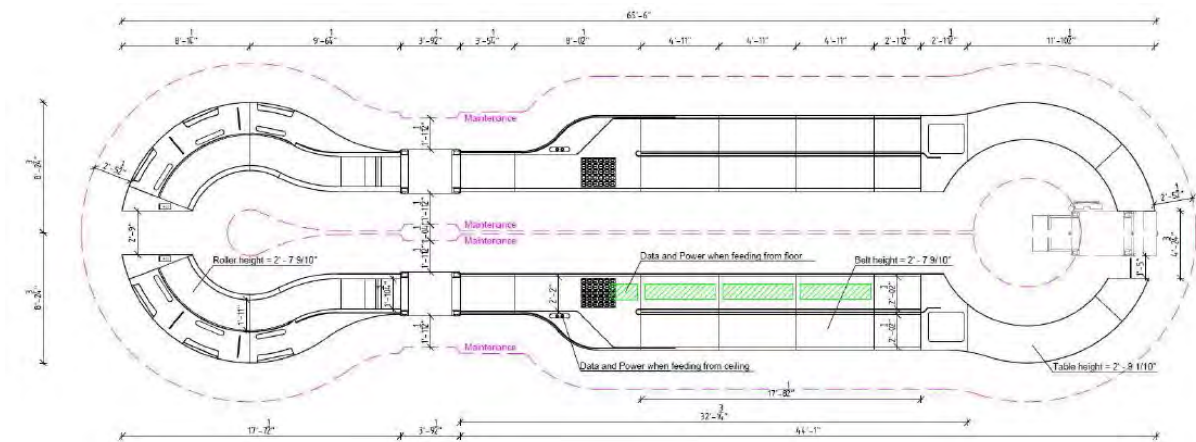


Figure 59: ASL Example – Scarabee

¹⁴¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.3.2, 2010

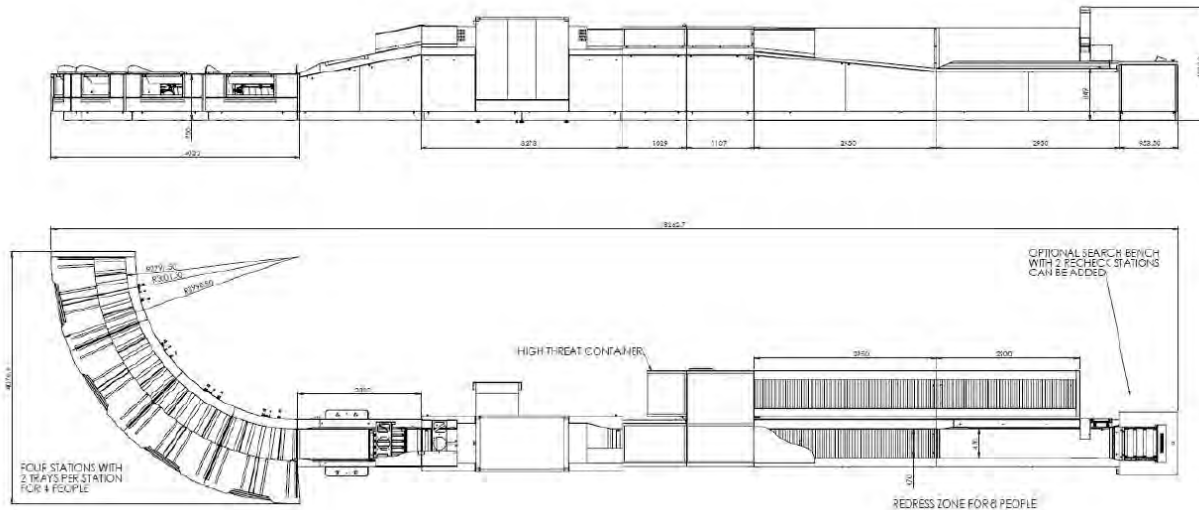


Figure 60: ASL Example – SCANNOJET Vanderlande Industries

iii. Trusted Traveler, TSA PreCheck, and Clear

TSA Checkpoint Design Guide Revision 5.1 (2014) 3.2.1 provides layouts with different security screening lane configurations that include PreCheck lanes.

The main purpose of implementing trusted traveler lanes is that they process passengers at a faster rate than standard lanes, because less divestiture is required – passengers do not need to remove shoes and belts, and do not need to take laptops or liquids out of their carry-on bags. Passenger are therefore incentivized to join a trusted traveler program, because their experience at the SSCP will be faster and simpler.

Operational requirements must be met in order to expand one or more lanes to PreCheck at a given checkpoint. Requirements include¹⁴²:

- Sufficient predicted or realized volume for sustained periods to open a new lane or expand to an adjacent lane
- Designs are managed by an RBS coordinator
- PreCheck lane is operated with an AT2 X-ray and CEIA WTMD
- Sufficient personnel are trained and available to run additional PreCheck lanes as necessary
- Ability to restrict non-PreCheck passengers from accessing the PreCheck lane
- Maintain a minimum of one standard lane operating within the checkpoint
- If implementing a dual use lane, provide a visible indicator for TSOs to identify mode of operation (PreCheck Standard)

¹⁴² TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 3.2.1, 2014

Depending on the airport configuration and which airlines are increasing in volume, there are three options which an airport may expand their PreCheck lane:

- Option 1: Move an existing PreCheck lane to better accommodate traffic patterns and expansion
- Option 2: Add a new PreCheck lane at a new checkpoint that previously did not have sufficient volume
- Option 3: Expand existing PreCheck to an adjacent lane (either full-time or part-time as “Dual Use”)

Due to a variation of PreCheck demand at certain times, the checkpoint can be configured to allow for flexing screening lanes. If at least one PreCheck lane is currently operational, the checkpoint is capable of expanding to additional lanes as needed. With equipment layout and queue planning, limited reconfiguration and time is required to “flex” from one PreCheck lane to additional lanes.

iv. Secondary Search

Secondary screening is typically located in the “dead” operator space on back-to-back lanes or at the end of the lane for odd numbered lanes. This area should be clear of exiting passengers. The secondary screening area typically consists of Explosive Trace Detection (ETD) unit, a Bottle Liquid Scanner (BLS), an Alternate Viewing Station (AVS) (only provided in AT2 which represents the second deployment of the AT units which consists of the Rapiscan 620DV, the Smiths 6040aTiX, and the L3 ACX 6.4-MV), a Mobile Cabinet, a search table and a passenger search chair and mat. The area is approximately 3’-0” to 5’-0” from the end of the screening lanes in order to minimize travel time and the distance that TSOs have to carry bags.¹⁴³

For the passenger search position TSA guidelines consider that the area comprising the inspection search and the mat should be 6’-0” by 6’-0”, in order to be able to accommodate passengers in wheelchairs and that passengers will be able to maintain eye contact with their belongings.

v. VIP Screening

Depending on the number and type of VIPs the airport is likely to handle, facilitation/processing may be done in dedicated standalone VIP facilities/buildings or handled through the passenger terminal assuming that appropriate controls are in place. Careful consideration is required when planning these facilities and airports and planners should seek inputs from government and local regulatory authorities to better understand the possible threats and needs¹⁴⁴.

When calculating demand levels for the SSCP, VIP demand cannot get subtracted from peak demand for general passengers. VIP lanes are voluntary by developer / airline.

¹⁴³ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.5, 2.6 & 2.12, 2014

¹⁴⁴ IATA ADRM 10th Edition, Section 3.4.11.12.3e, 2017

vi. Known Crewmember (KCM)

Planners should carefully consider the location for security screening of air crews. Where possible, dedicated checkpoints, or those combined with staff screening, will often make the most operational sense¹⁴⁵.

vii. Private Screening

Private Screening Room (PSR) is approximately 6'-0" by 8'-0" (minimum dimensions) with 8'-0" high glass panels and a 3'-0" door on either the short wall (S3) or the long wall (S3-A). Larger private screening rooms of 8'-0" x 8'-0" or greater is optimal.¹⁴⁶ The private screening room (or booth) should meet ADA accessibility standards.

Due to the relatively infrequent utilization, normally one private screening room or booth per checkpoint is sufficient. More may be required at large, high-volume checkpoints, or where experience has shown that a high percentage of private searches occur. Verify requirements with local TSA officials.

viii. Recomposure

TSA provides composure benches approximately 14'-0" from an AIT depending on the equipment arrangement. This area is typically out of the main passenger flow.¹⁴⁷

Additional benches and tables beyond those recommended in the TSA CDG should be provided to improve the passenger experience and the lane throughput rate. The numbers, types, and configuration of furniture will be dependent on available space, and the degree to which the terminal management wishes to provide additional non-revenue space to improve lane rates and passenger experience.

i. Post-Security Area / Concourse

The overall concourse program is primarily dependent on the terminal aircraft parking arrangement and airfield infrastructure. In most cases, the linear frontage of the terminal airside component correlates to aircraft wingspans and wingtip clearances between aircraft. Information used to develop concourse gate requirements include:

1. Circulation Area

Factors in determining concourse circulation corridor width include:

- Single- or double-loaded concourse
- Moving walkways, determined on the basis of
 - Walking distance between gates and concourse exit portals
 - Passenger demographics (i.e., aging population, passengers with disabilities)
- Percentage of passengers using the conveyance system

¹⁴⁵ IATA ADRM 10th Edition, Section 3.4.11.12.3d, 2017

¹⁴⁶ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.11.1, 2014

¹⁴⁷ TSA Checkpoint Design Guide (CDG) Revision 5.1, Section 2.13, 2014

Port Authority Minimum Circulation Corridor Width (feet)		
	Concourse Configuration	
	Single Loaded Concourse	Double Loaded Concourse
Circulation Corridor Width (feet)	20	30

Note:

Minimum clear corridor widths above are required in addition to moving walkways, if provided.

For double loaded corridors with centrally located moving walkways, a minimum width of 15 feet should be provided on both sides of the walkways. Additional corridor width may be required for high-volume hub terminals, corridors with potential use of electric carts.

Table 23: PA Minimum Circulation Corridor Width

The procedure for calculating the circulation areas¹⁴⁸:

- Describe the design passenger flow per hour for travel in one direction and convert into passenger flow per minute.
- Calculate the required effective width.
- Adjust the required effective width to account for edge effects. Total (net) width equals to effective width plus 1.5 feet on each side of corridor.

If circulation facilities allow movements in both directions, use total passenger flows for both directions for step 1 and adjust total width by adding 1.5 feet for each side of corridor plus another 1.5 feet for counter-flow effect.

The program area is usually based on a percentage of the other public areas of the terminal and typically ranges from 15% to 30% of these areas. The percentage is a first approximation and will also vary with the terminal configuration and gross size of the terminal. The split between secure and non-secure (public) circulation is also a function of the terminal concept¹⁴⁹.

Moving walkways are recommended when passenger walking distances are long (exceeding 1,000 feet) and should be located to allow access to gates and concessions¹⁵⁰.

Moving walkways are available in different widths, designated by the width of the pallet passengers stand on. The minimum pallet width for an airport is 48 inches, but 56-inch pallets allow passengers with roller cases to easily pass other passengers without interference. Depending on the manufacturer, a 48-inch walkway is approximately 5 feet 10 inches in overall width and a 56-inch walkway is approximately 6 feet 6 inches wide.

2. Holdrooms

i. Methodology for Holdroom Area Requirements

Holdrooms are to be sized to accommodate the number of passengers on the largest aircraft of an aircraft design group that can be parked at each gate. Concessions, lounges and circulation areas may not be classified as “Holdrooms.”

¹⁴⁸ IATA ADRM 10th Edition, Section 3.4.6.1.3, 2017

¹⁴⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.10.4, 2010

¹⁵⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.10.6, 2010

Requirements are calculated based on a percentage of total passengers who could be at the gate at a given time. In recent years, airports and airlines have been attempting to minimize capital expenditures and operating costs. Space requirements for departure lounges are increasingly being determined based on: (a) assumptions regarding flight schedules, (b) shared space among adjacent gates, and (c) the percentage of passengers who wait for flights in adjacent concession areas¹⁵¹.

Based on the methodology described above, the following tables provide minimum PANYNJ holdroom area and holdroom seating requirements by aircraft design groups.

The following sizes are to be considered as minimum:

Port Authority Minimum Standards				
	Stand-alone Holdroom		Shared Holdroom	
	Holdroom Seats	Holdroom Area	Holdroom Seats	Holdroom Area
Group III	123	3,300	111	3,000
Group IV	155	4,100	140	3,800
Group V	257	6,600	232	6,200
Group VI	354	8,800	319	8,200

Table 24: Holdroom requirements

ii. Dimensional Criteria

Areas used as gate holdrooms must have the following characteristics:

- Clear sight of the Boarding Podium
- Not more than 125 feet from the Boarding Podium¹⁵²
- Good quality public address (PA) system for agents at each Boarding Podium to make announcements to passengers in the holdroom
- Not more than 300 feet from the closest Restroom

It is desirable to have natural light through windows and or skylights, and to have a view of the apron and in particular the aircraft associated with the holdroom. It is desirable to have power outlets (standard and USB) for at least 25% of the passenger population of largest aircraft served by the holdroom. Criteria for shared holdrooms can be found in Part 1, Section 4.

¹⁵¹ FAA AC 150/5360-13A, Section 6.4.1, 2016 (Draft)

¹⁵² Criteria currently under review by the Port Authority and subject to change

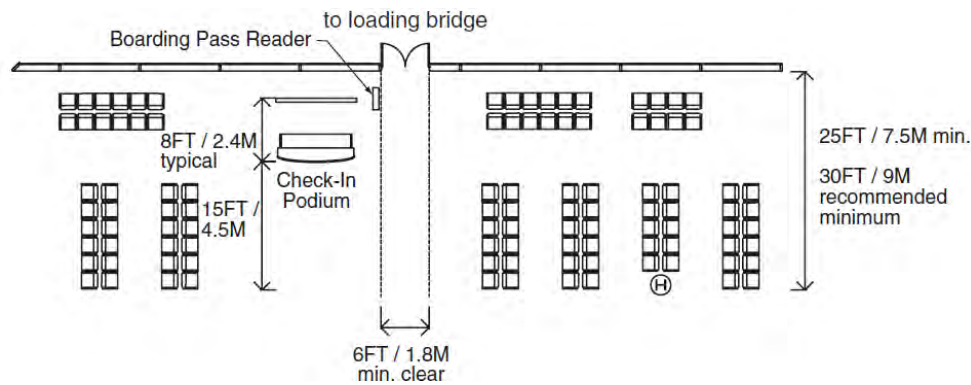


Figure 61: Holdroom schematic ¹⁵³

3. Concessions

When planning for concession space, it may be useful to benchmark the estimated space against such space at other airports and contact peer (comparable) airports to discuss their planning standards. In setting planning standards, such factors as the following should be taken into account for designing the concession areas¹⁵⁴:

- The efficiency of a terminal in terms of concentrating passenger flows
- Exposure to passengers
- The allocation of space pre- and post-security to reflect customer demand
- Configuration of the space in terms of frontage and depth preferred by concessionaires
- Passenger/customer characteristics
- Clustering of concessions to create desirable retail density

Next section provides the Port Authority guidelines for concession space requirements computation. As the needs and requirements for each terminal development may vary from one project to another, the calculation methodology, assumptions and results should be submitted to the Port Authority for review at the early stages of the planning process.

i. Methodology for Concession Space Requirements

Normally such calculations do not include seating, public toilets, circulation or other areas. Generic formulas usually take into consideration the following¹⁵⁵:

- Busy Hour Rate (from design day flight schedule)
- Penetration is based on the size of the commercial unit (depth times shop front width). For a typical unit, a maximum depth of 33 feet is advised. For a larger unit with a wider shop front, the depth can be increased;
- Dwell time is the time that passengers spend in the concessions area and differs for Domestic, International and New Model terminals;

¹⁵³ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.4.3, 2010

¹⁵⁴ ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, Chapter 11, Section 5.1.7, 2011

¹⁵⁵ IATA ADRM 10th Edition, Section 3.4.14.1.6, 2017

- Time spent on shopping, eating and other activities is an estimate based on data collected for that specific airport, but can be altered depending on the concessions offered; and

Commercial revenues are often an important source of financing for airport operations, maintenance and infrastructure development. According to IATA, some larger airports, up to 20 percent of the terminal area may be dedicated to retail shops and other concessions, although from 8 to 15 percent is more typical¹⁵⁶. An important step in determining the amount of supportable space is forecasting spend rates per enplaned passenger by concession category: food/beverage, convenience retail, specialty retail, and duty free.

While every airport will be different based on its passenger profile, the Port Authority recommends the use of the following ratio for preliminary planning, in line with the most recent IATA guidelines¹⁵⁷ with the objective to achieve world class service. This ratio is based on an international terminal configuration. Domestic terminal planning may have some variation and will be considered on a case by case basis:

- For new construction minimum concessions floor space: 13.0 ft² x each 1,000 annual enplaned passengers.
- For existing terminals concessions program redevelopment, the minimum concessions floor space standard of 13.0 ft² x each 1,000 annual enplaned passengers is recommended, provided the space is available for commercial development.

This ratio should be customized carefully depending upon the overall concessions planning concept (i.e., whether concessions are concentrated in specific zones or dispersed throughout the terminal). The type of activity occurring in any zone within the terminal will influence the type and amount of concessions space required for that zone.

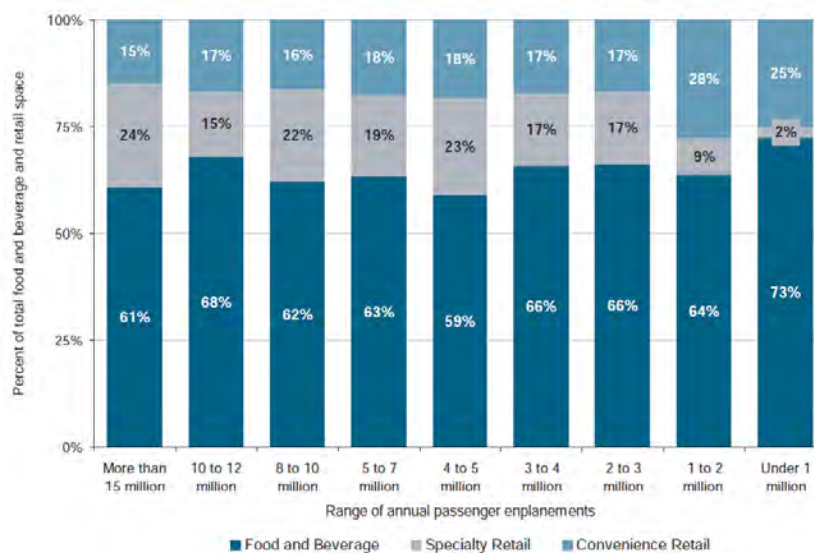


Figure 62: Percentage of space by major concession category ¹⁵⁸ (for comparison purposes only)

¹⁵⁶ IATA ADRM 10th Edition, Section 3.4.14.1.4, 2017

¹⁵⁷ IATA ADRM 10th Edition, Section 3.4.14.1.5, 2017

¹⁵⁸ ACRP Report 54, Resource Manual for Airport In-Terminal Concessions, Chapter V, Section 5.1.4, 2011

In addition, the Port Authority recommends the following ranges in terms of concession space allocation between pre-security and post-security areas:

Concession Location	Percentage of Concession Space
Pre-Security	10-20%
Post-Security	80-90%

Table 25: Percentages of concession spaces and sales based on the location within the airport

In order to provide a stellar customer experience, the Port Authority requires the provision of Food & Beverage concessions in all terminal pre-security areas. Special Consideration should be given to meter greater areas at the Arrivals Level.

j. Airline Customer service

The decision of whether or not to provide a dedicated airline customer service station post-security is up to the individual airline(s) operating at the terminal. The airline(s) should be consulted directly for requirements.

k. Premium Lounges

The size and number of lounges at an airport is highly dependent on the airline mix and passenger volume. Airlines within alliances have joined together at some airports to provide a single lounge for all of the alliance's passengers. This consolidation has reduced, in some cases, the total lounge area that would be required by the individual airlines, while providing their passengers with more services¹⁵⁹.

l. Nursing rooms

Each concourse should have a nursing room, separate from a restroom or family room, with a locking door or controlled entry, electrical power available, a sink and countertop, a baby changing station, soap, paper towel dispensers, and comfortable seating as minimum amenities. Pending legislation proposed to Congress may mandate that airports provide lactation rooms as noted in ACRP Report 157.

The objective is to establish rooms for a single or multiple user with optimum flexibility for nursing mothers and equipment such as strollers and carryon luggage.

m. Water filling stations

Water filling stations should be provided with each restroom bank and one additional for every three holdrooms. Planners should check policy versus water sales and local plumbing codes.

¹⁵⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11.4, 2010

n. Children's Play Areas

In order to increase the level of service and the passenger experience, many airports are incorporating children's play areas besides the holdrooms. The children should always be under adult supervision. One children's play area should be provided at least per 10 holdrooms.

o. Pet Relief Areas

The number of Service Animal Relief Area (SARAS) installations at the airports is incrementally increasing in response to the growing number of passengers accompanied by emotional support animals (ESA's) and officers on duty with law enforcement dogs. There are currently nine SARA's within the PANYNJ Airport System. On the non-secured side pet relief areas can be provided outdoors near the curbside. On the post-security side, provide at least one pet relief area per post-secure concourse. Additional locations may be provided based on the size or configuration of the sterile area.

Basic performance criteria are articulated in FAA Circular AC 150/5360-14A Appendix A, including "The SARA may be constructed in any shape, but the minimum size of a SARA should provide adequate space to accommodate a person using a wheelchair handling a service animal secured on a five-foot leash" and large enough for the animal to circle its handler (approximately 60 sq. feet). "In busier locations, a relief area may be sized to accommodate more than one service animal at one time."

p. International Arrivals

It is recommended to follow CBP regulatory requirements in Airport Technical Design Standards. These documents are confidential documents, which require Service Set Identification clearance. Accesses to these documents are granted to airport architects and planners on a project-by-project basis pending clearance of identification and background checks by Department of Homeland Security.

1. Sterile Corridor

The sterile corridor should be sized based on peak period demand. Where long walking distances are required, provide moving walkways.

It is recommended that a minimum width of 6-8 feet for each gate's deplaning corridor leading from the passenger boarding bridge to the sterile corridor. Because passengers from multiple simultaneously arriving aircrafts may use the sterile corridor, its width is similar to a concourse circulation corridor, but it may be somewhat less wide because passengers are all flowing in one direction only – towards the FIS¹⁶⁰.

2. International In-Transit Lounge for Passengers Not Entering the US

Currently the PANYNJ does not provide this facility.

3. Immigration (Conventional Option)

CBP primary facilities are sized for a capacity stated in terms of passengers per hour. This rating is "steady state," assuming a relatively well-distributed pattern of arriving flights.

¹⁶⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.4.3, 2010

i. Processing Elements and Space Calculation

The number of booths required for primary inspection is typically prescribed by the CBP based on the design hour passenger volume and, as such, consideration of dynamic issues will not usually impact that aspect of the facility. However, while agencies may specify minimum queue depths, they may be insufficient depending on the likely distribution of peak hour passengers amongst flights and the relative timing of those flights. Examining demand in a smaller time frame, 15 or 30 minutes, is often helpful in understanding the maximum length of queue to be accommodated. One other key area to consider in arrivals facilities is the impact of off-time (i.e., early or late) flights. In addition to a base analysis, if off-time data is available, a number of sensitivity tests should be performed to fully understand the dynamics of the facility¹⁶¹.

The FIS/CBP model is designed to estimate the passenger queue lengths, space requirements, and passenger delay time for primary processing; baggage claim requirements; and the time baggage claim devices will be in use. Among the many CBP facility requirements is the number of double inspection booths and the minimum passenger queue depth and width for primary inspection. This spreadsheet model allows the user to evaluate a CBP-recommended passenger flow rate and booth count, or user-selected values.

34	SINGLE ARRIVAL - PRIMARY PROCESSING EXAMPLE	INPUTS	OUTPUTS	EXAMPLE #2
35	# of Seats on Arriving International Flight	400		
36	Load Factor of Arriving Flight	80%		
37	# of Arriving Passengers on sample flight		320	
38	Existing # of Double Booths	6		
39	User Specified # of Double Booths	4		
40	Total Primary Processing Positions		8	
41	Unload Rate (Passengers/min)	20		
42	Primary Processing Rate (Passengers/Hr/Double Booth)	100	CBP suggests 100 Pax/Hr/Double Booth	
43	Choose the bucket size for the Mini Queue Model to use	5 Minute	←MAKE SELECTION	
44	Max # of Passengers in Queue		200	
45	Average wait time in Queue (min.)		15.9	
46	Max wait time in Queue (min.)		30.0	
47	Throughput Rate to Baggage Claim (Passengers/min)		6.7	
48	Width of Double Booth (ft.)	11.5	11.5 ft is standard	
49	Desired Passenger Space in Queue (sq. ft/ pax)	15.0		
50	Queue Model - Queue Area for Primary Processing (sq. ft)		3,000	
51	Queue Model - Queue Depth (ft.)		43	

Figure 63: Sample calculation screen for FIS requirements ¹⁶²

It is recommended to follow CBP regulatory requirements in Airport Technical Design Standards. These documents are confidential documents, which require Service Set Identification clearance. Accesses to these documents are granted to airport architects and planners on a project-by-project basis pending clearance of identification and background checks by Department of Homeland Security.

¹⁶¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.2, 2010

¹⁶² Source: ACRP Report 25, Vol 2, Airport Passenger Terminal Planning and Design, Federal Inspection Services/U.S. Customs and Border Protection Model, 2010

ii. Dimensional Criteria

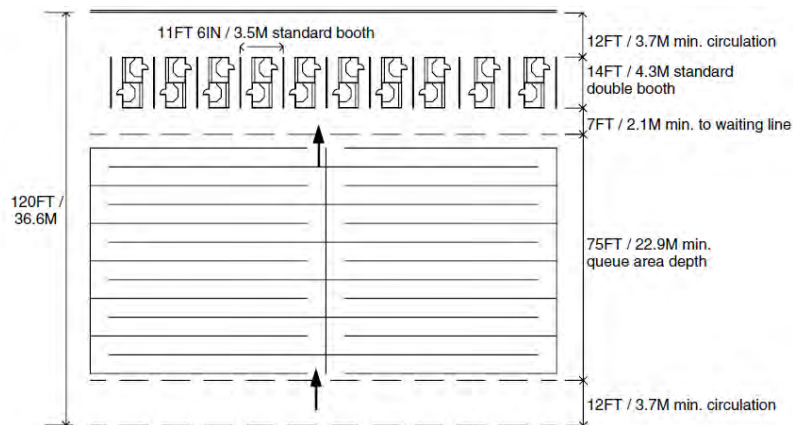


Figure 64: Schematic for FIS queue design¹⁶³

iii. Immigration (Automated Primary Option)

In this new protocol, all passengers utilize kiosks for primary (immigration) screening. The number and arrangement of kiosks should be determined based on peak period demand, average transaction times, and equipment failure rates. In general, it is expected that queuing here would be minimal, while queuing for the single agent check at the end (formerly customs only, now immigration plus customs) would be more substantial.

If the Automated Primary option is implemented, all passengers will utilize a kiosk for the initial primary (immigration) step in the CBP process. The number and arrangement of kiosks will be based on the peak period demand, processing rates, and percentages of passengers in each CBP processing classification (Global Entry / other expedited, US citizen standard, visitors)

At the time of this writing Automated Primary is an emerging protocol. Designers should consult with CBP to discuss specific requirements.

iv. International Bag Claim System

The guidelines consist of:

- Baggage claim device
- Active baggage claim area
- Circulation aisle between baggage claim devices and the active claim area
- Main circulation corridor
- Inbound Bag Make-up
- Bag unloading pier that includes conveyor and unloading area
- Tug cart parking area, and bypass lane

¹⁶³ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.2, 2010

Critical information necessary for calculating baggage claim requirements for each airline or groups of airlines includes:

- Operating parameters
 - Rules for use: claim device availability, flight close-out time, use/lease basis
 - First bag delivery to claim after aircraft arrival
- Demand basis
 - Planning schedule analyses by airline
 - Design aircraft and seating configuration
 - Passenger accumulation period
 - Percentage of passengers checking bags, and checked bags per passenger checking bags
 - Domestic baggage claim: total number of passengers claiming bags per flight and amount of time bags from a flight occupy the claim unit
 - International baggage claim: largest number of bags accumulated on the claim unit from an arriving flight. Because passengers may be delayed at immigration, the claim rate may be low, or zero, in case of extreme delays.
- Level of service criteria
- Dimensional criteria (space template)

v. Processing Elements and Space Calculation

The analytical approach presented below is based on the latest IATA ADRM guidelines and captures an ideal scenario, where the first passenger arriving and the first baggage arrive at the reclaim belt on the same time. Coordinating the arrival of bags on the carousels and that of the passengers in the hall minimizes facility requirements. However, this ideal situation is difficult to encounter.

The requirements from the following analytical approach should be supplemented with terminal passenger flow simulations, to account for additional requirements arising from the time difference between first passenger and first bag. In addition, the following approach does not account for additional passenger circulation area around the bag claim, which should be assessed via simulation.

CL _(NB/WB)	=	Carousel frontage for passenger line up (in feet)
PAX _(NB/WB)	=	Number of passengers in the design aircraft (Narrow Body/Wide Body)
SP	=	Claim frontage per passenger (ft)
PR	=	Ratio of passengers collecting bags
RR	=	Recirculation rate. Percentage of bags that will recirculate on the carousel using up space and preventing other bags from joining the carousel (in %). This number should be adjusted based on aircraft size (narrowbody/widebody), flight origin (international/domestic) and layout specific conditions.
BC _(NB/WB)	=	Number of Narrow Body/Wide Body baggage claim units
PHP	=	Peak hour number of terminating passengers, international/domestic transfer passengers, where applicable
P _(NB/WB)	=	Proportion of passengers arriving by narrow body/wide body aircraft.
OT _(NB/WB)	=	Average claim device occupancy time per narrow body/wide body aircraft (minutes) or assume 20 minutes for narrow body and 45 minutes for wide body
AC _(NB/WB)	=	Area of a carousel for narrow body/wide body aircraft
Cw	=	Carousel width (ft)
SB	=	Side buffer to allow passenger movement around the reclaim belt (total feet, allowing for both sides)
EB	=	End buffer to allow passenger movement around the reclaim belt (total feet, allowing for both sides)
A	=	Area of the baggage reclaim hall (sq ft)

** The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

Table 26: International baggage claim calculation inputs¹⁶⁴

Step 1: Determine the claim frontage length required to accommodate passengers from a specific aircraft served by the reclaim area. Please note, it is recommended to accommodate even the largest flight on one belt, to avoid splitting a flight onto two carousels.

Determine the claim frontage length required using the following formula:

$$CL_{(NB/WB)} = PAX_{(NB/WB)} * SP * PR * RR$$

¹⁶⁴ IATA ADRM 10th Edition

Port Authority Standard	
SPACE STANDARDS FOR WAITING AREAS (lf/pax) - MINIMUM	
Baggage Claim (SP)	2.0

Table 27: Port Authority minimum space standards for baggage claim waiting areas

Only passengers who have to collect bags at the airport should be included in the calculation.

Step 2: Determine the number of baggage claim devices using the following formula:

$$BC_{(NB/WB)} = (PHP * P_{(NB/WB)} * OT_{(NB/WB)}) / (60 * PAX_{(NB/WB)})$$

Note: The number and size of baggage claim devices will depend on various additional factors such as flight / airline assignment strategy and specific flight schedule characteristics. The baggage claim requirements from the analytical approach should be confirmed with the flight schedule, and increased as required.

Step 3: Determine the baggage claim area:

$$AC_{(NB/WB)} = (BDC_{width} + SB) * ((CL_{(NB/WB)} / 2) + EB)$$

This calculation should be repeated for all the different kinds of carousels (i.e., for wide body, narrow body aircraft). This is a generic calculation considering linear double-sided carousels. Different shapes will have different geometric calculations and possibly improved area requirements.

Step 4: Once we have the area for the different types of carousels:

$$A = BC_{NB} * AC_{NB} + BC_{WB} * AC_{WB}$$

Note (Additional Design Goals from IATA ADRM guidelines): the time between first passenger arriving at the reclaim belt and the first baggage arriving on the reclaim belt should be zero minutes, to maximize the efficiency of checking a hold bag for the passenger. The maximum time for delivery of the last bags of all flights should not be more than the time of the first passenger arriving at the reclaim belt plus:

- 30 minutes for narrow body aircraft flights
- 45 minutes for wide body aircraft flights

vi. Dimensional Criteria

The following figures provide layouts and dimensions of different baggage claim carousels configurations.

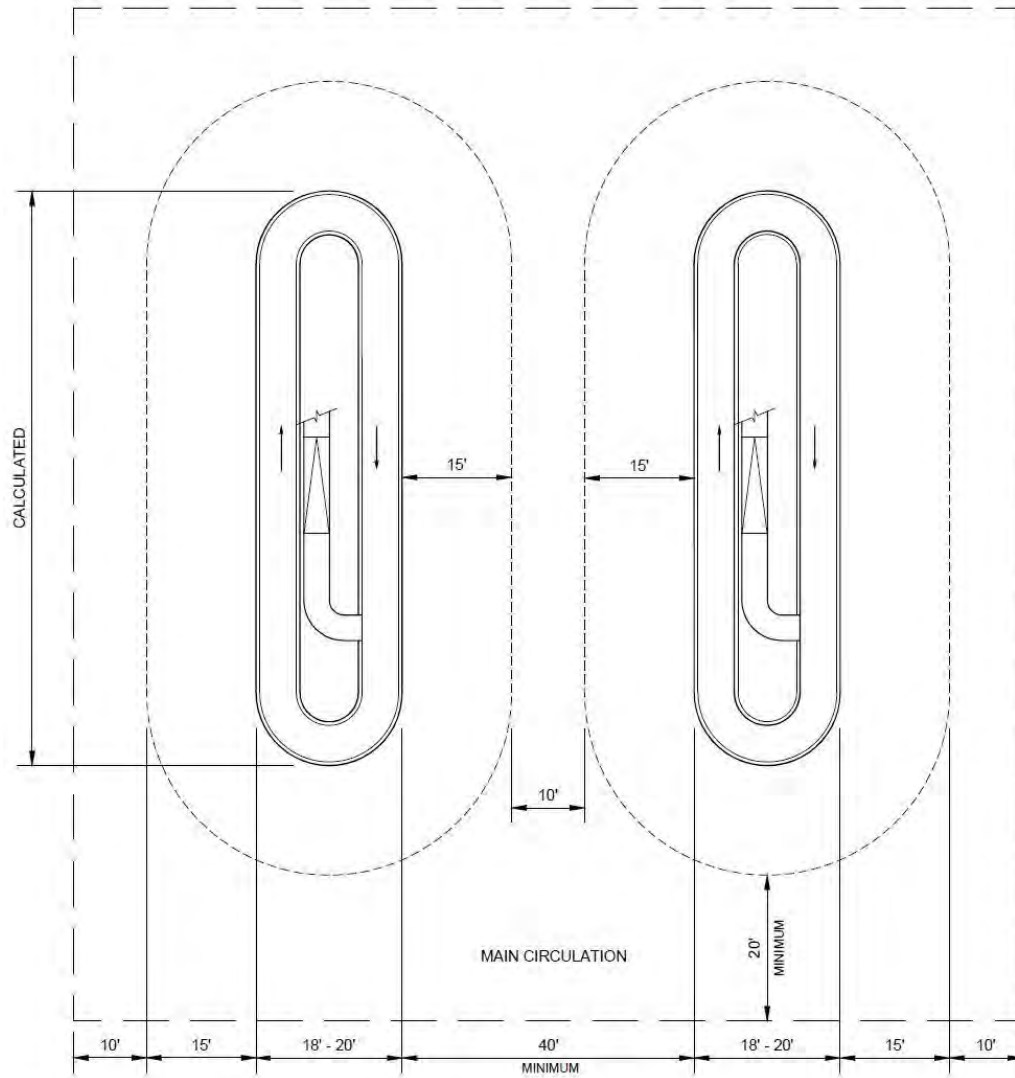


Figure 65: Round carousel schematic ¹⁶⁵

¹⁶⁵ Source: Port Authority of NY & NJ

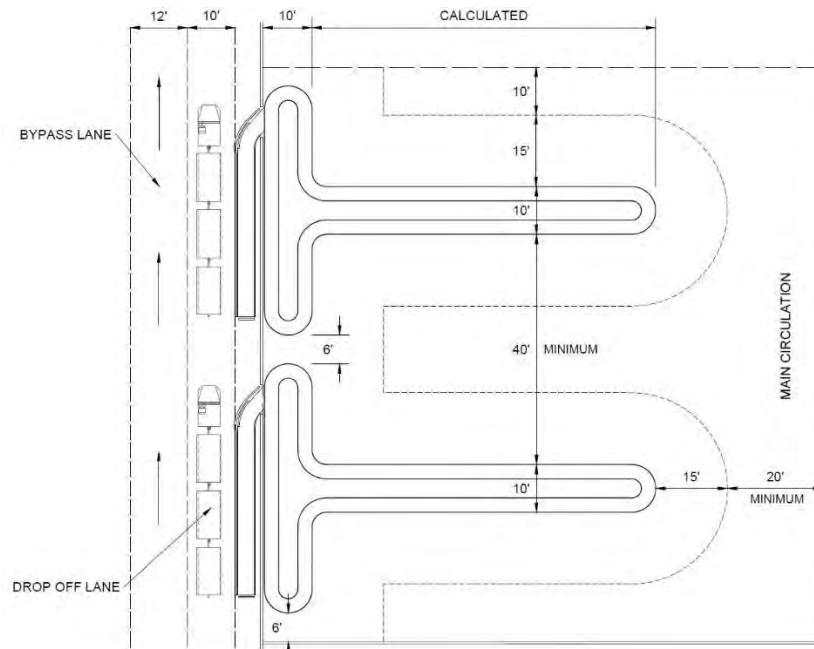


Figure 66: T-carousel schematic ¹⁶⁶

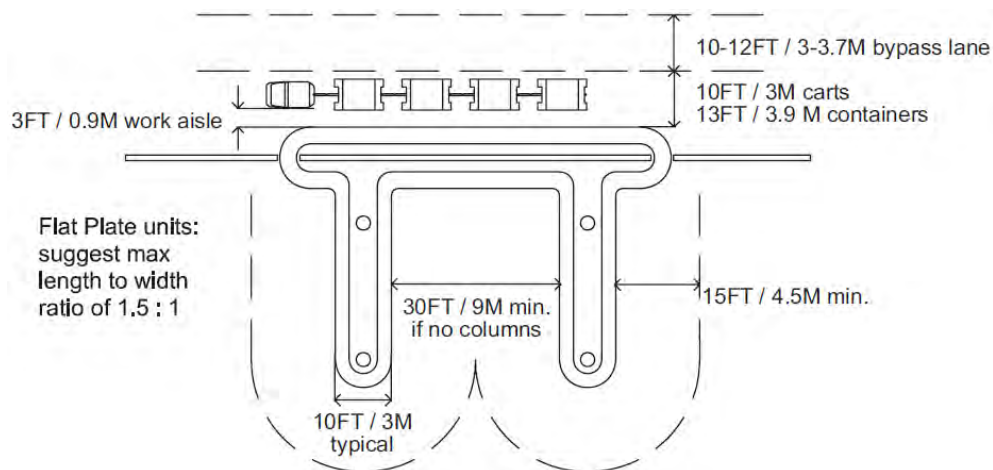


Figure 67: Flat plate carousel schematic ¹⁶⁷

4. Airline Baggage Service Office

Area requirements for Baggage Service Office (BSO)s are highly airport specific but should be based on the number and market share of airlines and O&D passengers¹⁶⁸.

¹⁶⁶ Source: Port Authority of NY & NJ

¹⁶⁷ Source: ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.7.3, 2010

¹⁶⁸ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.11.2, 2010

5. Baggage Carts

Baggage carts can be considered both an amenity and a revenue source. Whether provided free as a passenger service or for a fee, the following factors should be considered when planning the terminal¹⁶⁹:

i. Location and distance

The further a passenger needs to move his checked baggage, and the more bags there are, the more likely a passenger will want to use a cart. Thus, typically parking garages will generate more demand than curbside locations for departing passengers, and international baggage claims will generate more than domestic baggage claims.

ii. Space

Although carts are nested for storage, the area can become significant if demand is high and there are large surges of demand such as a peak arrivals bank of flights. Locating cart racks or staging areas should be considered in the planning process to avoid the carts becoming choke points in baggage claim areas and circulation corridors.

iii. Cart management

Typically, a third party will be responsible for cart operations. This responsibility includes picking up carts from around the terminal and adjacent parking areas and redistributing them to the locations where passengers need them. Terminal plans need to consider that long strings of carts will be moving to these locations and that ramps, doors, and other access points need to be planned to minimize conflicts with people and vehicles.

6. Customs

It is recommended to follow CBP regulatory requirements in Airport Technical Design Standards. These documents are confidential documents, which require Service Set Identification clearance. Accesses to these documents are granted to airport architects and planners on a project-by-project basis pending clearance of identification and background checks by Department of Homeland Security.

¹⁶⁹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.6, 2010

i. Processing Elements and Space Calculation

PI	=	Number of Primary Inspection Booths (single units)
PHP	=	Terminating Peak Hour Passengers
PK	=	Peak 30-minute Factor (in % of PHP)
$PT_{(PI/XR)}$	=	Process (throughput) Time per Passenger at Primary Inspection Booth/X-ray Facility (in seconds)
XR	=	Number of X-ray units
IR	=	Ratio of passengers to be inspected
PId	=	Depth of One Primary Inspection Booth Lane
PIw	=	Width of One Primary Inspection Booth Lane
$MQT_{(PI/XR)}$	=	Maximum Queuing Time at Primary Inspection Booth/X-ray Facility (in minutes)
$A_{(PI/XR)}$	=	Area Required for the Primary Inspection Booth/X-ray Facility
XRd	=	Depth of One X-ray Lane (in feet).
XRw	=	Width of One X-ray Lane (in feet). Includes X-ray Equipment, Circulation and Operator Position
Q_{MAX}	=	Maximum Number of Passengers Waiting in Queue
SP	=	Space per Person (in sq ft)
W	=	Corridor Width Before/Behind Desks (in feet) *

* The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

Table 28: Customs calculation inputs¹⁷⁰

When there is specific need for all arrival passengers to be processed by a customs agent on exit from the reclaim area, follow steps 1 to 3.

Step 1: Calculate the number of customs check positions using the following equation. It is considered that all passengers go through this facility when in place.

$$PI = ((PHP * PK * PT_{PI} / 60) / (30 + MQT))$$

Step 2: Calculate the maximum number of passengers in the queue

$$Q_{MAX} = 0.495 * \text{Peak 30-min (corresponding to a 30-minute MQT)}$$

Step 3: Calculate the area required for the customs check facility.

$$API = (PI * PId * PIw) + Q_{MAX} * SP + (PI * PIw * W)$$

Actual search facilities for customs can be estimated using the following equation, but should be verified with specific local border/custom requirements (i.e., proportion of passengers searched or type of check/search).

Step 4: Calculate the number of X-ray units required using the following equation.

$$XR = [(PHP * PK * IR * PT_{XR} / 60) / (30 + MQT)] * Cf$$

¹⁷⁰ IATA ADRM 10th Edition

Where Cf equals:

Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)	
For MQT	CF
3, and less	1.22
4	1.22
5	1.15
10	1.06
15	1.01
20	1.00
25	1.00
30	1.00

Table 29: Correction Factor (Cf) for Demand Variability (when less than 30-minute peak)¹⁷¹

Step 5. Calculate the maximum number of passengers in the queue.

$$Q_{MAX} = 0.495 * \text{Peak 30-min (corresponding to a 30-minute MQT)}$$

Step 6: Calculate the area required for the X-ray process using the following equation.

$$AXR = (XR * XRd * XRw) + Q_{MAX} * SP + (XR * XRw * 2 * W)$$

The corridor width will vary with the importance of passenger flows. Port Authority minimum standard width is 20 feet for all circulation corridors.

- ii. Secondary Screening (Public Health, Agriculture, Fish & Wildlife, etc.)

It is recommended to follow CBP regulatory requirements in Airport Technical Design Standards. These documents are confidential documents, which require Service Set Identification clearance. Accesses to these documents are granted to airport architects and planners on a project-by-project basis pending clearance of identification and background checks by Department of Homeland Security.

This office is usually located near secondary baggage inspection and may range in size from 200 to 900 square feet depending on the number of officers assigned and whether the USFWS requires examination and storage areas separate from the CBP¹⁷².

- iii. CBP support areas

The CBP guidelines require certain back-of-house areas for agent locker rooms, work-out areas, equipment storage, records-keeping, and other purposes. Designers shall follow the current CBP guidelines in force at the time.

¹⁷¹ IATA ADRM 10th Edition

¹⁷² ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.7, 2010

iv. FIS Exit Control

It is recommended to follow CBP regulatory requirements in Airport Technical Design Standards. These documents are confidential documents, which require Service Set Identification clearance. Accesses to these documents are granted to airport architects and planners on a project-by-project basis pending clearance of identification and background checks by Department of Homeland Security.

On the US non-secure side of the FIS exit, provide railings, low walls, and signage to prevent back-flow into the CBP inspection areas. Provide architectural barriers so that it is not possible for meeters / greeters, or other members of the public, to see into the CBP inspection areas. One-way flow may be controlled by staff, or automated exit lanes similar to exiting from secure side to non-secure side of the terminal.

7. International Recheck (Passenger and Baggage)

This process is similar to an originating passenger and can be sized in a manner similar to a kiosk bag drop because the bags should be tagged to their final destination. Some staffed counters should also be provided to accommodate flight re-bookings or to issue new bag tags if the original tags are damaged. Queues for transfer passengers are typically shorter than queues for originating passengers due to relatively short processing times¹⁷³.

Refer to Part 2, Section 5, Traditional Check-in Counters.

8. Meeter / Greeter Area

The number of meeters/greeters will depend not only on local passenger characteristics but also on how long prior to scheduled arrival times the meeters/greeters enter the terminal. This information should be determined by survey¹⁷⁴.

i. Space Calculation

P	=	Persons Present in Arrivals Hall
PHP	=	Terminating Peak Hour Passengers
$T_{(P/V)}$	=	Dwell Time for Passengers/Visitors (in minutes)
VR	=	Ratio of Visitors per Passenger
A	=	Area of the Arrival Hall
SR	=	Seat Ratio
$SP_{(S/ST)}$	=	Space per Seated/Standing Person

Table 30: Meeter/greeter area calculation inputs¹⁷⁵

Step 1: Calculate the number of person present in the arrivals hall using the following equation:

$$P = (PHP * T_p) / 60 + (PHP * VR * T_v) / 60$$

¹⁷³ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.5, 2010

¹⁷⁴ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.8.6, 2010

¹⁷⁵ IATA ADRM 10th Edition

Step 2: Calculate the area to provide in the arrivals hall using the following equation:

$$A = (P * SR * SP_s) + (P * (1 - SR) * SP_{st})$$

Source: IATA ADRM 10th Edition, Section 3.4.13.5, 2017

9. Concessions

Refer to Part 2, Section i, Concessions (Post-Security Area / Concourse)

10. Restrooms

Refer to Public Terminal Restrooms Appendix for the *PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms*.

11. General Visitor Information

The area required is relatively small, but location, typically on the arrivals pathway for passengers or in the baggage claim area, and visibility are crucial to the effectiveness of the service¹⁷⁶.

12. Domestic Arrivals

i. Backflow Prevention / Exit Lanes

Backflow prevention corridors should be sized to meet the peak demand, which is usually a surge of passengers from several simultaneous arriving flights. However, the width must be of a manageable size (not too wide) and the corridor of sufficient length for the officer's view range and to properly channel arriving passengers such that persons attempting illegal back-flow into the secure area can be detected and stopped.

It is expected that queuing for the automated exit lanes will be infrequent or negligible, unless an alarm occurs. Automated exit lanes will have a certain throughput of passengers per hour (in the order of about one passenger per two seconds or about 1,500-2,000 passengers per hour), and so the minimum number that must be provided is dictated by the peak arrival demand, which is usually a surge of passengers from several simultaneous arriving flights.

ii. Domestic Arrivals / Baggage Claim Hall

Baggage claim requirements include the amount of space needed to accommodate the types, numbers, and sizes of baggage claim devices, and space required to support terminal activity.

iii. Space Calculation

Sizing of the arrivals hall is calculated separately from concession areas. The size of the arrivals hall depends on the number of persons during the peak hour, the amount of time passengers and visitors spend in the public area, the space they require as well as the number of seats to be provided. It is assumed that passengers carry their baggage while moving in this area¹⁷⁷.

The total amount of this area is ultimately determined by the number of passengers expected to be near the claim unit and the desired LOS. This area includes the active claim depth along the unit (retrieval

¹⁷⁶ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.14.4, 2010

¹⁷⁷ IATA ADRM 10th Edition, Section 3.4.13.5.3, 2017

area), depth for others in the traveling party, plus a circulation zone to and away from the Terminal Building Facilities claim unit (peripheral area). It has been found, however, that 15 feet is typically the minimum recommended depth for the retrieval and adjacent peripheral areas at all airports¹⁷⁸.

This depth results in a minimum separation of 30 feet between adjacent claim units or the “arms” of a flat plate claim. Columns, bag cart racks, and other structures should not be within the retrieval area. Objects located within the peripheral area usually will require additional separation. A minimum separation between the active claim area and walls or baggage cart racks is recommended to be 25 feet for both domestic and international claim units.

Additional area, outside of the peripheral claim area, needs to be provided for access to the claim area, circulation to ground transportation counters (rental cars, public transportation, commercial vans, etc.), seating for meeters/greeters and passengers waiting for transportation pick-up, etc. The dimensions of this circulation zone is 20 feet minimum, with additional width required dependent on projected passenger volumes and functions adjacent to the claim units, such as rental car counters.

P	=	Persons Present in Arrivals Hall
PHP	=	Terminating Peak Hour Passengers
$T_{(P/V)}$	=	Dwell Time for Passengers/Visitors (in minutes)
VR	=	Ratio of Visitors per Passenger
A	=	Area of the Arrival Hall
SR	=	Seat Ratio
$SP_{(S/ST)}$	=	Space per Seated/Standing Person

Table 31: Baggage claim area calculation inputs¹⁷⁹

Step 1: Calculate the number of person present in the arrivals hall using the following equation:

$$P = (PHP * T_p) / 60 + (PHP * VR * T_v) / 60$$

Step 2: Calculate the area to provide in the arrivals hall using the following equation:

$$A = (P * SR * SP_s) + (P * (1 - SR) * SP_{st})$$

Source: IATA ADRM 10th Edition, Section 3.4.13.5.4, 2017

When calculating the overall arrival hall size, concession space within the arrival hall shall be calculated separately from the total arrival size of the arrival hall. Refer to Section i Concessions (Post-Security Area / Concourse)

iv. Domestic Baggage Claim System

Refer to Part 2, Section p, International Baggage Claim System

¹⁷⁸ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.7.5, 2010

¹⁷⁹ IATA ADRM 10th Edition

v. Airline Baggage Service Office

Refer to Part 2, Section p, Airline Baggage Service Office (International Arrivals)

vi. Baggage Carts

Refer to Part 2, Section p, Baggage Carts (International Arrivals)

vii. Meeter/Greeter Area

In the case of a meeter/greeter lobby, seating may account for a smaller portion of the area with greeter standees and passenger circulation through the space making up the bulk of the area. The number of meeters/greeters depends not only on local passenger characteristics, but also on how long prior to scheduled arrival times the meeters/greeters enter the terminal¹⁸⁰.

Refer to Part 2, Section p, Meeter / Greeter Area (International Arrivals)

viii. Concessions

Refer to Part 2, Section i, Concessions (Post-Security Area / Concourse)

ix. Restrooms

Refer to Public Terminal Restrooms Appendix for the PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms.

x. General Visitor Information

Refer to Part 2, Section 16, General Visitor Information (International Arrivals)

q. General Public Areas

1. Methodology

i. Circulation

Refer to Part 2, Section i (Circulation Section in Post-Security Area / Concourse.)

The program area is usually based on a percentage of the other public areas of the terminal and typically ranges from 15% to 30% of these areas. The percentage is a first approximation and will also vary with the terminal configuration and gross size of the terminal. The split between secure and non-secure (public) circulation is also a function of the terminal concept.¹⁸¹

ii. Vertical Circulation

Escalators

The majority of passengers will use escalators (up to 90%) as compared to stairs or elevators. Escalators should be sized to handle peak surge loads (5-minute periods) without excessive queuing.¹⁸² Escalators should be located such that if queues do develop, they will not interfere with other functions. More

¹⁸⁰ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.9.2, 2010

¹⁸¹ ACRP Report 25, Vol 1, Airport Passenger Terminal Planning and Design, Chapter VI, Section 3.10.41, 2010

¹⁸² ACRP Report 25, VI.3.10.6

important, there must be adequate space at the exit from escalators (or moving walks) so that passengers do not “back-up” on an escalator, which is a safety hazard. Where successive escalators are encountered, there should be a 40 foot gap between the respective escalator landings.

Elevators

The size and number of elevators at a given location will depend on the expected use. They can either be pushed (hydraulic) or pulled (traction), and each use depends on the number of floors being served. Because most passengers will use escalators, waiting time and speed are often not as important as providing a minimum size for wheelchairs and attendants.¹⁸³

2. Restrooms

Information used to develop restroom requirements include:

- Demand basis
 - Identification of governing building and plumbing codes
 - Type of Construction identification
 - Determining demand by location (concourse, public areas, etc.)
- Level of service criteria
 - Fixtures per male/female ratio
- Dimensional criteria (space template)

ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, provides more detailed explanations and best practices for planning and designing terminal bathrooms.

Above and beyond code requirements, airport restrooms should be designed with more space than restrooms in typical commercial or public buildings due to airport passengers often having carry-on baggage and other possessions.

See Public Terminal Restrooms Appendix for the *PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms*

3. Concessions

Refer to Part 2, Section i, Concessions (Post-Security Area / Concourse)

4. Facilities for Passengers with Disabilities

As with any public accommodation, airport designers are responsible for complying with local codes and the Americans with Disabilities Act (ADA). IATA ADRM 10th Ed., 3.4.15., discusses design considerations when planning for facilities to accommodate passengers with disabilities.

i. Processing Facilities

Processing facilities should be designed to be accessible to passengers in wheelchairs as well as ambulant passengers with reduced mobility. Some service desks/counters should be designed with a lower height to allow those in wheelchairs to speak to service associates at an “eye-to-eye” level.

¹⁸³ ACRP Report 25, VI.3.10.6

ii. Self-Service Equipment

A number of the self-service processing facilities should be adapted for use by people with disabilities. The height of some self-service units should be reduced to enable access at wheelchair height. In addition, a clear and easily locatable designated point should be provided for those who may have trouble with the self-service equipment. Similarly, automatic ticket machines should be adapted for access from wheelchair height

iii. Reserved Seating Areas

Seating areas reserved for persons with disabilities should incorporate signage to discourage others from using them. These areas should be close to a staffed desk or designated point, and be reasonably close to essential facilities, such as toilets and refreshments. Seating areas for people with disabilities should be discreet and consideration given to special privacy requirements.

iv. Public Facilities

All areas and services in the terminal building that are open to the public should be accessible to people with disabilities. The airport/airline provides escorts and wheelchairs to passengers transferring between flights if they request wheelchair assistance. Wheelchair storage should also be located to minimize the average amount of time needed to reach any gate in a single concourse.

Toilet facilities for passengers needing assistance should be provided throughout the terminal, sized to allow for full access by people with disabilities and a second person for assistance. Specially designed facilities that address the special needs of those who are unable to stand or walk should be located at sufficient intervals. Embossed tactile markings should be used where appropriate, such as on the wall adjacent to door handles at accessible toilets. Refer to Public Terminal Restrooms Appendix for the *PANYNJ Airport Planning Standards Guidelines For Public Terminal Restrooms*.

v. Security

Security checks can be a source of concern for people with disabilities because of issues such as sensitivity around physical searches or handling of specialized mobility or medical equipment. Aisle widths and passenger screening equipment should permit the passage of passengers using wheelchairs.

With a view that, as far as practicable, people with disabilities should be self-sufficient, those designing screening points should consider the height of preparation and reclaim tables as well as the accessibility of trays. Automated roller beds and tray return systems avoid passengers having to push/pull multiple trays. This helps all passengers, but aids people with disabilities.

If no lanes dedicated to people with disabilities are used, consideration as to how an individual with a disability will reclaim baggage/trays after screening (without impacting the passenger flow) should also be a priority.

vi. Gate Facilities

Priority seating should be installed at the gate. Seating should be provided for at least one caregiver who may be traveling with an individual with a disability. Priority boarding should also be provided to allow special needs passengers additional time to board the aircraft prior to other groups. Where aircraft are

on remote stands, the transport links to and from these stands should be accessible to an individual with a disability.

vii. Baggage Retrieval, Immigration and Customs

Baggage claim, immigration and customs areas should allow for the passage of wheelchair users and passengers being transported in airport buggies.

5. First Aid / Emergency

The scale of facilities and their purpose should determine the location, which, however, should be chosen whenever possible within walking distance of the passenger area(s). Facilities should be strategically located for easy accessibility in case of an aircraft accident and be capable of expansion to serve on short notice as an enlarged aircraft accident first-aid receiving station.¹⁸⁴

6. HVAC

Building mechanical systems (HVAC) space ranges from 12 to 15 percent of the gross total space approximated for all other terminal functions. A value of 10 to 12 percent is used in relation to the connector element space. This allowance does not cover separate facilities for primary source heating and refrigeration (H&R plants).¹⁸⁵

It may be appropriate to consider HVAC system backup. Most terminals are fed from a central electrical plant, either remotely or on site. Although electrical HVAC equipment may be powered by an emergency generator, the chilled water system may not, which negates the effectiveness of the electrical components in the cooling system. Sensitive electronic equipment in a non-air-conditioned room may become damaged or will shut down in a short time due to overheating.¹⁸⁶

7. Lighting

Maximize the use of daylighting to decrease the amount of artificial lighting, as well as minimize the amount of heating and cooling of the area. Automatic daylight dimming controls for the lighting can greatly reduce energy costs, but consideration of glare control is also important to ensure occupant comfort.

Reduce the light power density for the project by selecting efficient fixtures and ballasts and by increasing the surface reflectivity of walls, floors, and ceilings. Lighting controls can also have an effect. Consider occupancy sensors when appropriate and employ automatic daylight dimming controls.¹⁸⁷

8. Public Address / Visual Paging System

Public address (PA) systems should provide a range of services including local and area-wide paging and public notification. Audio speakers should be placed and audio output should be dynamically adapted to ambient noise levels so that announcements can be clearly heard throughout the local areas even at

¹⁸⁴ ICAO Doc 9184 12.3

¹⁸⁵ FAA AC 150-5360-13, 78

¹⁸⁶ ACRP Report 25, VI.4.2.11

¹⁸⁷ ACRP Report 25, III.8.2 and III.8.3.3

peak traffic levels. Performance specifications should be based on acoustic testing or, where this is not possible, on acoustic modeling of the local environment. The PA system should enable individual zones to be paged by a PC-based administration interface that provides controls for audio inputs, outputs, and control signals.

When used for emergency notification, PA systems should provide supplemental reach to overhead paging, parking, inter-building, and even individual area notification including compliance with Federal Emergency Decision and Notification Protocol and other inter-agency requirements.¹⁸⁸

9. Wayfinding & Signage

The following are factors to consider when developing a signage and wayfinding program:

- Graphic standards – a uniform visual theme that complies with industry, international standards and local code is important and should be consistent in appearance, concept, and location; carefully considering font type, font size, character spacing, and signage illumination for a wide range of users. Note that it is good practice for temporary and tenant branded signage to be consistent with airport graphic standards.
- Terminology – consistent and easy to understand wording is important.
- Spacing – a consistent frequency of signage and placement is a value, considering building design and passenger flows.
- Maintenance and fabrication – materials and site locations should optimize signage maintenance.
- Code compliance – program should accommodate all special requirements, such as ADA Standards for Accessible design and local building codes.¹⁸⁹

ACRP Report 52, Wayfinding and Signage Guidelines for Airport Terminals and Landside, provides more detailed explanations and best practices for developing signage and wayfinding programs.

10. Advertising

A well-developed advertising program will ensure that all sites and media are fully integrated with the terminal architecture and environment, all sites are located for maximum effectiveness and sales, advertising does not conflict with wayfinding and other commercial signage, and the latest sign/telecommunications technologies are incorporated where appropriate.

An in-terminal advertising program should include the following elements:

- Identification of the optimum media range for the terminal and the markets specifically served by the airport
- Identification of the best locations for each type and size of advertising media
- Identification of the optimal number of advertising units for the terminal, by type
- Sites and networks to promote airport retail and other services to passengers

¹⁸⁸ ACRP Report 25, VI.4.6

¹⁸⁹ FAA 150/5360-13A, 6.4.12

- Identification of the rules that the advertising provider(s) will need to follow in operating the advertising business at the airport
- Design guidelines for the key advertising units, including sizes and parameters to be respected by the designers.

In-terminal advertising includes static displays such as dioramas, baggage claim device wraps, baggage cart advertising, banners, wall wraps, product displays, concession advertising, digital screens, nontraditional advertising, sponsorships, and other creative advertising locations.¹⁹⁰

r. Design Criteria

1. Circulation

Refer to Part 2, Section i (Circulation Section in Post-Security Area / Concourse.)

2. Vertical Circulation

Refer to ACRP Report 25, VI.3.10.6 for layouts and dimensions for escalators and elevators.

In front of elevator doors, and at the end of escalators, provide 8 – 10 feet of clear space for waiting and/or changing directions, before any cross circulation, walls, objects, etc.

3. Restrooms

The PANYNJ has reviewed the ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design; Port Authority Pedestrian Signing and Wayfinding Airport Standards Manual; Americans with Disabilities Act (ADA) Standards for Accessible Design; among other relevant documents. APD has established recommendations based upon the reviewed documents including but not limited to:

- Restroom Requirements and Planning Considerations for Restroom Location
- Fixture Needed Calculation – Methodology Guidelines
- Design Considerations for Spatial Relationships
- Accessibility Considerations
- Design Preferences
- Artistic Feature Requirements

Refer to Public Terminal Restrooms Appendix for the *PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms*.

4. Concessions

Refer to Part 2, Section i, Concessions (Post-Security Area / Concourse).

5. Wayfinding & Signage

ACRP Report 52, Wayfinding and Signage Guidelines for Airport Terminals and Landside, provides more detailed explanations and best practices for developing signage and wayfinding programs.

¹⁹⁰ ACRP Report 54, 6.10

6. Advertising

The following table from ACRP Report 54, 6.10, is an example for the design considerations for advertising sizes and locations from an advertising master plan done for another airport.

Type of Advertising Unit	Size	Recommended Locations in Terminal	Specific Location in Sample Terminal	Total number of units (advertising faces)
Backlit column format (single or double sided)	55" x 37"	In locations where people are on the move and not stationary	Double-sided, in the circulation areas of the plaza between the octagons and in the bus stations	34 (68)
Backlit horizontal (single or double sided)	40" x 50"	In locations where people are on the move and not stationary	Double-sided, in the circulation areas of the plaza, facing the restaurant areas	18 (36)
Indoors spectacular backlit	8' x 10'	In locations where people are on the move and not stationary	On the washroom walls, facing the main bus parking	35
Wall wraps	Various sizes (very adaptable)	Inside circulation corridors; around building columns; on jet bridges	Proposed to identify the sponsored zones. To be used around each main terminal column in the specific sponsored zone, which are contiguous to the circulation corridors with octagons, and the circulation corridor where the main food and concession area is located	42
Exhibition areas	Various areas for various products with sales personnel	In wide circulation areas where people have time to browse	In the large area between the main plaza food and concession area and the central check-in area	1

Table 32: Sample advertising criteria

s. Back-of-House Areas

1. Methodology

i. Employee screening

If employee screening is combined with KCM screening, refer to Section 8.

ii. Airline Spaces

The ATO is usually located immediately behind, or in proximity to, the check-in counter to provide support functions for the airline staff handling check-in and ticketing. Typically, these offices are 25 to 30 feet deep along the length of the counter.

At non-hubbing airports, other offices are typically provided for the equivalent of 10 to 25 square feet/linear foot of ATO counter, but requirements can vary greatly.¹⁹¹

The demand for operations areas is a function of the size and types of aircraft being operated and individual airline operating policies. A planning-level program area for operations can be based on the number of gates (as expressed in EQA) and airlines at an airport.

Operations areas may range from less than 1,000 square feet/EQA, to well over 2,000 square feet/EQA at hub locations.¹⁹²

iii. Concessions Spaces

ACRP Report 54, 11.3 provides percentages regarding the storage areas for concessions:

Category	Storage (percent of leasable concession space)
Duty free	30%
Food and beverage	15%
Convenience retail	20%
Specialty retail	15%
Services	10%

*Table 33: Storage space requirements by concession category*¹⁹³

For additional information, refer to Part 1, Section 4.

iv. Port Authority Spaces

There is no rule of thumb for sizing airport offices because each airport has different staffing requirements and management structures. Planning for these facilities should be considered early in the programming process with input from the airport operator.

Some airports prefer to locate management offices within the terminal while others prefer a location in a separate building. Such location decisions depend on the size of the airport staff, availability of space in the terminal, and the cost/benefit of in-terminal vs. remote locations for a given airport management's operating philosophy.¹⁹⁴

¹⁹¹ ACRP Report 25, VI.3.11.1

¹⁹² ACRP Report 25, VI.3.11.3

¹⁹³ Source: ACRP Report 54

¹⁹⁴ ACRP Report 25, VI.3.14.4

v. Other Agencies' Offices and Support Spaces

Airport Police/Security Office space needs vary according to based staff and nature of arrangements with local community law enforcement agencies.¹⁹⁵

vi. Other Tenants' Offices and Support Spaces

A percentage of the functional areas (1% to 2%) is generally used in the absence of specific airport requirements for maintenance, janitorial and storage areas.¹⁹⁶

vii. Ramp Control

If a ramp control tower or room is to be provided, the designer should consult directly with the operator for requirements. The control room size will generally be dependent on the number of staff operation positions (usually 3-6), and equipment. It is preferable, but not mandatory, to have direct visual access to the area under control. Areas not visible can be covered with cameras. In addition to the control room, support spaces including coffee station, meeting / training room, storage, IT room, and staff lockers may be provided.

In the near future, ramp control towers may migrate to a "remote tower" model with staff in a ground-level room viewing high-resolution monitors, with visual access provided exclusively via a high-quality camera array mounted on a tall pole or antenna structure. Such remote towers have been implemented at a few locations in Europe and Australia, and are in the test pilot stage in the US at the time of this writing.

viii. Vehicle Screening

Screening should occur at a location far enough from the terminal or other sensitive area to ensure that a dangerous vehicle is interdicted well before it is able to cause damage to any intended target. The screening location must include a barrier to prevent further intrusion, adequate room for security workers to perform the inspection, space to store any specialized equipment, shelter for workers and/or working animals, and a method for a rejected vehicle to turn and leave the screening area.

The capacity of the screening location should be determined based on the number of vehicles in the peak hour, available manpower, available space to perform simultaneous inspections, and available parking positions at the terminal.

ix. Loading Docks

Estimating the number and size of loading docks involves many factors: the location (landside or airside); the relative size of the terminal; whether concessions have a central receiving area separate from the terminal; the number of individual concessions that may get separate deliveries; the average size of delivery trucks (vans, larger straight trucks, or semi-trailers); and airport policies with regard to operating hours.¹⁹⁷

¹⁹⁵ FAA AC 150-5360-13, 78

¹⁹⁶ ACRP Report 25, VI.3.14.2

¹⁹⁷ ACRP Report 25, VI.3.14.3

x. Incoming Goods Screening

Screening should occur at a location far enough from the terminal or other sensitive area to ensure that a dangerous vehicle is interdicted well before it is able to cause damage to any intended target. The screening location must include a barrier to prevent further intrusion, adequate room for security workers to perform the inspection, space to store any specialized equipment, shelter for workers and/or working animals, and a method for a rejected vehicle to turn and leave the screening area.

The capacity of the screening location should be determined based on the number of vehicles in the peak hour, available manpower, available space to perform simultaneous inspections, and available parking positions at the terminal.

xi. Trash and Recycling

Trash rooms should be large enough to accommodate the trash handling equipment required and to provide storage for packaged trash generated during a 3-day period. Space should be provided for sorting paper, glass, and metals for recycling. Airports that have trash containers that are picked up by vendors should have at least one loading bay for the trash container.¹⁹⁸

xii. Building Services (MEP)

At the planning and programming stage, utilities areas are typically estimated as a percentage of the enclosed functional areas of a terminal. This percentage will vary with the geographic location of the terminal, the provision of central plant functions either within the terminal or remotely and, in some cases, architectural design considerations that may limit the use of roof-top equipment.

Most newer terminals allocate space to utilities in the range of 10% to 12% of functional areas if the terminal has its own heating/cooling plant, but many terminals are outside of this range. The existing percentage should be calculated and adjusted for expansions based on the adequacy of existing facilities.¹⁹⁹

Recent trends in computer systems, telecommunications, and other building systems have increased the demand for utility space in many terminals. Some of this increased demand may be accommodated in the airline operations areas, whereas common-use systems need to be accommodated in airport-controlled areas.

xiii. IT/Communication Rooms and Facilities

Due to the distance limitations of copper Ethernet cabling, telecommunications rooms should be distributed throughout the terminal to provide adequate capacity coverage and reach for both planned and future applications. Working space around equipment racks for maintenance personnel should be provided, and there should be enough room to accommodate reasonably foreseeable future expansion requirements. Telecommunications room design should address panel space for cable terminations, switches and relays, remote field panels, remote diagnostic and management computer stations, and power service with redundancy and/or emergency backup capability, as appropriate. Special

¹⁹⁸ ACRP Report 54, 11.6.7

¹⁹⁹ ACRP Report 25, VI.3.14.1

consideration should be given to providing adequate physical clearance to access the equipment including HVAC service based on thermal analyses of installed equipment and local UPS to power equipment in the event of a power failure.²⁰⁰

2. Design Criteria

i. Employee Screening

[Under development]

ii. Airline Spaces

FAA AC 150-5360-13, 70 provides different layouts and dimensions for ATO/support space. Tenant airlines should be consulted to assess their floor area requirement, as the requirements vary considerably by airline.

iii. Vehicle Screening

Final denial barrier placement is based on the activation time for weapon delivery methods and the response time needed for a given scenario. For example, to stop a high-performance vehicle that accelerates from a stop at the ID check, given an 8-second response time, an active barrier should be placed approximately 330 feet from the access control point so that it can close before the vehicle reaches it.²⁰¹

iv. Loading Docks

ACRP Report 54, 11.1.2, provides a useful table regarding the sizes of the loading dock areas:

Size of Terminal Concession Area	Required Loading Bays
Up to 50,000 square feet of gross floor area	1 per 25,000 square feet or fraction thereof of gross retail floor area
Between 50,000 square feet and 100,000 square feet of gross retail floor area	1 per 20,000 square feet or fraction thereof of gross retail floor area
Over 100,000 square feet of gross retail floor area	5 plus 1 per 50,000 square feet or fraction thereof of gross retail floor area over 100,000 square feet

Table 34: Loading dock requirements as a function of concession floor area ²⁰²

t. Landside Automated People Mover (AirTrain)

The Port Authority airports have developed or are developing Automated People Mover (APM) systems to transport passengers between terminals or between terminals and other landside activity centers, such as parking and rental car facilities, ground transport centers, and local transit stations at or near the airport. The Port Authority has branded their APMs under the name “AirTrain,” and each of the AirTrains that exist or are under consideration operate on the non-secure side, or landside, of the

²⁰⁰ ACRP Report 25, VI.4.2.11

²⁰¹ Site and Urban Design for Security, Guidance Against Potential Terrorist Attacks, FEMA 430, 5.5.2, December 2007

²⁰² Source: ACRP Report 54, 11.1.2

airport, meaning that the passengers who ride these systems have not cleared security prior to boarding the trains.

The main purposes of landside APMs are to reduce airport roadway congestion and relieve roadway capacity shortfalls by enabling large-scale airline hubbing operations (connecting separate landside terminals) and convenient connections to landside facilities and regional transit that otherwise may only be provided by roadways.

Even though the development of the AirTrain's primary infrastructure would generally be the responsibility of the Port Authority, developers must know how large each station, platform, and other supporting facilities must be within their terminal development area to handle peak hour passenger demand. Therefore, developers are required to coordinate with the Port Authority to review existing and future AirTrain plans and incorporate system requirements into their station design.

1. References

- ACRP Report 37: *Guidebook for Planning and Implementing Automated People Mover Systems at Airports*
- ACRP Report 37A: *Guidebook for Measuring Performance of Automated People Mover Systems at Airports*
- ACRP Report 118: *Integrating Aviation and Passenger Rail Planning*
- IATA ADRM, 10th Edition
- National Fire Protection Association (NFPA) 130: *Standard for Fixed Guideway Transit and Passenger Rail Systems*

2. Planning and Design

Landside APM systems are usually designed to accommodate passengers with large checked baggage or even baggage carts. Therefore, the same APM vehicle may have a different effective capacity if it is being used in an airside post-security location as opposed to a landside pre-security location. Trip times on these systems may be long to reach remote parking lots, rental car sites, or off-airport intermodal facilities. The general functions of landside APM systems are described below.

Landside Circulation — APM systems enable the movement of passengers between airport activity centers such as terminals, parking lots, and rental car centers. These APM systems reduce the number of buses operating on the airport roadway, thereby lessening roadway congestion and auto emissions on airport property.

Sufficient integration of a landside APM system into the terminal complex will allow terminals to expand their physical size and passenger throughput while still meeting level-of-service thresholds for connect time and walk distance.

Transit Connections — APM systems also serve to connect an airport terminal with an urban or regional transit system. Passengers can connect to transit systems such as city buses or regional rail systems through intermodal centers. These APM systems also help to reduce roadway congestion and auto emissions.

When an APM connects a terminal to a regional rail station, passengers arriving from that rail service will impact the function and operating patterns of the in-terminal station. Passenger arrival patterns at the station via the regional rail service depend on that service's train frequency and capacity. Typically,

long trains arrive periodically and discharge a large group of passengers in a very short time. Such surged demand must be accommodated by the high capacity provided by high frequency APM service.

Major international airports have a wide variety of land uses on their premises. With airport growth, the expansion of terminals and roadways often forces other facilities such as rental car centers and parking structures to relocate to more remote locations. Landside APMs have been used to facilitate and serve such relocations at many airports.

It is recognized that with the expansion of PANYNJ's airports to accommodate growing passenger demand, it is critical that terminals improve and increase landside APM access to and from the facilities.

Goals:

- Promote transit modal access to the airport by providing a nearly seamless connection to airport facilities from regional transit.
- Reduce regional auto congestion and emissions by reducing/eliminating airport bus traffic and thus allowing an airport to increase its origination / destination capacity for a given roadway system.
- Integrate AirTrain stations with terminal planning to provide passengers with more convenient connections that facilitate seamless passenger flows to the terminal, a critical factor in providing a high-quality passenger experience.
- Provide direct, convenient connections to the road and AirTrain landside surface access that are within short walking distances. IATA standards suggest a walking distance of less than 1,000 feet between conveyance systems.
- Provide multiple passenger processing facilities that are connected via AirTrain, shuttle buses and walking routes to provide frequent and quick connections, operationally connecting the processing facilities and importantly ensuring convenient land and airside passenger flows.
- Better connect separate processing terminals to allow hubbing operations between facilities.
- Provide a multifunction landside APM that serves more groups within the airport organization and passengers such as car rental, passenger and/or employee parking, and regional rail.

3. APM Car Occupancy Demand

Consideration should be given to the effect of high peak flows on multi-station APMs that can lead to trains filling to capacity at early stops, leaving passengers unable to board the train further down the line. This condition can lead to increased Minimum Connecting Times (MCTs) and a poor perception of the level of service. Careful airline allocation, both during planning and operations, can help to minimize this problem but not necessarily eliminate it. Passenger flow peaking profiles are a vitally important design input.

4. APM Station Design Requirements

i. Pedestrian/Passenger Circulation Requirements

- Pedestrian flows shall be safe, direct, and convenient.
- Passengers with reduced mobility shall have appropriate access to and egress from the AirTrain station, as well as an ease of movement within the AirTrain station. ADA guidelines shall be strictly adhered to.
- Passengers shall be provided with appropriate directional guidance to ticketing, information, station exits, and any other appropriate destination.

- Bi-directional passenger flow must be provided between the passenger queuing areas and the platform area.
- There shall not be obstructions (e.g. columns, queue areas, signage etc.) in the primary pedestrian paths of travel.
- A sufficient number of doors shall be provided at each entrance, exit, and any other doorway to accommodate the projected pedestrian traffic flow.
- Adequate queuing and run-off space shall be provided for all public stairs and escalators. The required queuing and run-off areas for vertical circulation elements shall not overlap unless otherwise noted herein.

ii. Passenger Circulation Design Criteria

The general process for sizing transit facilities to handle passenger capacity begins with three steps:

- Identify the unit capacity for each circulation element and establish acceptable LOS for passenger circulation.
- Quantify the inbound passenger flow and capacity requirements of the passenger circulation elements restricting exiting from the facility.
- Quantify the outbound passenger flow and capacity requirements of the passenger circulation elements restricting access from the entrance to the platform and train.

Because entering passengers are assumed to arrive steadily throughout the course of the peak hour, there is a constant flow of passengers towards from the entry to the platform. That escalator's capacity is thus sized by dividing the forecast hourly entering volume by the hourly capacity of a single vertical circulation element (stair or escalator). The forecast hourly volumes are multiplied by a surge factor of 1.3 since surging is anticipated in the peak hour. The 1.3 surge factor is the typical industry standard surge factor used for designing transit facilities.

The capacity of these circulation elements is determined considering:

- The maximum throughput established for each passenger circulation element.
- The emergency egress requirements as determined by the National Fire Protection Association (NFPA) 130: Standard for Fixed Guideway Transit and Passenger Rail Systems.
- Minimum level of service (LOS) conditions governing interpersonal spacing and throughputs of passenger circulation elements under normal operating conditions.
- Any service standards (e.g., a requirement to clear the platform of arriving passengers within a given length of time after the trains arrives) established for performance.
- The waiting/queuing conditions at the platform level (in terms of passenger LOS and maximum time spent in or length of queue).

NFPA 130 egress requirements determine if the vertical circulation design meets the minimum passenger circulation design and performance standards for emergency evacuation. One of the primary provisions specified by the code is that there shall be sufficient exit capacity to evacuate station occupants (including those on trains) from platforms in 4 minutes or less and to a point of safety in 6 minutes or less.

Quality LOS design requirements are an industry design standard and different from NFPA 130 emergency egress requirements. NFPA 130 requirements only satisfy conditions during emergency evacuations while LOS requirements determine the operational performance standards required for

daily operations and functionality of the transit facility. LOS is covered in more detail in the following section.

5. Passenger Level-of-Service Criteria

Level of Service (LOS) pedestrian performance standards, established in *Pedestrian Planning and Design* (Fruin, 1971), provide a method for evaluating pedestrian circulation conditions and sizing elements. Unlike fire/life safety codes that may consider crush loads in emergency egress conditions, pedestrian LOS standards consider “normal” operating conditions, considering passenger comfort and convenience.

LOS performance standards establish a basis of design that considers human movement under various crowding conditions as well as the physical dimensions of the human body in determining the practical capacity of passageways, stairs, escalators, elevators, and other circulation elements. The normal psychological preference of avoiding contact with other passengers is also a determinant of inter-person spacing in queues and other crowded situations. It should be noted that this psychological envelope or personal space is often influenced by cultural and environmental factors.

The available space for passengers within AirTrain station platforms is impacted by the presence of baggage and other devices such as baggage carts, wheelchairs, and strollers which take up space. The amount of space occupied by international travelers is often the highest among all airport users since they carry the most baggage (typically two or more bags) and have a higher likelihood of using a baggage cart. Domestic travelers typically carry less baggage than international travelers (one or two bags) and are less likely to use a baggage cart. Flight crews carry slightly less baggage than domestic travelers (typically one bag), and airport employees typically do not carry baggage. The mix of AirTrain passengers and the space they occupy can therefore affect the capacity of the system.

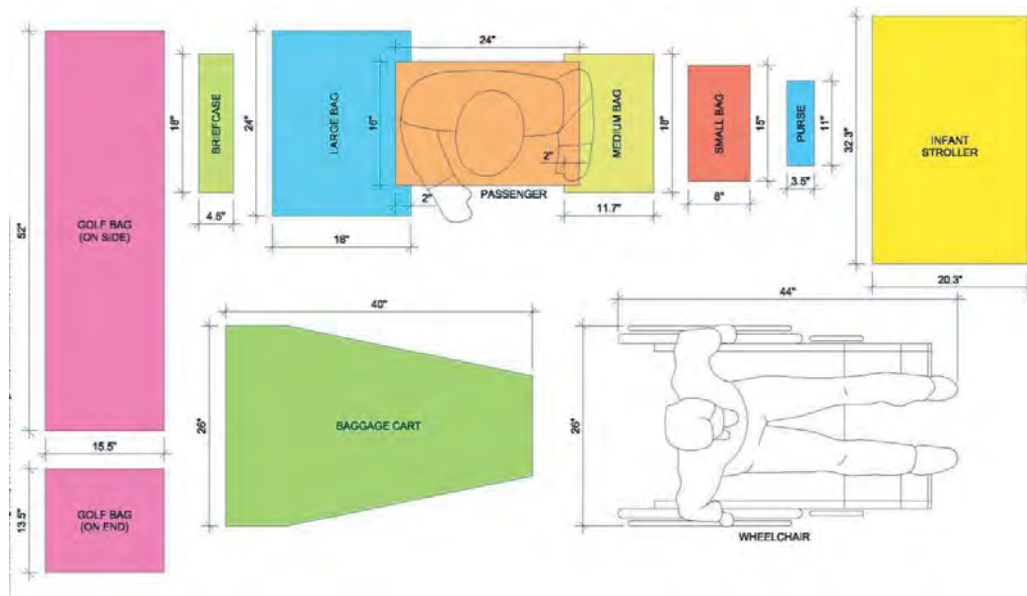


Figure 68: Typical Passenger Space Allocations²⁰³

²⁰³ ACRP Report 37: Guidebook for Planning and Implementing Automated People Mover Systems at Airports

The minimum capacity of the facility's passenger circulation system is determined by the most stringent of these factors as applied to each element of the system. The key elements of the regular passenger circulation system (excluding emergency egress) are:

- Platforms
- Vertical Circulation Elements (elevators, escalators, and stairs)
- Passageways/Concourses
- Entrances/Exits
- Fare Gates and Turnstiles
- Ticket Vending Machines

All pedestrian circulation elements shall be appropriately sized to handle the projected passenger/pedestrian demand. These elements shall be designed to an acceptable passenger LOS C/D threshold (not to maximum capacity) utilizing the following LOS C/D parameters and consistent with the design guidelines as provided in this section:

Traffic Flow Element	Evaluation Criteria (without baggage)	Evaluation Criteria (with baggage)	Level of Service
Platforms	7 Square feet per person	14 Square feet per person	C/D
Queue Areas	7 Square feet per person	14 Square feet per person	C/D

Table 35: Platform and Queue Areas²⁰⁴

6. Platform Design

The platform area is where customers access trains. The platform area must facilitate multiple customer circulation functions: circulation along the platform, boarding and alighting trains, queuing at the platform edge while waiting for a train, queuing at vertical circulation elements, run-off at vertical circulation elements, and waiting at benches or rest areas. Because of these complex—and often conflicting—circulation characteristics, overcrowding on the platform may create uncomfortable, or dangerous situations where customers are crowded near the platform edge. Therefore, sizing platforms is critical and designers should err on the side of safety when determining the size of the platforms.

The following principles should be applied to the design of platforms:

- All elements of the platform area must support safe customer circulation and access to the trains.
- The design of the platform must minimize the need for circulating customers to make decisions that may cause unnecessary hesitation. Because platforms are typically crowded and subject to customer surges and cross flows, pausing customers can cause circulation problems for all patrons. The design of the platform shall meet NFPA 130 criteria and AirTrain criteria for clearance.
- Platform access points and vertical circulation elements should be situated to encourage balanced vehicle loading and unloading. Customers tend to board vehicles near the points where vertical circulation elements intersect the platform.

²⁰⁴ PANYNJ PATH Harrison Station Planning Standards

- Visual obstructions should be minimized and alcoves or other hidden areas on the platform avoided for orientation, safety, and security reasons.
- The platform areas should not contain any support or nontransit functions (e.g., vending or concessions) that may obstruct, inhibit, or impede customer circulation.
- The path of emergency egress along the platform must be clearly delineated by signage and lead as directly as possible to an area of safety.

i. Platform Clearance Requirements

The platform shall be designed to clear the platform of passengers in required platform clearance time or less by providing the number of vertical circulation units required for optimum vertical circulation operations of LOS C/D, during peak train demand load conditions during one peak hour. The LOS C/D design criteria to meet the platform clearance requirements:

- Required platform clearance time shall equal 80% of service headway. Design will be based on the AirTrain service line operating at three-minute headway during peak periods. Thus, for any AirTrain station, the required platform clearance time is 144 seconds.
- 70 passengers per minute for the average escalator capacity and 10 passengers per minute per foot were assigned to calculate platform clearance requirements.
- There will be 10 cars per train.
- Uniform passenger distribution clearance time is calculated by dividing the total train alighting volume by the total vertical circulation element exit capacity.

ii. Platform Length

Platform length is typically determined by the length of the longest train anticipated plus whatever additional length is required for operational considerations. In this case, the platform length will accommodate a 10-car AirTrain train.

iii. Platform Width

Platform width is typically determined by several factors:

- The width of any vertical circulation elements located within the length of the platform.
- A preferred minimum clear distance to any obstruction such as a vertical circulation element from the platform edge. This distance includes the 2'-0" wide platform safety edge, a clear passage for customers circulating along the platform length, and a 1'-0" buffer zone along the length of the obstruction. The edge of the platform shall be measured from the inside edge of the rubbing strip. The rubbing strip shall not be included in the width of the platform safety edge. The precise dimension is to be determined by passenger flow analysis and code.
- Patronage and emergency exiting requirements.
- Space requirements as determined by Level of Service requirements.

The total width of the platform is equal to the sum of these factors. In no case, should the width of the platform be less than the minimum standards established herein or by the PANYNJ.

In addition to vertical circulation elements, circulation space, safety edges, and buffer areas, platforms must provide room for the following program requirements, many of which may contribute to the width of the platform:

- PANYNJ facility phones (e.g. General, Pay and Passenger Assistance)
- AirTrain vision monitors
- Benches
- Passenger information displays/variable messaging system
- Platform end gates
- Fire department facilities (e.g., standpipes, hose cabinets, and extinguisher cabinets)
- Underplatform access, such as manholes
- Support areas (service and support spaces)
- Emergency egress (e.g. stairs, vestibules, corridors as required)

u. Information Services

Airports continually strive to improve customer service to meet the growing levels of sophistication and service demanded by today's passengers. Customer satisfaction is influenced by the presence and degree of various stressors along the journey, with the onus on the airport and airlines to reduce or eliminate as many of these friction points as possible. Airports and airlines are making improved customer service a priority through providing passengers accurate, timely, and actionable information – collectively known as “information services”, reducing the uncertainty inherent in various parts of the airport experience.

1. References

- ACRP Report 13 - Integrating Airport Information Systems
- ACRP Report 25 - Airport Passenger Terminal Planning and Design
- ACRP Report 157 – Improving the Airport Customer Experience

2. Flight Information and Passenger Information

Flight information is the most fundamental category of information for passengers. The standard approach is to use monitors or screens showing departing flight destination cities, flight numbers, times, gate numbers, and status. The screens and the IT system that supports them are known as Flight Information Display System or FIDS. With mobile technology, other options for receiving flight information are supplementing FIDS. These include²⁰⁵:

- Text messages or emails from the airline notifying the passenger of departure time, gate number, and any flight status changes.
- Flight status on airline apps, usually through push notifications.

²⁰⁵ ACRP 157 Improving the Airport Customer Experience, Section 8.16

- Flight status available through third-party apps, airport apps, or mobile websites. These approaches usually require the passenger to seek the information.

It is likely that the use of mobile devices to receive flight status information will continue to grow, however, FIDS must continue to be provided at key locations such as the ticketing hall and immediately after security checkpoints, and other zones where passengers must make wayfinding decisions. In addition, the use of visual paging can help minimize the acoustic clutter in busy terminals, whereby video screens show messages for passengers as an alternative to voice announcements²⁰⁶.

3. Passenger Tracking and Queue Management

Customer perceptions of wait time are influenced by the quality of the information they have available about the expected wait time. People are subject to less stress when they have an accurate estimate of the amount of time they will spend waiting in a queue. Uncertainty over the time required to reach the departure gate is a major source of stress at the airport²⁰⁷.

Technology for measuring, managing, and predicting waiting times is available in new queue management systems now being used at several US, European and Asian airports. These systems use predictive software in conjunction with camera-based, Bluetooth or other technologies measuring of passenger flows to predict processing times and passenger movements in terminals.

i. Camera/Sensor-Based Systems

One kind of new technology for managing queues is about developing software and hardware that analyzes groups of people and how they are moving, how they are distributed, the time they are spending in a given place, and how many individuals are in a given area; then predicts movements and flows. This type of technology uses overhead cameras or sensor and software to monitor persons without the use of facial recognition systems. The predictive software can monitor the status of queues at airline check-in counters or security checkpoints, and then provide counts, densities, travel times, and predictions based on movements. In addition, a mobile app can inform airline and airport managers of current conditions and issue alerts that allow them to make decisions about staffing and opening new counters or checkpoint lanes, and can inform other decisions.

ii. Bluetooth-Based Systems

Bluetooth-based systems use the unique Media Access Control (MAC) address of phones and mobile tablets when Bluetooth is enabled to monitor the time it takes passengers to go through the checkpoints using sensors on predetermined paths. This technology can also be useful for monitoring and managing wait times at check-in, in taxi queues, at retail concessions, in baggage claim, and in immigration and customs queues, and can provide an overall picture of how terminal facilities are operating on any given day.

²⁰⁶ ACRP 157 Improving the Airport Customer Experience, Section 8.16.1

²⁰⁷ ACRP 157 Improving the Airport Customer Experience, Section 8.4

iii. Facial Recognition Systems

Facial recognition software applications for airports use overhead cameras throughout the airport to measure and monitor the number of persons in queues, times their processing to identify current or predicted bottlenecks, and provides guidance on real-time staffing to manage current and projected queue lengths.

Unlike a Bluetooth-based system, which relies on passengers having their smart phones' Bluetooth function switched on, this type of system uses facial recognition to identify individual passengers, and time their movements through the system. The system does not personally identify individuals, but it does track an individual anonymously throughout the airport. The system creates a biometric, numerically coded identifier for the passenger upon the passenger entering the terminal. At each waypoint, the customer's face is matched to existing identifiers.

The cumulative data of many passengers is used to develop average, minimum, and maximum wait times, which are communicated to airport staff at a desktop computer showing the dashboard, which includes current and predictive reporting, or through a mobile app. Airport staff can respond by opening additional lanes, adding staff, or diverting passengers to another queuing area. The airports are also able to use the software to analyze concession usage.

iv. Beacons

The recent popularity of beacon technology at airports has fostered new opportunities in terminal design, and their use goes beyond identifying locations. With an add-on sensor, beacons can enhance certain features within the terminal by monitoring temperature ranges and lighting levels and then sending signals back to the heating and ventilation system to self-adjust throughout the day. This not only reduces the airport's energy consumption but also enhances the overall passenger experience.

Because of the technology's capability to deliver hyper-contextual content to the passenger, beacons can serve as a wayfinding tool for passengers to navigate around the terminal independently, get up-to-date airline boarding information or changes, and receive targeted concessions coupons as passengers pass through certain points within the terminal. Keeping the passengers informed can allow for less trafficked spaces to still be visible to the passenger and navigate to.

In addition, beacons can track passenger patterns through Bluetooth technology. Data collected can be used to inform airports of bottleneck/congestion points and customers' spending habits so that airports can more effectively position retail and hospitality offerings to customers and provide personalized services. I-Beacon technology is illustrated in Figure 69²⁰⁸.

Terminal developers should discuss options for passenger tracking and queue management technologies with the constituent airlines, terminal managers, and other stakeholders to determine the optimal system or systems to deploy. Providing these systems can help terminal managers improve customer service and perceptions in the most efficient way, and can serve as a measuring tool for facility and staff performance.

²⁰⁸ ACRP Report 157 Improving the Airport Customer Experience, Section 7.3.1



Courtesy of SITA.

Figure 69: I-Beacon Technology ²⁰⁹

4. Digital Signage & Wayfinding

Airport operators, airlines, and passengers are rapidly adopting a wide range of digital technologies to smooth many facets of the air travel experience. Digital displays are an ideal fit for airports because their bright, dynamic images grab and hold attention, even in settings with abundant ambient light. They can be configured into many shapes and sizes, and be deployed both inside and outside air terminals.

i. Digital Signage

Digital signage offers many advantages over traditional static signs. They allow content to rotate, make updating content easy, and provide interactivity with touch-enabled screens.

Advances in light-emitting diode (LED) technology is creating opportunities to create large-scale high-definition (HD) displays of unlimited size, similar to the HD replay screens used in major sports stadiums. Large-format LEDs offer an affordable means of display for advertising, sponsorship information, local tourism promotions, public art, and other messaging. The most extensive and elaborate use of this technology in the United States is in the expanded Tom Bradley International Terminal (TBIT) at Los Angeles International Airport, where the installation serves as the public art component of the terminal project. Video art was chosen because the moving image is the medium for which Los Angeles is best known around the world. Two views of the Great Hall in the departures area are shown in Figure 70.

²⁰⁹ ACRP Report 157 Improving the Airport Customer Experience, Section 7.3.1



Figure 70: LAX Bradley International Terminal video art displays ²¹⁰

Besides substantial entertainment value, the video walls also give passengers another reason to stay in the terminal's Great Hall, which also features an extensive array of shops and boutiques and a variety of dining options. Other airports are embracing this new technology for revenue-producing purposes.

ii. Digital Information Kiosk

Touch-enabled wayfinding kiosks can help passengers navigate the airport by providing detailed maps and a wealth of useful guidance showing passengers how to get to where they want to go. Boston Logan airport has invested in infobars (Figure 71), which are kiosks with interactive touch-screen devices that provide information to passengers, including automated maps showing how the customer can reach a desired location; concession information; and information on airline, concessions, and other services.



Figure 71: Infobar interactive kiosks at Boston Logan ²¹¹

iii. Walking Distance

Walking distances are a customer service issue when the length of the walking distance is an inconvenience for the passenger or a challenge for a person with reduced mobility. Eliminating or reducing the negative effects of long walking distances on the customer experience may require long-term fixes and significant capital investment. Therefore, it may require waiting until there is a major

²¹⁰ ACRP Report 157 Improving the Airport Customer Experience, Section 10.3

²¹¹ ACRP Report 157 Improving the Airport Customer Experience, Section 10.4.1

terminal refurbishment project in order to bring the costs and operational impacts to manageable levels²¹².

Some airports are indicating walking distance or time-to-walk estimates on airport flight information displays or terminal map displays in order to allow customers to plan their movements and manage their time effectively while the airport is able to manage expectations. An example of a directory with walk times at London Gatwick airport is shown in Figure 72. This is a simple and effective way to convey fundamental information to passengers, and is recommended for any terminal building with walking times greater than 15 minutes from security checkpoint to gate.



Figure 72: London Gatwick Airport directory with walking times to gates

iv. Restrooms

Survey research on customer satisfaction has established a direct link between the quality and cleanliness of restrooms and the overall customer experience.

Customer feedback on how well restrooms are meeting their needs can be obtained through a variety of means including touch-screen ratings. Many airports including Port Authority facilities have installed devices where passengers can rate the restroom using a five-point scale (shown in Figure 73). Some airports also allow touch-enabled displays that allow passengers to alert janitorial staff that a restroom needs cleaning or paper goods resupplied.

Customer feedback screens are recommended for all airports restrooms, because they improve passengers' perceptions of the airport caring about customer service, and provide real-time actionable information to airport staff responsible for restroom maintenance.



Figure 73: Restroom touchscreen feedback system ²¹³

²¹² ACRP Report 157 Improving the Airport Customer Experience, Section 8.5

²¹³ Singapore Airport

5. Virtual Assistants and Robot Ambassadors

In addition to the customer service staff at information booths, many airports also provide roving ambassadors or customer service representatives who move about the terminal or rail platforms during the airport's peak travel times. New types of roving ambassadors, such as roving customer service robots, have been introduced at a several airports.

Indianapolis International Airport (IND) was the first U.S. airport to debut a roving robot. It uses a standard iPad running FaceTime mounted on a stick figure wearing an IND polo shirt. IND staff remotely operate the robot and can be seen by and interact with the customer directly. The robot, which resembles a smaller version of the Segway transporter, is controlled via Wi-Fi connection, with the iPad showing a live video image of the operator, also carried by Wi-Fi, who can maneuver the robot and conduct conversations with passengers. The robot, as shown in Figure 74, is called a "personal airport consultant" and is popular with airport users and creates a human connection with passengers.

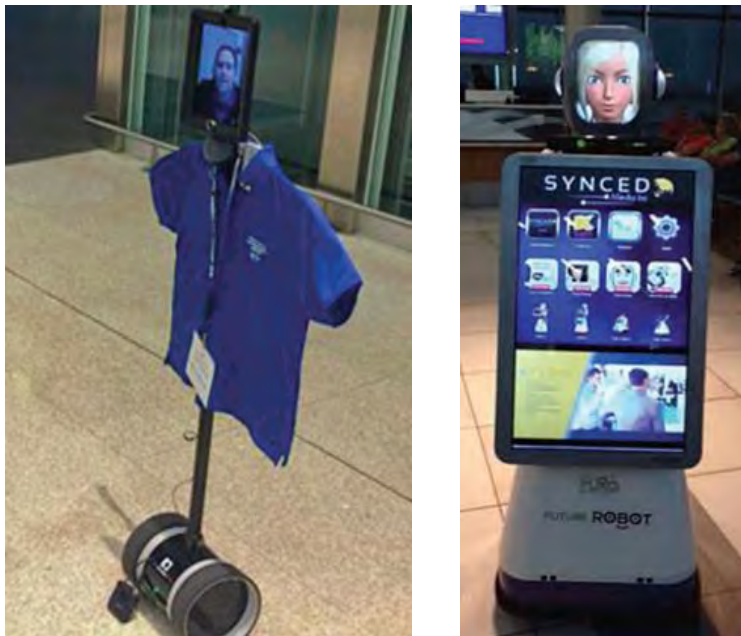


Figure 74: Indianapolis and Edmonton International Airports Airport Robots ²¹⁴

Edmonton International Airport (EIA) has also been testing a robot that is fully automated and has a touch screen with icons indicating how the robot can assist passengers, including leading passengers to their chosen destination. They have the potential to communicate in 30 different languages.

Similar virtual assistants are in use at Manchester, London Luton, and Birmingham airports in the UK, as well as some Port Authority terminals including JFK T5. The virtual assistants use holographic imaging technology and make the standard information announcements on prohibited items and inspection procedures to passengers entering the security checkpoint. The virtual assistants are attention grabbers and are less expensive than staff. The Manchester airport virtual assistant is shown in Figure 75.

²¹⁴ ACRP Report 157 Improving the Airport Customer Experience, Section 10.4.1



Figure 75: Holographic virtual assistant at Manchester Airport ²¹⁵

6. Automated Food Ordering Systems

Concession and holdroom integration is a growing trend to optimize passenger exposure to revenue-generating opportunities while providing a more pleasant experience for the passenger waiting to board²¹⁶. OTG Management, a food and beverage concessionaire, has installed thousands of tablets in its food and beverage locations at Newark-Liberty, LaGuardia, Kennedy, Minneapolis–St. Paul, and Toronto Pearson airports²¹⁷. The tablets allow for online ordering of food using a visual menu, which also makes recommendations. The tablets are loaded with games, news, and entertainment apps, a flight tracker app, Google maps, and other features to inform and entertain the customer before and after the meal. The visual menu is available in multiple languages, making it useful in international terminals.

At a few airports, online ordering is provided via airport or third-party apps and mobile websites, offering flexibility for online ordering for pickup or delivery at the gate without the attendant cost of installing touch-screen tablets.



Figure 76: Automated food ordering, Toronto Pearson International Airport ²¹⁸

²¹⁵ ACRP Report 157 Improving the Airport Customer Experience, Section 10.4.1

²¹⁶ ACRP Report 157 Improving the Airport Customer Experience, Section 7.3.3

²¹⁷ ACRP Report 157 Improving the Airport Customer Experience, Section 8.12.2

²¹⁸ ACRP Report 157 Improving the Airport Customer Experience, Section 7.3.3

Remote ordering is expected to grow as point-of-sale systems used by restaurant operators increasingly have the capability to support online ordering and payment. Touch-screen ordering is also expected to increase as an extension of point-of-sale systems at busy food and beverage concessions²¹⁹.

Terminal operators are encouraged to provide or enable online concessions ordering, as a time-saving customer service enhancement, and a way to promote retail concession sales, especially for concession outlets that are less visible or get less foot traffic due to their location.

²¹⁹ ACRP Report 157 Improving the Airport Customer Experience, Section 8.12.2

SECTION IV: LANDSIDE

Part 1 - Concept of Operation Parameters

1. Roadways

- a. Airport roadway should be designed to streamline traffic flows, enhance vehicular capacity, and improve overall access to, from, and between the terminals. Primary consideration should be given to the following design elements:
 1. Optimize free flowing traffic movements throughout the airport where possible;
 2. Eliminate or minimize signalized intersections using grade-separated structures;
 3. Maximize the length of merge and diverge points;
 4. Maximize the distance of weaving sections;
 5. Maximize the distance between motorist decision points; and
 6. Avoid multiple decision points in the same gore area.
- b. New landside facilities shall be designed to achieving a minimum Level of Service (LOS) threshold of C during the morning and evening peak periods. In addition, the designs shall meet the proposed future peak hour traffic demands based upon the design day flight schedule (DDFS) projections.
- c. The airport access roadway system shall provide airport access/egress, and circulation from/to:
 1. Main Access Highways; and, (Airport Specific)
 2. Local Street Network. (Airport Specific)
- d. The on-airport roadway system shall provide the following vehicular circulation and recirculation:
 1. Enter Direct to Terminal;
 2. Terminal to Exit;
 3. Enter Direct to Parking;
 4. Parking to Exit;
 5. Terminal to Parking;
 6. Parking to Terminal; and,
 7. Inter-terminal Connections.
- e. Direct ingress/egress shall be provided for delivery vehicles to/from the terminal loading docks.
 1. Terminal loading docks should be located so delivery vehicles are not required to pass through terminal frontage roadways to access the loading docks.
- f. All airport circulation and recirculation movements shall be provided on airport property.
- g. Roadway Elements
 1. Landside roadways should be designed taking into account coordination of existing conditions, critical design criteria, structural foundations, impacts to

both existing and proposed utilities and potential future transit systems, other elements include:

- Horizontal and Vertical Roadway Design;
- Roadway and Utility Phasing;
- On-grade and Elevated Pavement Design;
- Signage;
- Utility Routing;
- Storm Water Routing;
- Sanitary Sewer Routing; and,
- Pavement Removal.

h. Traffic volume assignments for each roadway link shall be developed as outlined in Part 2 of this section.

2. Terminal Frontage Curbside

Terminal frontages, carrying mostly air passenger traffic, are typically one-way roadways that operate in a counter-clockwise direction to enable passenger pick-up and drop-off by different modes of vehicles. Key factors in frontage roadway design include speed limit and other signage, pedestrian crossings (at-grade or grade-separated), adequate transition areas, sidewalk and curb widths, Americans with Disabilities Act (ADA) accessibility, and frontage curb capacity.

Based on various terminal configurations, clockwise operations may be desirable. Actual frontage length, lane requirements and operation parameters shall be developed based on the analyses outlined in Part 2 of this section.

Terminal frontage shall provide for the desirable Level of Service A curb space operation such that for a vehicle arriving at the terminal frontage, the probability of no space at the curb is less than or equal to 10 percent and the lane utilization factor is 0.9. This represents a “free-flow” frontage operation where there is little or no interference between vehicles or pedestrians.

Terminal frontages typically consist of four or five traffic lanes, usually with two lanes or one wide lane for passenger pick-up/drop-off, one lane for maneuvering, and one or two bypass lanes. Depending on the demand and terminal design a second independent high-occupancy-vehicle (HOV) arrivals and departure frontage or alternate pick-up/drop-off areas should be considered.

The frontage roadway layout should be organized to provide most efficient operations for travelers including provisions for curb front baggage check in and safe pedestrian crossings. ADA passenger loading and zones along the frontage should be identified and clearly marked.

Terminal frontages need to provide for the following ground transportation modes:

- Private Auto;
- Taxis;
- For-Hires – Black Cars, Private taxis, Uber, Lyft and other Transportation Network Companies (TNC);
- Public Transit/Coach Buses;
- Courtesy Vehicles – Hotels and Off-Airport Parking, etc.;

- On-Airport Buses/Vans – Airline Employees, etc.;
- Off-Airport Buses /Vans – Super Shuttles, Charter Buses, etc.;
- Delivery Vehicles - UPS, FedEx, Food Deliveries. etc.;
- Authorized Vehicles - Police, maintenance vehicles, Security vehicle, etc.; and,
- Other – Tow trucks, Contactor maintenance vehicles, etc.

Terminal frontages can be common shared frontage or individually segmented. At common curb frontages, the various vehicular modes share a common curb front making it unnecessary to separate traffic volumes by vehicle type. At an individually segmented curb front the different modes have their own processing area.

Arrivals curb frontages should be segmented to provide dedicated areas for the following:

- Taxis;
- Public Transit Buses;
- Courtesy Vehicles;
- On-Airport Buses; and,
- Off-Airport Buses.

Private auto, for-hires, TNC, delivery, authorized and other vehicles can utilize the common use section of the Arrivals frontage.

Independent High Occupancy Vehicle (HOV) frontages or alternate pickup/drop-off areas can be provided for the segmented functions of the Arrivals frontage, thereby freeing up common use curb frontage. HOV frontage can also be used to provide the departure's drop-off function for public transit buses, courtesy vehicles, on-airport and off-airport buses.

Departures frontages can be segmented or common use according to expected volumes and mode shares.

At-grade pedestrian crosswalks shall be signal controlled as a matter of safety. Crosswalks shall be conspicuously marked.

Pedestrian islands shall be provided with canopies for passenger comfort and protection from the weather.

3. Surface and Garage Parking

- a. All parking facilities shall comply with ADA and PA Sustainability guidelines.
 1. Minimize travel distances for recirculation to/from terminals and parking.
 2. Parking structures shall provide elevators for vertical circulation between levels.
 3. Grade separated terminal connectors shall be temperature controlled.
 4. Parking structures shall be provided with finishes to enhance views from the adjacent community.
 5. Functional Requirements
 - i. Short Term parking demand forecast for the airport shall be determined in accordance with the procedures outlined in Part 2 of this section.

- ii. The Long Term parking demand forecast for the airport shall be determined in accordance with the procedures outlined in Part 2 of this section.
 - iii. The parking demand forecast for an individual terminal shall be determined in accordance with the procedures outlined in Part 2 of this section.
 - iv. A service building to house revenue control system equipment, toll collector restroom, and other support space shall be provided at each exit plaza.
- 6. The parking facilities designs must comply with the Transportation Security Administration (TSA) 300-foot security standoff requirements for larger airports.

4. Taxi Hold Operations

- a. Prior to pick-up taxis must first go to a centralized taxi hold or staging area.
 - 1. Taxi pick-up will be at a dedicated area along the arrivals frontage, at the HOV frontage or at an alternate pick-up area.
 - 2. Prior to reaching the taxi dispatch location and fare pick-up zone, a taxi queue area in the vicinity of the arrivals level frontage must be provided.
 - 3. Taxi holds should be located to provide quick access for the taxis to reach the terminal taxi queue zone and the arrivals curbside, and can be located outside of the central terminal area (CTA).
 - 4. The terminal frontage sidewalk shall be designed to accommodate passenger queuing while waiting for a taxi.
 - 5. Taxi hold space, taxi queue area, curbside and frontage requirements shall be determined in accordance with the procedures outline in Part 2 of this section.
 - 6. Taxi drop-off typically occurs at the Departures frontage.
 - 7. After drop-off taxis may exit the airport or circulate to the central hold.
 - 8. Taxi hold areas require rest room facilities.

5. Transportation Network Companies (TNC) Operations

- a. Prior to pick-up TNC vehicles must first go to a centralized hold or staging area with geofence boundaries.
 - 1. TNC hold should be located to provide quick access for the drivers to reach the new terminal arrivals curbside and can be located outside of the central terminal area (CTA).
 - 2. TNC hold space requirements shall be determined in accordance with the procedures outline in Part 2 of this section.
 - 3. TNC drop-off typically occurs at the Departures frontage.
 - 4. After drop-off TNC vehicles may exit the airport or circulate to the central hold.
 - 5. TNC hold areas require restroom facilities.

6. Cell Phone Lots

- a. Cell phone lots should be located to provide quick access for drivers to reach the terminal arrivals frontage and can be located outside of the CTA. Motorists coming to the airport just

- to pick-up arriving passengers should first go to one of the nearby cell lots to wait. Once the arriving party reaches the terminal sidewalk with luggage in hand, he or she can then call the driver, and the waiting motorist can be curbside within minutes to quickly pick up the traveler and be on their way.
- b. Cell phone lots are needed because of airport security concerns. Cars are no longer allowed to linger outside terminals in loading zones, forcing motorists to circle the area again and again while waiting for arriving parties. This causes congestion with slow-moving traffic and encourages accidents.
 - c. Before cell phone lots, motorists would park along airport roadways waiting for calls from arriving passengers. Many received tickets, and the illegal practice made it difficult to police the airport and adjacent areas properly. Conversely, some motorists would use nearby hotel parking lots, gas stations, and mini-marts to wait for calls. As a result, cell phone parking lots have become a virtual necessity.
 - d. Designated cell phone lots make it easier for law enforcement to control and monitor areas surrounding airports. Moreover, airport traffic moves smoother, faster, and more efficiently, as people approaching the terminals already know where their party is waiting. Motorists are able to get in and out quickly and easily, whether dropping parties off or picking them up.
 - e. Motorists must stay in their cars while using the lots. Time limit (e.g., one hour) should be imposed to avoid using the cell phone lots as an alternative to parking. Cell phone lots should be provided with rest room facilities.
 - f. The cell phone lot(s) space requirements shall be determined in accordance with the procedures outlined in Part 2 of this section.

7. Bicycle Access

- a. Consider impacts of bicycle storage and supporting facilities, such as showers and locker rooms, that may influence the terminal program requirements for employees and passengers traveling with bicycles to the airport made possible by access on buses, shuttles, or an Airtrain System.
- b. Planners should refer to the PANYNJ Sustainable Infrastructure Guidelines: Appendix 03 and the PANYNJ Sustainable Building Guidelines for more information regarding the PANYNJ's sustainability rating program and integration with USGBC for bicycle installations.

8. Landside Utilities

- a. Existing utilities should be relocated outside the footprint of new structures.
- b. New utilities should be located outside the footprint of new structures.
- c. Utilities should be located such that they are accessible for maintenance/repairs.

Part 2 - Landside Traffic Analysis Methodology and Design

1. References

- Airport Cooperative Research Program (ARCP) Report 25, Volume 1: Airport Passenger Terminal Planning and Design.
- ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.
- 2010 Transportation Research Board Highway Capacity Manual (HCM).
- Most recent Airport Data Collection Report (if available).
- Existing and Future Design Day Flight Schedules (DDFS).
- Americans with Disabilities Act (ADA) Applicable Standards and Guidelines

2. Landside Traffic Analysis Methodology

The objective of the landside traffic analysis is to support the design team in identifying the optimal configuration for the airport landside facilities (roadways, terminal curbside, parking, taxi operation, etc.) in response to new airside and terminal design arrangements.

The evaluation process entails developing a traffic simulation model, such as VISSIM, which utilizes dynamic and static assignment methods to direct traffic to specific parking facilities and terminal frontages, analyzes curbside vehicle loading and unloading at terminal frontages, evaluates the landside roadway network and uses iterative dynamic assignment methods to direct traffic into and out of the airport via the least congested route.

The traffic volumes to be used in the analyses shall be developed from existing and future Design Day Flight Schedules (DDFS) and other parameters including, but not limited to, the air passenger cumulative distributions at curbside frontage arrival times, vehicle occupancy rates, and expected modal splits.

Figure 77 provides a flow chart that identifies the individual steps of this process which will be specified in greater detail below.

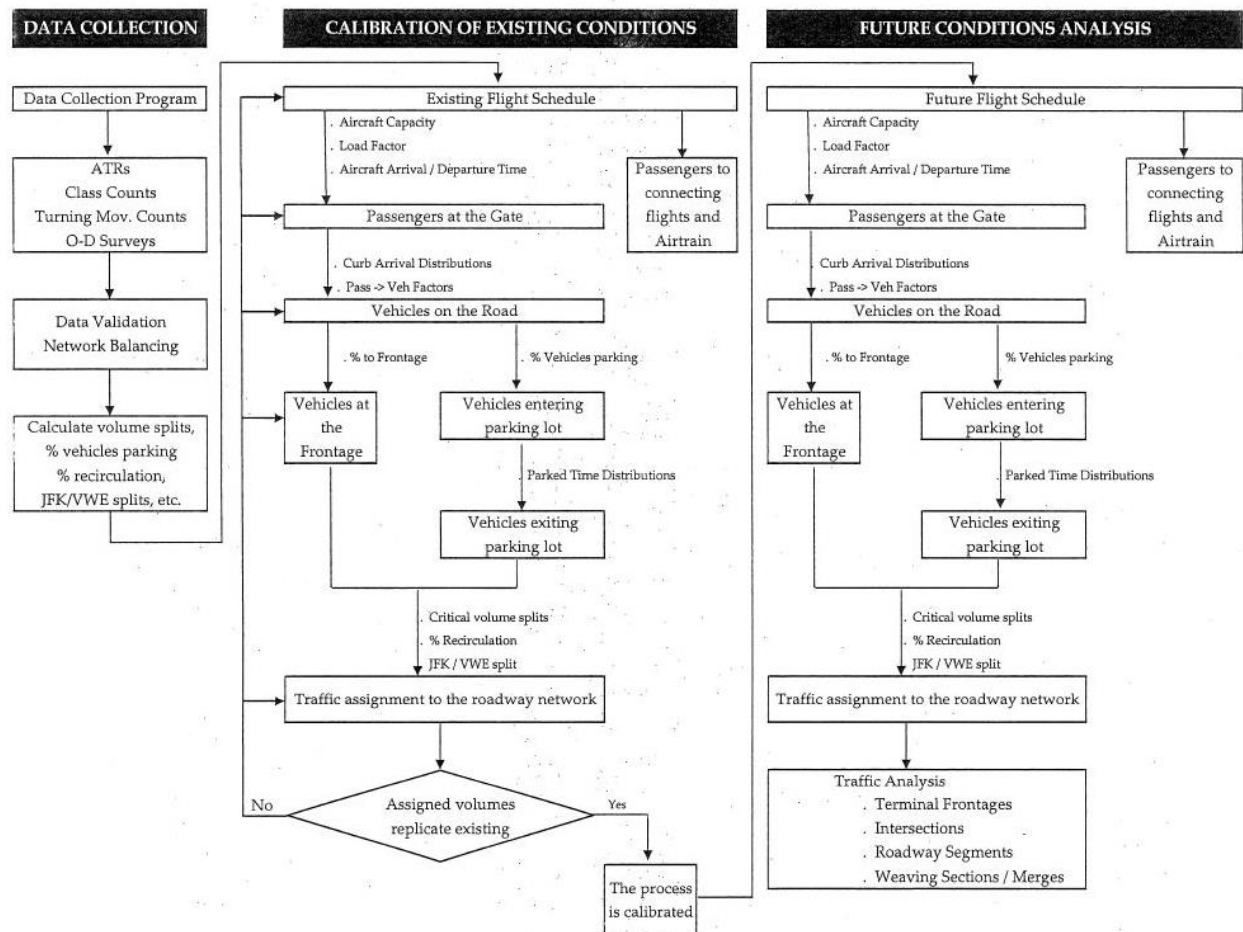


Figure 77: JFK Airport traffic analysis methodology

3. Landside Traffic Data Collection Program

a. Purpose

The purpose of the traffic data collection program is to obtain current information for the roadways within and leading into and out of the airport Central Terminal Area (CTA), as well as, the vehicle and pedestrian activity at the individual terminal curbside frontages. The data should include, but not limited to, traffic counts, vehicle classifications, curbside dwell times by vehicle mode, pedestrian counts, physical inventories of lane configurations, curbside space allocations, parking and taxi operations and travel time surveys. The information is necessary to calibrate the existing conditions traffic simulation model and to develop balanced traffic volume flow maps to reflect base year conditions. Presently, VISSIM is the preferred simulation modeling platform.

The data can be obtained using various equipment and methodologies, which include, but not limited to, automatic traffic recorders, video cameras, and field personal.

General observations should also be made to study the extent of double and triple parking, lane blockages, queue lengths and durations, and pedestrian-vehicle interactions. Several other sources of data should be explored including taxi pool dispatch data and vehicle entry-exit flows to parking facilities.

1. Month and Duration of the Data Collection

The data should be collected for a 7-day period during the month of August, typically the peak month for air passenger activity at the airport. During the duration of the study period, equipment and personnel must be monitored on a daily basis to ensure that data are accurately recorded for the correct time interval.

2. Data Collection Plan

Prior to implementing the data collection program, a thorough, well-thought-out data collection plan is required to ensure the success of the effort. All the logistics and details need to be fully developed because a problem with even one detail can cause a problem with the entire data collection program. It is also important to prepare for the unexpected, to the extent possible, and have a back-up plan, because most data collection efforts involve events out of one's control, such as traffic incidents, weather, and other unplanned incidents. The data collection plan must be submitted for approval prior to implementation of the program.

3. Automatic Traffic Recorders (ATR)

Automatic Traffic Recorders (ATR) should be installed on key roadway segments to measure continuous directional traffic in 15-minute intervals for the entire duration of the study period. Data from the ATRs represents the temporal distribution of vehicular volume throughout the day, as well as throughout the week. Traffic volumes should be recorded in 15-minute intervals and aggregated into hourly volume profiles by day.

JFK International Airport 2015 CTA Data Collection Program

Automatic Traffic Recorder (ATR) Counts

ATR SUMMARY TABLE - VEHICLE COUNTS									
Interval Beginning	LOCATION No	7							
	STREET NAME	Entrance Ramp to Terminal 8 from Van Wyck Expressway							
	DESCRIPTION	ATR							
	DATA TYPE	RAW VEHICLES							
Interval Beginning	15-Minute Volumes							Ave. of Tue, Wed, Volumes	
	8/23/2015	8/24/2015	8/25/2015	8/26/2015	8/27/2015	8/28/2015	8/29/2015	15-Minutes	Hourly
	Sunday*	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday		
00:00	63	28	35	38	58	51	47	44	137
00:15	35	13	33	42	27	42	48	34	115
00:30	30	22	25	27	41	32	27	31	95
00:45	45	20	21	37	26	27	21	28	75
01:00	20	23	11	31	24	17	17	22	58
01:15	35	17	17	14	12	13	12	14	44
01:30	18	7	10	7	14	10	12	10	40
01:45	28	6	12	8	14	6	7	11	39
02:00	20	11	5	4	15	8	4	8	43
02:15	22	4	6	7	17	7	6	10	51
02:30	12	9	9	7	13	10	8	10	66
02:45	16	10	16	15	16	10	15	16	87
03:00	14	21	11	15	21	13	16	16	106
03:15	26	38	23	20	33	14	27	25	126
03:30	22	37	35	26	29	27	32	30	160
03:45	44	27	39	28	37	45	40	35	196
04:00	49	49	41	36	30	28	43	36	256
04:15	58	58	58	62	59	55	54	60	322
04:30	74	91	62	78	58	55	72	66	372
04:45	82	84	101	88	96	83	86	95	411
05:00	99	103	108	108	88	68	92	101	424
05:15	118	125	99	117	112	124	126	109	423
05:30	85	161	91	121	104	115	114	105	406
05:45	136	114	109	105	111	115	122	108	386
06:00	96	123	79	103	117	102	108	100	369
06:15	108	96	92	95	91	88	97	93	339
06:30	74	93	81	87	87	92	93	85	311
06:45	77	75	93	91	92	85	104	92	290
07:00	20	79	49	74	65	71	87	69	275
07:15	64	72	57	75	61	71	83	64	294
07:30	60	55	59	63	72	86	90	65	292
07:45	50	60	86	72	72	94	76	77	307
08:00	62	96	71	87	78	77	93	79	304
08:15	69	66	76	63	78	42	99	72	300
08:30	68	93	67	80	91	75	95	79	298
08:45	80	76	86	71	63	88	80	73	289
09:00	60	58	82	81	63	68	77	75	277
09:15	57	71	71	65	74	89	72	70	262
09:30	60	71	73	65	72	68	68	70	248
09:45	63	70	64	59	62	59	60	62	239
10:00	58	56	64	60	58	44	53	61	230
10:15	56	52	53	64	51	44	55	56	234
10:30	47	45	53	72	56	63	51	60	236
10:45	49	59	54	53	51	77	57	53	242
11:00	75	59	70	63	61	67	61	65	255
11:15	70	63	72	56	46	61	67	58	259
11:30	63	61	83	54	63	69	59	67	266
11:45	75	89	65	69	62	68	74	65	276
12:00	79	71	71	78	59	69	68	69	304
12:15	89	69	74	61	58	84	46	64	324
12:30	63	78	89	64	77	68	66	77	364
12:45	100	76	95	89	96	91	76	93	393
13:00	101	94	90	90	90	82	89	90	425
13:15	125	110	101	107	103	94	106	104	459
13:30	110	109	103	109	106	95	90	106	485
13:45	129	138	116	119	141	124	119	125	512
14:00	112	115	124	131	118	114	114	124	536
14:15	129	138	127	132	128	114	120	129	566
14:30	152	145	123	134	144	132	126	134	608
14:45	165	165	135	146	165	130	160	149	662
15:00	190	173	147	142	176	140	140	155	691
15:15	202	190	158	164	190	189	154	171	708
15:30	196	190	179	179	206	189	171	188	706
15:45	238	211	177	171	185	179	173	178	668

*Note: Due to logistical reasons, Sunday volumes from 0:00 to 13:00 were obtained from Sunday, August 30, 2015. Volumes from 13:15 to 23:45 were obtained from Sunday, August 23, 2015.

ATR SUMMARY TABLE - VEHICLE COUNTS									
Interval Beginning	LOCATION No	7							
	STREET NAME	Entrance Ramp to Terminal 8 from Van Wyck Expressway							
	DESCRIPTION	ATR							
	DATA TYPE	RAW VEHICLES							
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	Sunday*	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday		
16:00	207	185	169	177	169	160	152	172	651
16:15	201	159	170	151	186	165	169	169	597
16:30	204	186	140	154	154	167	146	149	535
16:45	188	134	165	136	183	162	131	161	489
17:00	161	120	108	112	133	127	126	118	423
17:15	154	93	90	120	110	111	126	107	393
17:30	144	71	99	92	118	110	103	103	386
17:45	100	82	96	96	95	98	115	96	386
18:00	105	85	83	93	94	103	96	90	413
18:15	96	99	80	107	105	103	100	97	458
18:30	109	105	110	103	97	119	119	103	503
18:45	156	92	105	139	122	102	116	122	544
19:00	131	106	140	130	136	111	134	135	549
19:15	147	106	153	129	145	127	116	142	519
19:30	135	119	157	123	153	147	103	144	466
19:45	134	121	128	117	136	112	104	127	404
20:00	125	120	109	113	95	125	99	106	354
20:15	137	97	95	86	89	105	83	89	316
20:30	114	94	78	89	81	102	88	83	301
20:45	95	82	71	83	77	87	75	77	297
21:00	81	83	66	70	68	112	109	68	300
21:15	98	106	79	86	54	81	123	73	321
21:30	108	96	85	77	76	78	114	79	325
21:45	113	84	90	64	85	96	118	80	301
22:00	89	75	79	95	93	83	107	89	279
22:15	71	71	82	76	72	58	75	77	236
22:30	72	70	65	53	49	71	79	56	203
22:45	76	60	60	51	61	65	69	57	197
23:00	74	59	42	44	54	39	58	47	189
23:15	74	64	36	39	56	42	66	44	
23:30	38	45	38	47	64	44	58	50	
23:45	43	54	48	51	48	36	64	49	
24 HR VOL	8,752	8,005	7,722	7,782	8,037	7,865	8,068	7,847	

AM Peak Hour								
HR BEG	05:00	05:15	05:00	05:00	05:15	05:15	05:15	05:00
HR VOL	448	523	407	451	444	456	470	424
P.H.F.	0.82	0.81	0.93	0.93	0.95	0.92	0.93	0.97

PM Peak Hour								
HR BEG	15:45	15:15	15:30	15:15	15:00	15:15	15:30	15:15
HR VOL	850	776	695	691	757	717	665	708
P.H.F.	0.89	0.92	0.97	0.97	0.92	0.95	0.96	0.94

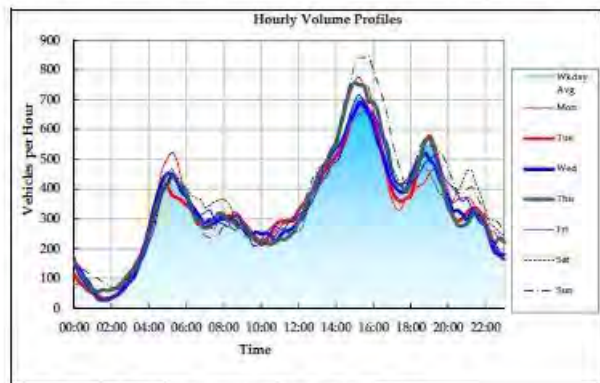


Figure 78: Sample format for ATR count

4. Turning Movement Counts (TMC)

Turning Movement Counts (TMC) video cameras should be installed at key intersections to record continuous traffic volumes by movement during the study period. Data collected from the TMCs show the distribution of vehicular and pedestrian movements at each intersection. The turning movement count volume data should be aggregated in 15-minute and hourly intervals for all vehicular and

- On-Airport Buses/Vans (Employee buses, Airline inter-terminal shuttles, etc.);
- Off-Airport Buses/Vans (Hired Shuttles, Parking Shuttles, Charter buses, etc.);
- Delivery Vehicles (UPS, FedEx, Food Deliveries, etc.);
- Authorized Vehicles (Police cars, Maintenance vehicles, Security vehicles, etc.); and,
- Other (Outside contractor's maintenance vehicles, Tow trucks, etc.).

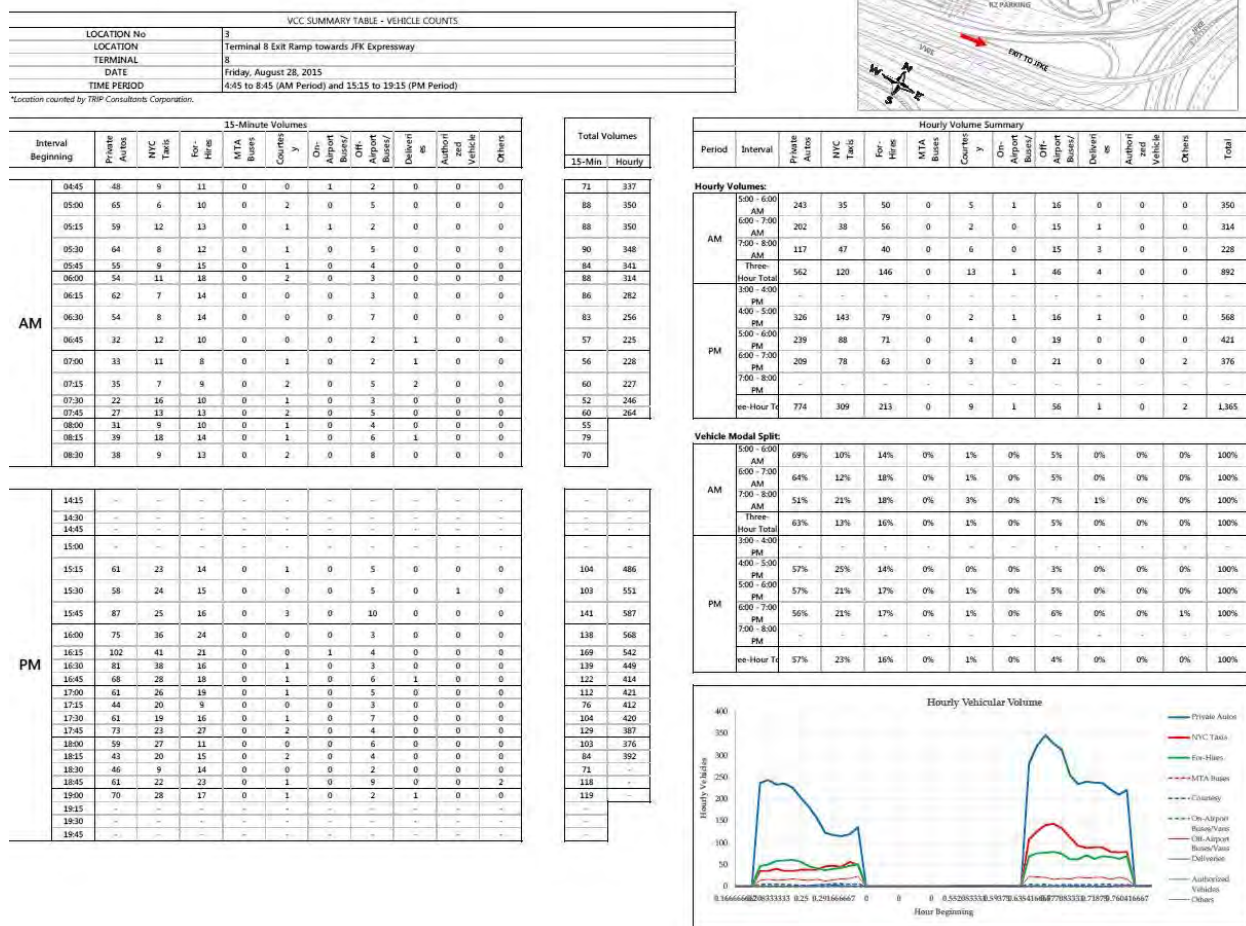


Figure 80: Sample format for VCC count

6. Terminal Frontage Operational Counts

Terminal Frontage video cameras are to be installed at the individual terminal frontages to record sample vehicle occupancies and dwell times by the ten vehicle types identified above. Video equipment should be deployed at multiple locations along the active terminal frontages of each of the airport terminals to record 24-hour patron activity. Eight hours of recorded video footage centered on the weekday 6:00 AM to 10:00 AM peak and the 4:00 PM to 8:00 PM peak periods should be used to calculate vehicle occupancy. The parameters are to be measured from sampled vehicles that stopped at each frontage lane to conduct a transaction (drop-off or pick-up passengers). The counts are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed

not to be a typical weekday, the counts shall be performed on an alternative weekday within the survey period.

The dwell time are to be measured from the beginning that a vehicle stopped at the frontage and ended when the vehicle began to leave its parked position at the frontage. The occupancy is to be measured as the number of passengers who alighted or boarded the vehicle. The counts are to be summarized by 15-minute and hourly intervals.

The video recording should also be used to identify the number of vehicles parked in the second and third frontages lanes, queue lengths, queue durations, and average vehicle delays both for through traffic and curbside pick-up and drop-off.

When compared to approach ramp ATR counts, the video recordings can be used to separate through and recirculation traffic from traffic destined to the frontage curbs.

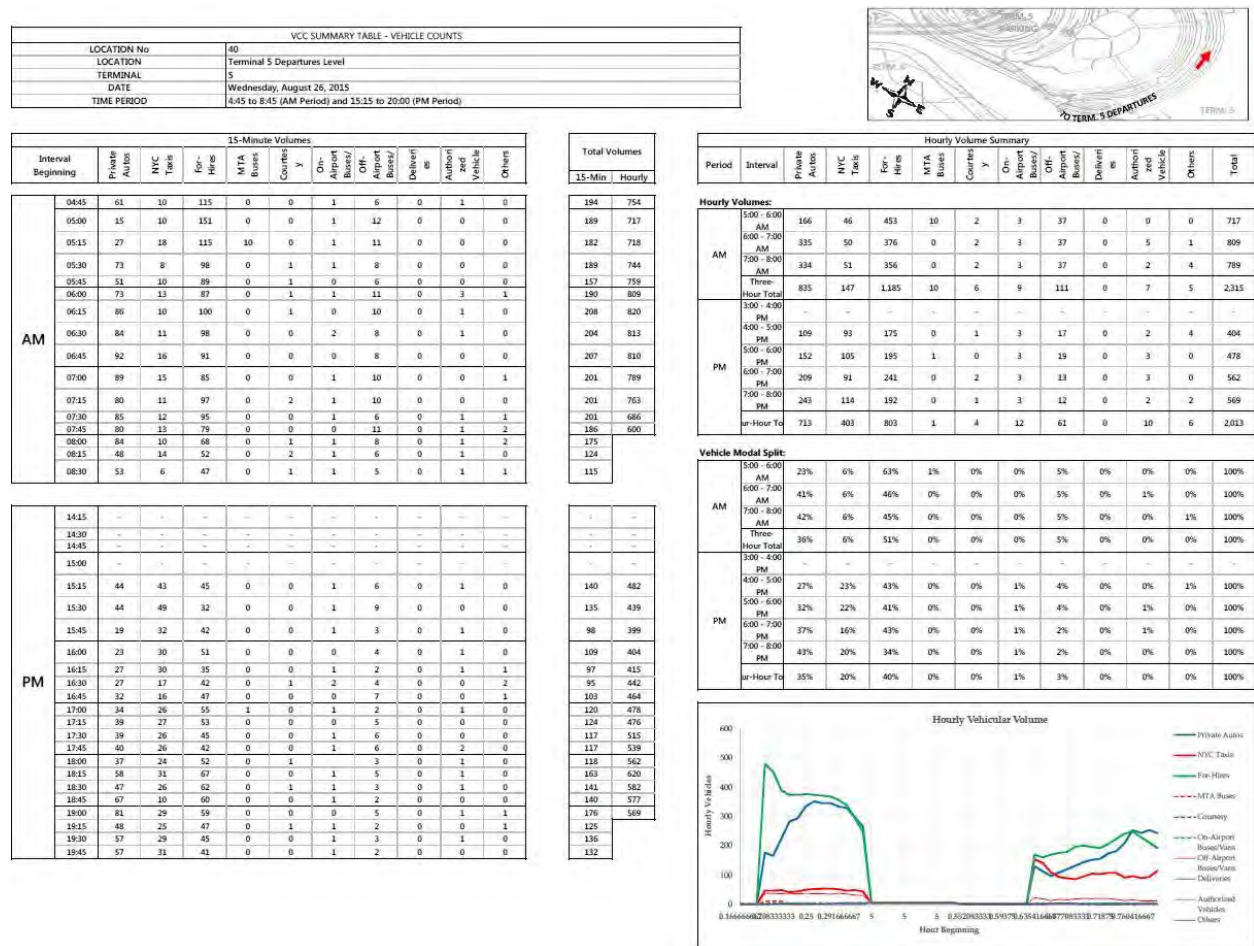


Figure 81: Sample format for frontage count

DOMESTIC TERMINAL - ANALYSIS VEHICLE DWELL TIMES AND OCCUPANCY RATES (Terminal 5)

Frontage	Vehicle Class	Dwell Time (sec)		Vehicle Occupancy Rate		Sample Size (No. of Vehicles)		% Breakdown by Vehicle Length Group				Equivalent Vehicle Length
		AM	PM	AM	PM	AM	PM	Cars	Vans (AM/PM)	Mini Buses (AM/PM)	Large Buses (AM/PM)	
Departing Flights	Private Autos	109	126	1.85	1.54	298	168	100%	-	-	-	25
	Taxis	78		1.51		67		100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	92	110	1.87	1.66	163	136	100%	-	-	-	25
	Public Transit/Coach Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles[1]	59		4.20		5		-	40%	60%	-	35
	On-Airport Buses/Vans	252		5.75		4		-	-	75%	25%	36
	Off-Airport Buses/Vans	100		3.35		40		-	50%	45%	5%	36
Arriving Flights	Private Autos	122	99	1.72	1.87	95	105	100%	-	-	-	25
	Taxis	89	120	1.33	1.48	183	150	100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	100		1.82		152		100%	-	-	-	25
	Public Transport Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles[1]	99		2.00		1		-	-	100%	-	35
	On-Airport Buses/Vans	217		1.50		2		-	100%	-	-	36
	Off-Airport Buses/Vans	229		2.68		19		-	69%	26%	5%	36

INTERNATIONAL TERMINAL - ANALYSIS VEHICLE DWELL TIMES AND OCCUPANCY RATES (Terminal 7)

Frontage	Vehicle Class	Dwell Time (sec)		Vehicle Occupancy Rate		Sample Size (No. of Vehicles)		% Breakdown by Vehicle Length Group				Equivalent Vehicle Length
		AM	PM	AM	PM	AM	PM	Cars	Vans (AM/PM)	Mini Buses (AM/PM)	Large Buses (AM/PM)	
Departing Flights	Private Autos	144		1.74		39		100%	-	-	-	25
	Taxis	97		1.59		269		100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	134		1.38		53		100%	-	-	-	25
	Public Transit/Coach Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles	-		-		-		-	-	-	-	35
	On-Airport Buses/Vans	-		-		-		-	-	-	-	36
	Off-Airport Buses/Vans	297		3.31		26		-	77%	4%	19%	36
Arriving Flights	Private Autos	133		1.69		310		100%	-	-	-	25
	Taxis	94		1.39		104		100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	94		1.45		269		100%	-	-	-	25
	Public Transit/Coach Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles	117		3.38		8		-	25%	75%	-	35
	On-Airport Buses/Vans	51		2.50		2		-	-	50%	50%	36
	Off-Airport Buses/Vans	101	129	3.03	4.23	38	57	-	58% / 63%	26% / 16%	16% / 21%	36

DOMESTIC/INTERNATIONAL TERMINAL - ANALYSIS VEHICLE DWELL TIMES AND OCCUPANCY RATES (Terminal 4)

Frontage	Vehicle Class	Dwell Time (sec)		Vehicle Occupancy Rate		Sample Size (No. of Vehicles)		% Breakdown by Vehicle Length Group				Equivalent Vehicle Length
		AM	PM	AM	PM	AM	PM	Cars	Vans (AM/PM)	Mini Buses (AM/PM)	Large Buses (AM/PM)	
Departing Flights	Private Autos	149	170	1.85	1.97	700	616	100%	-	-	-	25
	Taxis	89	108	1.48	1.75	160	239	100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	100	109	1.69	1.95	499	622	100%	-	-	-	25
	Public Transit/Coach Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles	122		4.66		35		-	49%	51%	-	35
	Off-Airport	110	129	3.69	4.16	80	106	-	58%	34%	8%	36
	All Others	272		-		-		100%	-	-	-	36
Arriving Flights	Private Autos	158	171	1.77	2.02	232	273	100%	-	-	-	25
	NYC Taxis	106	101	1.59	1.89	359	377	100%	-	-	-	25
	For-Hire (Limo's, TNC, etc.)	164	149	1.63	2.01	193	289	100%	-	-	-	25
	Public Transit/Coach Buses	-	-	-	-	-	-	-	-	-	-	-
	Courtesy Vehicles[1]	116		2.67		3		-	100%	-	-	35
	Off-Airport[2]	455	331	3.56	3.72	32	46	-	64%	21%	15%	36
	All Others	197		-		-		100%	-	-	-	36

Figure 82: Sample format for dwell and occupancy count

Vehicle Class	Departures								Arrivals							
	AM Period (5 to 9 AM)				PM Period (3 to 7 PM)				AM Period (5 to 9 AM)				PM Period (3 to 7 PM)			
	4-Hour Volume	Vehicle Modal Split	Occ. Rate	Pax Modal Split	4-Hour Volume	Vehicle Modal Split	Occ. Rate	Pax Modal Split	4-Hour Volume	Vehicle Modal Split	Occ. Rate	Pax Modal Split	4-Hour Volume	Vehicle Modal Split	Occ. Rate	Pax Modal Split
Private Autos	1,523	54.5%	1.85	53.1%	1,357	42.6%	1.97	40.4%	824	43.2%	1.77	42.6%	1,328	46.6%	2.02	45.1%
Taxis	260	9.3%	1.48	7.3%	456	14.3%	1.75	12.0%	663	34.8%	1.59	30.8%	921	32.3%	1.89	29.2%
For-Hire (Limo's, TNC, etc.)	805	28.8%	1.69	25.7%	1,117	35.1%	1.95	32.8%	195	10.2%	1.63	9.3%	287	10.1%	2.01	9.7%
Public Transit/Coach Buses			1.8	4.2			1.9	4.2			2	4.5			2.1	5
Courtesy Vehicles[1]	46	1.6%	4.66	4.0%	22	0.7%	4.66	1.5%	18	0.9%	2.67	1.4%	2	0.1%	2.67	0.1%
On-Airport Buses/Vans									6	0.3%			4	0.1%		
Off-Airport Buses/Vans	142	5.1%	3.69	9.9%	211	6.6%	4.18	13.3%	153	8.0%	3.56	15.9%	255	8.9%	3.72	15.9%
Others	16	0.6%			20	0.6%			47	2.5%			55	1.9%		
Total	2,792	100%	1.90	100%	3,183	100%	2.08	100%	1,906	100%	1.80	100%	2,852	100%	2.09	100%

(A) Excludes recirculating vehicles and vehicles parking via the frontage road

Figure 83: Sample format for mode split calculation

7. Terminal to/from Parking Passenger Counts

Terminal to/from parking passenger count shall be conducted at each CTA parking facility to collect passenger volume between terminals and parking in both directions. These counts shall be conducted for one typical weekday at each terminal. The data collection shall cover a total of 15 hours on a weekday from 4:00 AM to 10:00 AM and from 1:00 PM to 10:00 PM. The counts are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed not to be a typical weekday, the counts shall be performed on an alternative weekday within the survey period. The counts are to be summarized by 15-minute and hourly intervals.

8. Parking Data Collection

A parking study is required to evaluate the parking demand needs for the airport. Parking data containing the exact time that vehicles entered and exited the parking facilities shall be gathered and processed to illustrate the parking utilization throughout a typical day. Fifteen (15) minute entering and exiting volumes are to be obtained for each parking facility for a consecutive two-week period including the overall survey week. In addition, an on-site parking utilization survey should be conducted during the midday period on a typical weekday.

Traffic volumes entering and exiting on-airport parking lots are to be calculated for the 4:00 AM to 10:00 AM and 1:00 PM to 10:00 PM peak periods on a typical weekday (i.e., Tuesday - Thursday) using the 24-hour entry and exit transaction data provided by airport parking operator. The counts are to be summarized by 15-minute and hourly intervals. The counts are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed not to be a typical weekday, the counts shall be performed on an alternative weekday within the survey period.

To calculate the parking utilization for each parking facility, the entry and exit volumes are applied to the parking utilization numbers obtained from the on-site survey for the midday period. The daily turnover, or the amount of spaces made available for additional parking, should varies for each parking facility. These rates are calculated by dividing the daily exiting volumes by the capacity for each parking lot.

9. Cell Phone Lot and TNC Hold Area Counts

Vehicle entry and exit counts shall be conducted at each Cell Phone Lots and TNC Hold Areas. These counts shall be conducted for one typical weekday at each facility. The data collection shall cover a total of 15 hours on a weekday from 4:00 AM to 10:00 AM and from 1:00 PM to 10:00 PM. The counts are to be summarized by 15-minute and hourly intervals.

The information is necessary to support the design team in identifying cell phone lot and TNC hold sizing requirements. The information should identify the maximum accumulation of vehicles in the cell phone lots and TNC hold areas to determine sizing needs.

The counts are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed not to be a typical weekday, the counts shall be performed on an alternative weekday within the survey period.

10. Taxi Operation Survey

Traffic operation survey should be conducted at taxi hold areas (parking areas where taxis must wait before being sent to terminal frontages to pick up passengers on the arrivals level), taxi pocket areas (areas where taxis queue in the vicinity of the arrivals level frontage before reaching the taxi dispatch location and picking up fares), and at the curbside passenger pick-up areas. The survey should be conducted for a total of 15 hours on a weekday from 4:00 AM to 10:00 AM and from 1:00 PM to 10:00 PM for each terminal. The counts are to be summarized by 15-minute and hourly intervals.

The information is necessary to support the design team in identifying taxi hold sizing requirements. The data shall include in/out counts at taxi hold areas and queue length measurements at taxi pocket areas near terminal frontages. The information will also identify the maximum accumulation of taxis in the hold area to determine sizing needs.

The taxi volumes entering and exiting taxi hold areas can be obtained using a combination of automatic traffic recorder (ATR), video recordings and manual counts, and if available from the taxi hold dispatcher. The taxi hold dispatcher information should identify the terminal to which the taxi is sent.

At the curbside passenger pick-up areas, the time passengers need to wait to board a taxi and the length of the resulting passenger queue also needs to be recorded for a total of 15 hours on a weekday from 4:00 AM to 10:00 AM and from 1:00 PM to 10:00 PM. The counts are to be summarized by 15-minute and hourly intervals. The information should identify average and maximum queue lengths and durations.

The counts are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed not to be a typical weekday, the counts shall be performed on an alternative weekday within the survey period.

11. Travel Speed Runs

A series of travel time runs should be performed along the main access routes to the airport from respective originating points outside of the CTA to midpoints located at the most attractive point along approach ramp to the arrival and departure frontage of each terminal. Control points need to be established at distinctive points along the frontage approach ramps. The travel time runs should end at a location outside of the CTA in the vicinity of the originating point. Thus, each run will record the travel time to the terminal and the travel time from the terminal for the selected route.

The travel times should be collected using the floating car method by traveling with general traffic during the weekday 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak hours for the airport and for the terminal frontages. The targeted number of runs per travel time route should be a minimum of two runs per terminal frontage peak hour. The travel time runs should be conducted using a combination of

GPS devices to store timestamps and record corresponding coordinates, and a manual travelogue to indicate speeds at particular locations, stop delay causes and times, and record travel speeds along the individual frontages. If the vehicle is stopped at a red traffic signal, the number of signal cycles to advance through the intersection should be recorded.

The travel time speed runs are to be performed for a typical weekday, free of major incidents. If the day, the counts are conducted is deemed not to be a typical weekday, the travel time speed runs shall be performed on an alternative weekday within the survey period.

	Van Wyck Expressway					JFK Expressway				
	Segment	# of Runs	Distance (mi)	Average Speed (mph)	Travel Time (min)	Segment	# of Runs	Distance (mi)	Average Speed (mph)	Travel Time (min)
Terminal 8	Peak Hour 5:30AM-6:30AM Arrivals									
	Start - Airtrain	2	0.34	41	0.50					
	Airtrain - 1	2	1.40	49	1.74	Start - 1	2	0.95	41	1.41
	1 - 8A.2	2	0.72	29	1.47	1 - 8A.2	2	0.21	36	0.35
	8A.2 - 8A.3	2	0.25	11	1.28	8A.2 - 8A.3	2	0.21	11	1.32
	8A.3 - 1	2	0.30	29	0.80	8A.3 - 1	2	0.47	30	0.98
	1 - Airtrain	2	1.40	46	1.82	1 - End	2	0.97	42	1.41
	Airtrain - End	-	-	-	-					
	Total				7.62	Total				5.47
	Peak Hour 5:30AM-6:30AM Departures									
	Start - Airtrain	2	0.37	45	0.47					
	Airtrain - 1	2	1.40	54	1.55	Start - 1	2	0.96	47	1.23
	1 - 8D.2	2	0.74	38	1.17	1 - 8D.2	3	0.23	24	0.70
	8D.2 - 8D.3	2	0.23	19	0.75	8D.2 - 8D.3	3	0.24	16	0.89
	8D.3 - 1	2	0.70	25	1.71	8D.3 - 1	3	0.51	35	0.91
	1 - Airtrain	2	1.40	55	1.54	1 - End	3	0.97	48	1.21
	Airtrain - End	1	0.39	47	0.50					
	Total				7.69	Total				4.94

- Start - Southbound Van Wyck Expressway at Belt Parkway
Southbound JFK Expressway at 150th Avenue
- 1 - An All Terminal sign on the overpass structure along JFK Expy
All Terminal overhead sign structure along Van Wyck Expy
- Airtrain - Overhead Airtrain Tracks
- A2;A3 - Arrivals Frontage Entrance; Arrivals Frontage Exit
- D2;D3 - Departures Frontage Entrance; Departures Frontage Exit
- End - Northbound Van Wyck Expressway at Belt Parkway
Northbound JFK Expressway at 150th Avenue

Figure 84: Sample travel time study

4. AirTrain Passenger Survey

The AirTrain Passenger Count Survey shall be conducted at each AirTrain station using video recordings and field personnel and shall include the following:

a. Station Passenger Counts

The station passenger count data shall be collected over seven continuous 24-hour days during the survey period. The cameras shall record data, for each train line, at each station, in 5-minute intervals for the following:

- Total number of passengers entering the station, with or without a baggage cart;

- Number of passengers entering the station with a baggage cart;
- Total number of passengers exiting the station, with or without a baggage cart;
- Number of passengers exiting the station with a baggage cart;
- Percentage of employees entering and exiting the station; and,
- Total number of passengers boarding and alighting each AirTrain car by train line and collecting train arrival time for one weekday and one weekend day during the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak periods.

AirTrain passengers shall be classified as employees if they wear a uniform or possess a visible ID. All other passengers shall be classified as non-employees. Passenger volumes shall be summarized in 15-minute and hourly intervals for each station.

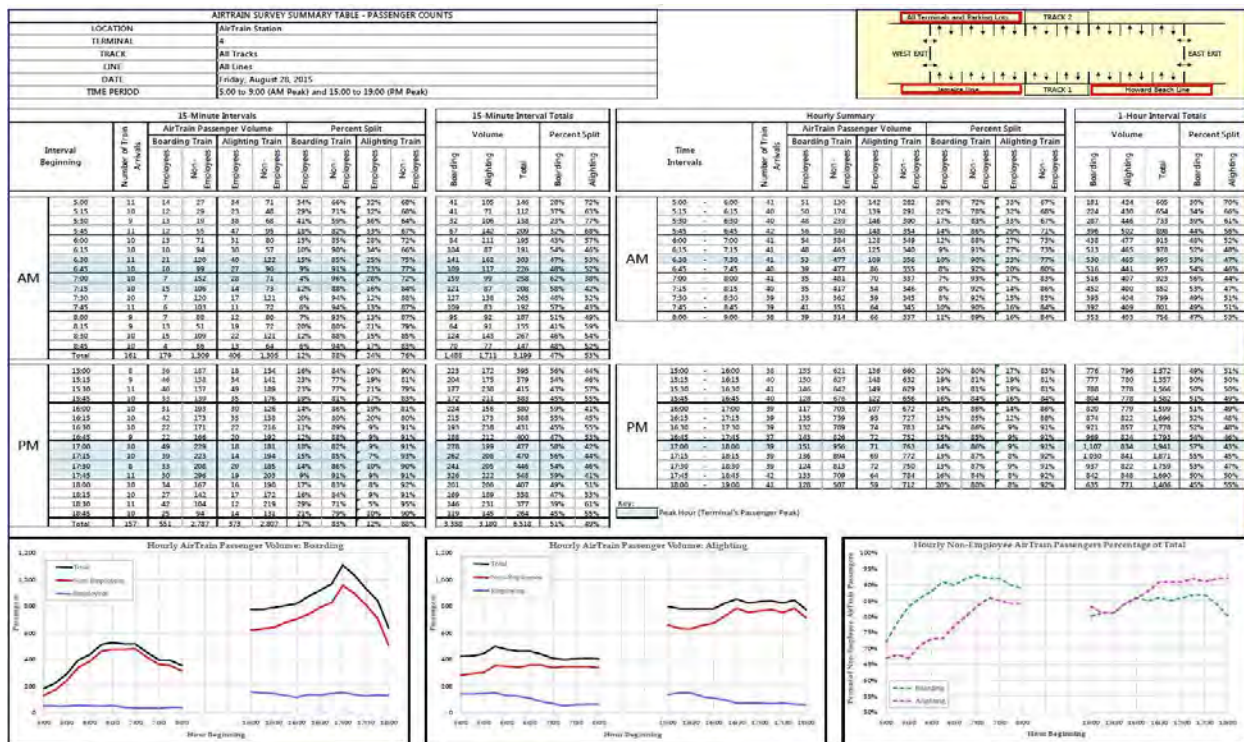


Figure 85: Sample format for AirTrain passenger count

b. Station Origin and Destination Counts (O-D Counts)

The station O-D counts shall be collected for one weekday from 12:00 AM through 11:59 PM. The following two actions are to be performed:

Distribute one color-coded 3" x 5" card to each passenger entering the station. Each station shall have a unique color card. Record the unique identifier sequence number of the cards distributed within each hour.

Collect color-coded 3" x 5" cards from as many passengers exiting station as practical. Do not record the time.

Data on the distribution of O-D survey cards shall be tabulated by station and hour using the unique identifier on each card. The O-D survey cards collected shall be sorted to determine the number of cards collected at each station in each hour of the survey. The counts are to be summarized by 15-minute and hourly intervals. A proper sample size for the survey must be provided for accuracy. The sample size must be submitted for approval prior to implementing the survey



Figure 86: Sample format for AirTrain link comparison

c. AirTrain Car Passenger Occupancy

The AirTrain car passenger occupancy data should be collected for one weekday and one weekend day during the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak periods. The counts are to be summarized by 15-minute and hourly intervals. Data shall be recorded between every station stop for the following:

- Total number of passengers in the AirTrain car without baggage; and,
- Total number of passengers on the AirTrain car with baggage; including number of bags per passenger and baggage type.

d. AirTrain Headway, Dwell Time, and Passenger Congestion Counts

AirTrain headway and dwell time data shall be collected for each pair of adjacent AirTrain stations. The data will be collected simultaneously with the AirTrain passenger counts. The data shall be collected for one weekday and one weekend day during the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak

periods. Data on start time, headway, and dwell time shall be collected for each train at each station in each direction of travel. Data shall be recorded in the format [hour: minute: second] to the nearest whole second, using a 24-hour clock [e.g., ISO standard 8601]. The counts are to be summarized by 15-minute and hourly intervals.

e. Station Queuing

Station queuing shall be recorded at each station for the number of passengers who are not able to board the AirTrain, while specifying the reason for each instance (e.g., train car capacity exceeded; station congestion, or other). This data shall also be collected simultaneously with the AirTrain passenger counts and the headway and dwell times. The information shall be recorded on the data collection forms under a column called “number of passengers left” with a “reason” column next to it. The counts are to be summarized by 15-minute and hourly intervals.

f. Event Log

A log of events per station shall be kept throughout the Survey Period to record any notable occurrences or anomalies including the time of occurrence and duration (e.g., AirTrain doors held open, AirTrain doors recycled, or other).

5. Air Passenger Interview Surveys

Airport Passenger Interview Surveys shall be conducted at each of the individual terminals to obtain information regarding air passenger characteristics such as arrival time before flight departure, airport access, trip origins, and the use of ground transportation modes. The direct interviewing of departing air passengers in the waiting areas at the departure gates and the baggage claim area for arriving passengers will be utilized to ensure the appropriate target audience responds to the survey and generates positive cooperation rates. A proper sample size for the survey must be provided for accuracy and submitted for approval prior to implementing the survey. The data shall be collected over two continuous weekdays during the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak periods.

The surveys are to be performed for a typical weekday, free of major incidents. If the day the counts are conducted is deemed not to be a typical weekday, the surveys shall be performed on an alternative weekday within the study period.

A sample interview form is shown below.

1. Type of Flight

International Flight
Domestic Flight

2. Purpose of Flight

Business
Pleasure

3. O/D Passenger Mode of Access

Private Car
Private Car parked at Airport
Rental Car
Taxi
Limousine/Town Car
Uber/Lyft
Super Shuttle/Shared Ride Van
Coach Bus
Train/Subway/AirTrain
Off-Airport Parking/Hotel Shuttle

4. Local Passenger Origin/Destination

Home Zip Number _____

5. Buffer Time Spent at Airport

Time at Airport prior to Flight (Departures) _____

Time at Airport after Flight (Arrivals) _____

6. Travel Group Size

Number of Air Passengers _____

Number of Visitors (did not fly) _____

Figure 87: Sample passenger survey form

6. Existing and Future Design Day Flight Schedules (DDFS)

Typically obtain from the airlines or the terminal developer, the DDFS identifies the terminal that the aircraft arrived to or departed from, aircraft arrival and departure times, aircraft capacity and aircraft load factor. Information on passenger type, origin/destination or transfer, also needs to be obtained. A sample DDFS and connection percentage matrix is shown below.

Operator	Equipment	Seats	ArrOrigin	ArrFlightNumber	ArrSchTime	DepDestination	DepFlightNumber	DepSchTime	Stand minutes	Arrival Market	Departure Market	Arrival Terminal	Departure Terminal	Arr Pax	Dep Pax
DL	78W	226	LAX	16	7/31/2014 16:48	LAX	427	7/31/2014 20:00	192	DOM	DOM	Terminal 4	Terminal 4	203	215
DL	78W	226	LAX	16	7/31/2014 17:48	LAX	427	7/31/2014 21:00	192	DOM	DOM	Terminal 4	Terminal 4	203	215
OS	772	308	AMS	639	7/30/2014 10:35	VIE	87	7/31/2014 13:55	1640	INT	INT	Terminal 1	Terminal 1	277	293
MU	346	324	PVG	587	7/30/2014 14:25	PVG	588	7/31/2014 16:25	1560	INT	INT	Terminal 1	Terminal 1	292	308
DL	764	246	ARN	203	7/30/2014 15:54	BOG	449	7/31/2014 12:30	1236	INT	INT	Terminal 4	Terminal 4	221	234
SU	77W	365	SVO	102	7/30/2014 17:20	SVO	103	7/31/2014 19:10	1550	INT	INT	Terminal 1	Terminal 1	329	347
AA	32B	102	SFO	164	7/30/2014 17:30	LAX	117	7/31/2014 15:00	1290	DOM	DOM	Terminal 8	Terminal 8	92	97
B6	E90	100	AUS	1094	7/30/2014 17:53	ROC	586	7/31/2014 09:44	961	DOM	DOM	Terminal 5	Terminal 5	90	95
AA	738	148	STT	1074	7/30/2014 18:00	POS	425	7/31/2014 00:55	415	DOM	INT	Terminal 8	Terminal 8	133	141
AA	32B	102	LAX	2	7/30/2014 18:00	LAX	3	7/31/2014 12:30	1110	DOM	DOM	Terminal 8	Terminal 8	92	97
B6	E90	100	BUF	2601	7/30/2014 18:04	AUS	795	7/31/2014 09:29	925	DOM	DOM	Terminal 5	Terminal 5	90	95
JL	788	186	NRT	4	7/30/2014 18:25	NRT	3	7/31/2014 09:40	915	INT	INT	Terminal 1	Terminal 1	167	177
B6	321	190	LAS	711	7/30/2014 18:59	PUJ	869	7/31/2014 08:20	801	DOM	INT	Terminal 5	Terminal 5	171	181
AA	738	148	SJU	1472	7/30/2014 19:00	PTY	807	7/31/2014 01:45	405	DOM	INT	Terminal 8	Terminal 8	133	141
AA	32B	102	LAX	172	7/30/2014 19:00	LAX	19	7/31/2014 11:00	960	DOM	DOM	Terminal 8	Terminal 8	92	97
DL	321	190	SEA	1473	7/30/2014 19:11	BOS	439	7/31/2014 12:59	1068	DOM	DOM	Terminal 4	Terminal 4	171	181
DL	73H	160	LAS	2658	7/30/2014 19:20	SLC	463	7/31/2014 11:52	992	DOM	DOM	Terminal 4	Terminal 4	144	152
B6	E90	100	BOS	1317	7/30/2014 19:24	BTU	1634	7/31/2014 09:19	835	DOM	DOM	Terminal 5	Terminal 5	90	95
9E	CR9	76	SAV	3319	7/30/2014 19:29	RDU	2932	7/31/2014 08:30	781	DOM	DOM	Terminal 4	Terminal 4	68	72
AA	320	150	RDU	3295	7/30/2014 19:30	DCA	3225	7/31/2014 11:00	930	DOM	DOM	Terminal 8	Terminal 8	135	143
9E	CR9	76	IAD	6127	7/30/2014 19:30	BUF	2906	7/31/2014 08:15	765	DOM	DOM	Terminal 4	Terminal 4	68	72
9E	CR9	76	DTW	3364	7/30/2014 19:35	CHS	2962	7/31/2014 08:10	755	DOM	DOM	Terminal 4	Terminal 4	68	72
AA	738	150	DCA	1029	7/30/2014 19:40	MIA	1085	7/31/2014 09:00	800	DOM	DOM	Terminal 8	Terminal 8	135	143
9E	CR9	76	DCA	3394	7/30/2014 19:40	ACK	2975	7/31/2014 08:05	745	DOM	DOM	Terminal 4	Terminal 4	68	72
9E	CR9	76	CMH	6068	7/30/2014 19:40	MSY	2888	7/31/2014 08:10	750	DOM	DOM	Terminal 4	Terminal 4	68	72
DL	73H	160	STI	327	7/30/2014 19:49	SAN	2506	7/31/2014 10:20	871	INT	DOM	Terminal 4	Terminal 4	144	152
AA	32B	102	LAX	12	7/30/2014 20:00	SFO	179	7/31/2014 10:30	870	DOM	DOM	Terminal 8	Terminal 8	92	97
B6	E90	100	ORD	606	7/30/2014 20:00	SYR	116	7/31/2014 09:10	790	DOM	DOM	Terminal 5	Terminal 5	90	95
DL	321	190	SFO	468	7/30/2014 20:02	SFO	432	7/31/2014 11:45	943	DOM	DOM	Terminal 4	Terminal 4	171	181
CX	77W	275	YVR	889	7/30/2014 20:10	HKG	845	7/31/2014 01:30	320	PRE	INT	Terminal 7	Terminal 7	248	261
B6	321	190	SDQ	410	7/30/2014 20:15	MCO	583	7/31/2014 06:00	585	INT	DOM	Terminal 5	Terminal 5	171	181
9E	CR9	76	ROC	6144	7/30/2014 20:15	JAX	2919	7/31/2014 08:00	705	DOM	DOM	Terminal 4	Terminal 4	68	72

Figure 88: Sample DDFS format

Operation Type	Origination / Destination	Connection	Load Factor
DAL - International / Pre-cleared	57.70%	42.30%	90%
DAL - Domestic Mainline	85.92%	14.08%	90%
DAL - Regional Jet	55.10%	44.90%	90%
IAT - International/ Domestic	90.00%	10.00%	90%

Source: Phase 3 Delta JFK IAT Planning Assumptions provided by Delta

Figure 89: Sample O&D and connection profiles

7. Passenger Arrival Curves at the Frontage

The distribution of time before/after flight departure/arrival times that passengers arrive to the frontage is referred to as a frontage arrival curve. These are typically obtained from air passenger interview surveys, the airlines, or the terminal developer. Originating passengers arrive at the airport before their departing flight allowing time for check-in, security screening, concessions, and flight boarding. Terminating passengers deplane and traverse the terminal to collect their checked bags if any at baggage claims. Terminating passengers will then proceed to the curbside based on their transportation need.

Minutes Before Scheduled Departure	Domestic Arrivals	International Arrivals
15-30	0.93%	0.24%
30-45	2.87%	0.47%
45-60	7.04%	1.17%
60-75	15.00%	4.39%
75-90	17.97%	7.47%
90-105	15.73%	11.00%
105-120	11.64%	13.17%
120-135	7.79%	14.23%
135-150	5.20%	12.19%
150-165	3.28%	9.08%
165-180	2.06%	6.28%
180-195	1.41%	4.43%
195-210	1.08%	3.20%
210-225	0.67%	2.30%
225-240	0.64%	1.76%
240-255	0.45%	1.10%
255-270	0.35%	0.98%
270-285	0.28%	0.69%
285+	5.61%	5.85%

Source: Phase 3 Delta JFK IAT Planning Assumptions provided by Delta

Figure 90: Sample show-up profile

	Departures		Arrivals	
	AM Period (5 to 9 AM)	PM Period (3 to 7 PM)	AM Period (5 to 9 AM)	PM Period (3 to 7 PM)
Frontage [1]	77%	69%	62%	64%
Air-Train Utilization [2]	16%	27%	24%	20%
Straight to Parking [3]	7%	4%	14%	16%

[1] Includes passengers from curb-and-park operations and passengers from vehicles that enter the parking lot via the recirculation entrance after unsuccessful attempts to use the curb

[2] Peak hour AirTrain utilization

[3] Straight to parking pax percentages during the 4-hour period

Figure 91: Sample air passenger distribution

8. Traffic Volume Forecasting Methodology

a. Existing Traffic Volume Forecast

Before developing traffic volume forecasts for the future analysis years, existing traffic volumes are forecast at each of the terminal frontages by converting air passenger volumes derived from the existing (base case) condition DDFS into traffic volumes and comparing the projected volumes to traffic volume count data.

The existing DDFS flight schedule includes air passenger volumes, which take into account load factors (the percentage of seats occupied on flights) and transfer rates (the percentage of passengers connecting to other flights that are not originating or departing [O-D] passengers). The air passengers at the gate need to be adjusted with the frontage arrivals curves to account for the time distribution of departing passengers at the departures level frontage before their scheduled flight departure time and the time distribution of arriving passengers at the arrivals level frontage after their scheduled flight arrival time.

Different distributions are used for each terminal based on data obtained from the Air Passenger Survey. Separate arrival distributions are used for each terminal for flights departing before or after 9:00 AM.

Modal split, vehicle occupancy, and vehicle influence (vehicle length by mode type) data from the Data Collection Program and the Air Passenger Survey are used to convert the air passenger volumes at the terminal curbsides into vehicular volumes for autos, taxis and limos/for-hire vehicles. The number of autos, taxis and limos/for-hire vehicles at the curb is determined by subtracting autos that go directly to parking with further adjustments for re-circulation traffic. Existing volumes for other vehicle types (including buses) are obtained from vehicle classification counts conducted at the terminal curbsides. Adjustment factors are then developed to calibrate the existing traffic volume forecasts to existing traffic volume count data recorded in the Data Collection Program.

Using the vehicular O/D data obtain from the Data Collection Program and the Air Passenger Survey, the calibrated forecasted vehicle at the curb volume, vehicle to/from parking and re-circulation traffic are than applied the airport roadway network and compared to the balanced flow map generated from the ground counts. Additional calibration factors are then applied, as necessary, to converge the two data sets.

Convergence should be determined through use of a GEH Statistic to avoids pitfalls that occur when using simple percentages to compare two sets of volumes. This is because the traffic volumes in the real world vary over a wide range. For example, the mainline of a freeway might carry 5000 vehicles per hour, while one of the on-ramps leading to the freeway might carry only 50 vehicles per hour (in that situation it would not be possible to select a single percentage of variation that is acceptable for both volumes). The GEH statistic reduces this problem; because the GEH statistic is non-linear, a single acceptance threshold based on GEH can be used over a fairly wide range of traffic volumes

For establishing the "baseline" scenario, a GEH of less than 5.0 is considered a good match between the projected and observed hourly volumes (flows of longer or shorter durations should be converted to hourly equivalents to use these thresholds). As a minimum, 85% of the volumes in a traffic model should have a GEH less than 5.0. GEHs in the range of 5.0 to 10.0 warrant investigation. If the GEH is greater than 10.0, there is a high probability that there is a problem with either the forecast volumes or the

count data (this could be something as simple as a data entry error, or a complication forecast calculations).

b. Future Traffic Volume Forecast

Traffic volume forecasts for the future analysis years are calculated in a similar manner using the DDFS for each terminal, which also takes into account load factors and transfer rates. Passenger volumes are converted into vehicular volumes for autos, taxis and limos/for-hire vehicles using the existing modal split and vehicle occupancy data and the same adjustment factors used to calibrate the existing forecasts; traffic volumes for other vehicle modes (including scheduled buses, courtesy vehicles, on-airport buses, public transit buses, delivery vehicles, authorized vehicles and other vehicles) are increased using a projected annual background growth rate.

Growth factors are developed by dividing the future traffic volume forecasts by the existing traffic volume forecasts at each of the terminal frontages for hourly periods in rolling 10-minute intervals. Traffic volumes for each of the hourly periods in the future analysis year are then projected by multiplying the existing Base Year balanced traffic volumes by the corresponding growth factors, which are prorated to reflect growth occurring from existing to the future analysis year.

9. Existing Conditions (Base Case) Simulation Model Calibration

This section defines and describes the development process and strategies for the VISSIM model that will be used to analyze the landside facilities within the airport. The VISSIM model will be developed and simulated with two separate but integrated components; a Dynamic Traffic Assignment model and a Static Traffic Assignment model.

Dynamic traffic assignment performs the traffic assignment to select optimal travel routes from an origin point to destination point and, in turn, transmits the collected routes to the static traffic assignment for visual simulation and network performance assessment (i.e., curbside activities, vehicle dwell times, number of vehicles double parked, or the recurrence of vehicle circulating). Static traffic assignment will also be applied public transit, courtesy vehicles and on-/off-airport buses based on the fact that each transit vehicle will operate on a fixed time table which is defined by headway and makes regular stops at designated stopping areas.

The parameters of the existing condition or base case model shall initially be calibrated to match field data, measurements, and other observations so that the simulation can be used to accurately depict operating conditions in future analysis scenarios. The model calibration process involved comparisons and adjustments of simulated overall traffic volumes, dwell times at the terminal curbsides, total travel times for bus routes, and queuing caused by lane blockages or traffic congestion.

Convergence shall be determined through use of a GEH Statistic to avoid pitfalls that occur when using simple percentages to compare two sets of volumes. This is because the traffic volumes in the real world vary over a wide range. For example, the mainline of a freeway might carry 5000 vehicles per hour, while one of the on-ramps leading to the freeway might carry only 50 vehicles per hour (in that situation it would not be possible to select a single percentage of variation that is acceptable for both volumes). The GEH statistic reduces this problem; because the GEH statistic is non-linear, a single acceptance threshold based on GEH can be used over a fairly wide range of traffic volumes.

For establishing the "baseline" scenario, a GEH of less than 5.0 is considered a good match between the projected and observed hourly volumes (flows of longer or shorter durations should be converted to hourly equivalents to use these thresholds). As a minimum, 85% of the volumes in a traffic model should have a GEH less than 5.0. GEHs in the range of 5.0 to 10.0 warrant investigation. If the GEH is greater than 10.0, there is a high probability that there is a problem with either the forecast volumes or the count data (this could be something as simple as a data entry error, or a complication within the simulation model).

The VISSIM model developed and calibrated for the Existing Condition shall be used as the basis for development of the Future No Build Condition and Build Condition models.

a. Model Construction

A traffic simulation model first needs to be constructed for the Existing Condition based on traffic volumes for both the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak periods which includes the peak hour with the airport's highest overall traffic volumes. The VISSIM model consists of all of the major roadways leading to/from the airport, the airport internal circulation roads, the terminal approach ramps including the terminal arrivals and departures.

b. Roadway Network

VISSIM uses a line and polygon layered network. Lines define the physical roadway geometry and polygons define decision points such as an intersection or on/off ramps. This feature representation allows for network coding in a link/connector fashion, which is the most feasible to code and model complex roadway geometries. Roadway links can be traced from aerial photo that are imported into VISSIM as a background image, and further refined with AutoCAD drawings to ensure link distances are reasonably accurate coded with information such as the number and width of lanes, vehicle speeds, and traffic control devices such as signals and stop signs.

c. Trip Tables

The Balanced Flow maps and Origin/Destination (O/D) trip table matrices are estimated based on field observed traffic volumes, the breakdown of vehicle classes collected from the data collection program and the air passenger survey information. Trip tables are prepared individually for each terminal frontage and parking garage. Subsequently, traffic volume flow maps are prepared for the entire airport and individual quadrants. The study area's outer boundaries are modeled as external stations where external stations are treated as exit and entry points for access to and from the airport.

d. Access Mode, Destination and Stop Choice

There are two primary modes accessing the airport autos and public transit. Auto consists of private automobiles, taxis, for-hire and TNC vehicles. Public Transit includes public transit buses; courtesy vehicles; on-airport buses; and, off-airport buses.

The auto mode has multiple possible stops and destinations including frontage roadways, parking facilities, cell phone lots and taxi/TNC hold areas. A trip with multiple stops is referred to as "trip chaining." Private autos with destinations to frontage roadways are assigned the same final destination as point of origin except for those re-routed to a parking lot after dropping off passengers. Autos destined to parking without stopping at frontage roadways remain at the lot/garage during the course of the simulation run, and return trips leaving parking lots were developed based on exit statistics

collected for each lot. All incoming taxis are re-routed to the taxi hold after passengers are dropped off, except deadhead trips which were assigned to the taxi hold directly. Prior to pick-up TNC vehicles must first go to a centralized hold or staging area with geofence boundaries. Cell phone lot users are simulated in a similar fashion,

e. Transit Routing and Assignment

Transit trips should be coded in VISSIM with static assignment based on the fact that each transit vehicle will operate on a fixed time table which is defined by headway and makes regular stops at designated stopping areas. For the airport models, it should be assumed that all transit vehicles will adhere to the assigned headway and make regular stops.

f. Dynamic Assignment

A dynamic assignment process shall be utilized to allow VISSIM to determine the optimal route for each vehicle to access the airport landside facilities. Dynamic assignment also helped to identify potential deficiencies in the roadway configuration which can cause bottlenecks and congestion. The dynamic assignment is also the key component in the process to determine route choices for static simulation to analyze the terminal frontage roadway activities such as double parking, vehicle recirculation, dwell time reinforcement and interaction of vehicles at the operational level.

g. Terminal Curbside Activities

Typically, on-street parking has designed parking spaces with proper markings and spatial layouts to allow a driver to maneuver in and out without hindering adjacent vehicles. Curbside parking, on airport roadways, generally does not have these spatial layouts except where designated for bus stops, taxi stands courtesy vehicle waiting areas. Private auto drivers will generally randomly park along the curbside as a space becomes available.

As demand outpaces supply, these drivers will double park. This creates a dynamic environment where parking rules are difficult to enforce and parking capacity is very difficult to quantify. As a driver approached the terminal roadway, they would slow down to look for any available parking space. Spaces in Lane 1 closest to the curbside will be filled first followed by Lane 2.

To reasonably replicate these activities, it will necessary to develop design speed profiles for each roadway to regulate travel speeds, and assign a hierarchy of attractiveness associated with cost to each curbside parking space. Spaces closest to terminal doorways are the most attractive, and the attractiveness decreases as the distance becomes further away from the terminal doorways and further away for the curbside.

h. Re-Circulation Traffic

Recirculation behavior at the frontages is based on a number of factors. The first factor is the number of available spaces at the destination frontage, which is determined using a combination of frontage lengths, individual parking space length, and the average dwell time of vehicles at the frontage. The second factor is the attractiveness of available spaces at the destination frontage. For example, curbside spaces are considered to be more attractive than spaces in the second or third lanes. Additionally, spaces physically located near the terminal doorways are considered to be more attractive.

If the frontage is too crowded and none of the spaces available at the frontage are sufficiently attractive, vehicles will skip parking at the frontage and to circle back via recirculation roadway. Vehicles that have made at least three attempts but cannot access the frontage curb will divert to the closest parking facility.

i. Critical Link Volume and Speed Comparison

To capture the true peaking characteristic, it will be necessary to simulate for both the 6:00 AM to 10:00 AM and 4:00 PM to 8:00 PM peak periods instead of peak hours. By simulating peak periods, the hours before the peak hour helped preload the network with traffic. The purpose of using dynamic assignment is to allow vehicles to travel from point A to point B in the shortest travel time, least distance traveled and at minimum cost. To reasonably reflect driver behavior, multiple assignments must be run to allow the model to converge based on travel time where variation is within 15% between successive runs. This would set the parameter for each driver to be familiar with the roadway network.

The VISSIM generated travel times and travel speeds along specific routes are compared with actual speed runs. In addition to auto travel time and travel speed, courtesy bus and airline connection bus travel times are calibrated against field observations. It was not necessary to calibrate vehicle dwell time and double parking. Dwell time is a direct input from field observations, and double parking is subject to availability which is a function of individual vehicle dwell time.

j. Measurement of Effectiveness (MOE)

VISSIM contains post processing procedures which provided an interface with GIS based mapping. These procedures provide custom formats in an Excel spreadsheet for the MOE summary as well as for bar charts and pie charts for graphical displays. The MOEs should be collected to include items such as: density, average speed, levels-of-service for multilane roadways, travel times along critical airport segments, frontage levels of service and vehicle delays, queue lengths on the frontage approach roadways, intersection delays by movement, intersection queue lengths by movement, and queue lengths in taxi hold areas.

10. Level-of-Service Performance Measures for Airport Terminal Access and Circulation Roadways

The key performance measures defining the level of service of an airport terminal area roadway are as follows:

- Average speed, which determines travel time;
- Traffic density, which determines the ability of motorists to easily maneuver into and out of travel lanes;
- Maximum volume-to-capacity (v/c) ratio, which indicates how close the roadway is to breakdown and is useful for determining other performance measures such as queue length and delays; and,
- Duration and length of queues.

With the exception of weaving analysis, the definitions and metrics presented in the 2010 HCM are applicable to airport roadways with un-interrupted operations and signalized or un-signalized (i.e., stop-sign controlled) intersections.

Criteria	Levels of Service				
	A	B	C	D	E
Free-flow speed = 50 mph					
Minimum speed (mph)	50	50	50	48.9	47.5
Maximum volume/capacity ratio	0.28	0.45	0.65	0.86	1
Maximum service flow rate (passenger cars/hour/lane)	550	900	1300	1710	200
Maximum flow (vehicles/hour/lane) (a)	440	730	1050	1380	1620
Free-flow speed = 45 mph					
Minimum speed (mph)	45	45	45	44.4	42.2
Maximum volume/capacity ratio	0.26	0.43	0.63	0.82	1
Maximum service flow rate (passenger cars/hour/lane)	490	810	1170	1500	1900
Maximum flow (vehicles/hour/lane) (a)	400	650	940	1250	1530
Free-flow speed = 40 mph					
Minimum speed (mph)	40	40	40	39	38
Maximum volume/capacity ratio	0.26	0.42	0.61	0.82	1
Maximum service flow rate (passenger cars/hour/lane)	450	740	1060	1400	1750
Maximum flow (vehicles/hour/lane) (a)	360	600	860	1130	1410
Free-flow speed = 35 mph					
Minimum speed (mph)	35	35	34	34	33
Maximum volume/capacity ratio	0.26	0.42	0.61	0.8	1
Maximum service flow rate (passenger cars/hour/lane)	410	670	980	1280	1600
Maximum flow (vehicles/hour/lane) (a)	330	540	790	1030	1290
Free-flow speed = 30 mph					
Minimum speed (mph)	30	30	30	29.6	29
Maximum volume/capacity ratio	0.26	0.41	0.6	0.79	1
Maximum service flow rate (passenger cars/hour/lane)	370	600	870	1150	1450
Maximum flow (vehicles/hour/lane) (a)	300	480	700	930	1170
Free-flow speed = 25 mph					
Minimum speed (mph)	24	25	25	24.8	24
Maximum volume/capacity ratio	0.25	0.4	0.59	0.79	1
Maximum service flow rate (passenger cars/hour/lane)	310	500	740	900	1250
Maximum flow (vehicles/hour/lane) (a)	250	400	600	800	1010

mph = miles per hour

(a) Flow rates adjusted to account for 0.95 heavy vehicle factor and 0.85 driver population factor due to occasional or unfamiliar users.

Source: ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.

Figure 92: LOS criteria for terminal roadways

a. Low Speed Airport Roadway Weaving Analysis

The operation of weaving and merging areas on airport roadways differs from the operation on non-airport roadways primarily because these operations occur at slower speeds on airport roadways than they do on freeways and arterial streets. The weaving analysis methodology outlined in 2010 HCM was developed for freeways and arterial streets on which vehicles operate at higher speeds than those on most airport roadways.

Although motorists on airport roadways are traveling at speeds (e.g., 35 mph or less) that are slower than those on freeways or arterial roadways, the limited distances between decision points compromise the ability of motorists to recognize, read, and react to roadway guide signs, or do not allow adequate time to complete required merging and weaving maneuvers.

All weaving analyses shall be done in accordance with the definitions and metrics outlined in ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.

Level of Service	Freeway Weaving Segment (pc/mi/ln)	Collector-Distributor Roadway (pc/mi/ln)	Airport Low-Speed Roadway (pc/mi/ln)
A	10	12	20
B	20	24	30
C	28	32	40
D	35	36	50
E	>35	>36	60
F	$v/c > 1.0$	$v/c > 1.0$	$v/c > 1.0$

Notes: pc/mi/ln = passenger cars per mile per lane.

If the density exceeds the LOS threshold, then the roadway is over capacity.

Source: ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.

Figure 93: LOS criteria for weaving segments

11. Terminal Curbside Frontage

In evaluating airport curbside roadway operations, analyses of both the curbside lanes (where motorists stop to pick up or drop off passengers) and the adjacent through lanes are required. These analyses are necessary because double- or triple-parked vehicles impede or delay the flow of vehicles in the adjacent through lanes. As a result, the capacity of the through lanes decreases as demand for curbside space approaches or exceeds the capacity of a curbside roadway segment, causing double or triple parking.

After removing transfer passengers from the arrival and departure curves, the distribution of passengers at the curb, direct to/from parking, and those using the light rail system (AirTrain) need to be determined to complete the curbside frontage calculations.

All terminal curbside frontage analyses shall be done in accordance with the definitions and metrics outlined in ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.

A utilization factor of 0.90 or less is the desirable planning target for new curbside roadways.

A utilization factor of 1.30 (65% of the combined capacity of the inner and second curbside lanes) is acceptable for existing facilities, recognizing that during peak hours and days of the year, demand will exceed capacity.

Criteria	Airport Curbside Levels of Service					
	A	B	C	D	E	F
<i>When double (and triple) parking is allowed at the curbside</i>						
Maximum demand for curbside standing or parking/effective curbside length (a)	0.90	1.10	1.30	1.70	2.00	>2.00
Maximum service flow rate						
5-lane curbside roadway (vph)	3,400	3,280	3,100	2,710	2,400	Up to 2,400
4-lane curbside roadway (vph)	2,830	2,790	2,680	2,220	1,800	Up to 1,800
3-lane curbside roadway (vph)	2,200	1,950	1,580	860	750	Up to 750
<i>When double parking is prohibited at the curbside</i>						
Maximum demand for curbside standing or parking/effective curbside length (a)	0.70	0.85	1.00	1.20	1.35	>1.35
Maximum service flow rate						
4-lane curbside roadway (vph)	2,830	2,830	2,800	2,730	2,600	Up to 2,600
3-lane curbside roadway (vph)	2,350	2,250	2,000	1,760	1,600	Up to 1,600
Maximum through lane volume to capacity ratio	0.25	0.40	0.60	0.80	1.00	1.00
vph = vehicles per hour						
(a) The ratio between the calculated curbside demand and the available effective curbside length.						
Source: ACRP Report 40: Airport Curbside and Terminal Area Roadway Operations.						

Figure 94: LOS criteria for airport curbside roadways

12. 3-D Visualization

Links and connectors in the VISSIM model are initially created in a 2D environment. At the terminal curbsides, the arrivals level (upper level) are slightly offset from the departures level (lower level) to permit both roadways to be simultaneously viewed in 2D. The 3D modeling environment is developed by adding elevations to the roadway links and shifting the departures level on top of the arrivals level at the terminal curbsides.

VISSIM includes a library of basic static and dynamic 3D objects. To improve the 3D visualization of the VISSIM model for presentation purposes, static 3D scenery objects specific to the airport may need to be developed. Many of the airport terminals and other buildings can be created by extruding the building outlines from the CAD drawings. Additional 3D objects such as overhead sign gantries, trees, sidewalks, railings, and bollards placed at the terminal curbsides and the other parts of the study area should be modeled in detail. To provide a more realistic experience, all the overhead signs to, within and from the airport, and much of the posted mounted signs along all terminals can be photographed. These photos can then be integrated into the VISSIM model.

The 3D modeling environment ultimately will be used to create screenshots and video clips of traffic conditions at the terminal curbsides as well as the overall traffic within study area.

13. Future Condition Analysis

Because the proposed development will take place in the future, the development environmental setting is not the current environment, but the environment, as it will exist at project completion, in the future. Therefore, future conditions must be projected. This prediction is made for a particular year, generally known as the "build year." The build year is the year when the development will be substantially operational, since this is when the development's effects will begin to be felt, and when mitigation of project impacts would have to be in place.

The assessment of existing conditions establishes a baseline, not against which the project is measured, but from which future conditions can be projected. The prediction of future conditions begins with an assessment of existing conditions because these can be measured, observed, and otherwise tested in the field.

14. Future No Build Condition

The existing environmental setting is used to project future conditions without the proposed action. This prediction is made for the year the action would be completed using the data about existing conditions together with information about expected future growth and developments. The scenario of the future without the proposed action, often referred to as the "no action" or "no build" condition, provides a baseline condition against which the incremental changes generated by the project can be evaluated. This sets the context in which to assess impacts.

Using existing conditions as a baseline allows the prediction of the future to a certain level of accuracy. Altogether, the no action analysis takes the existing observed condition and adds to it known or expected changes to arrive at a reasonable estimate of the future.

15. Future Build Condition

The future with the proposed action, also known as the "build" or "action" condition, is assessed and compared with the no action scenario. This assessment is performed for the same technical areas, using the same study areas, as the existing and no action assessments.

Many technical areas provide thresholds for what constitutes a significant impact; others require a more judgmental and qualitative assessment. Both qualitative and quantitative information is used, where possible, to determine the likelihood that the impact would occur, the timeframe in which it would occur, and its significance. Where no quantitative thresholds exist, a determination of significance must consider magnitude, duration, geographic scope, and irreversibility.

Part 3 - Landside Conceptual Design Criteria

1. Standards and References

- a. AASHTO: A Policy on Geometric Design of Highway and Streets
- a. AASHTO: Roadside Design Guide
- b. AASHTO: Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals
- c. Americans with Disabilities Act (ADA) Applicable Standards and Guidelines
- d. FHWA: Manual on Uniform Traffic Control Devices (MUTCD)
- e. PANYNJ Traffic Engineering Design Guidelines
- f. PANYNJ Civil Engineering Design Guidelines
- g. PANYNJ Civil Standard Details and Specifications
- h. PANYNJ Sustainable Infrastructure Guidelines
- i. PANYNJ Intersection Signalization Procedure
- j. PANYNJ Roadside and Median Barrier Design Manual
- k. PANYNJ Airport Roadway Sign Design Manual
- l. PANYNJ Manual for Pedestrian Signing and Wayfinding
- m. PANYNJ Intelligent Transportation System Design Guidelines

2. Scope

The roadway network shall be designed in accordance with the latest PANYNJ Engineering Design guidelines, as well as, current AASHTO standards/guidelines. The designs shall take into account the existing conditions; coordination with other landside improvements and impacts to existing and future utilities and provide right of way to accommodate a potential future light rail system. The overall terminal site design will impact a significant portion of the landside area, requiring a combination of new utility construction or relocation as necessary.

3. Roadway Geometrics

- a. Landside roadway horizontal and vertical geometry shall be in conformance with AASHTO: A Policy on Geometric Design of Highway and Streets requirements and the PANYNJ Civil Engineering Design Guidelines. The design speed for the terminal access roadway shall be 35 miles per hour. The design speed for the frontage approach ramps shall be 25 mph.
- b. Per PANYNJ Civil Engineering Design Guidelines, landside roadway drainage shall be design for 10-year rainfall return period and the gutter flow shall not encompass more than 1/3 the traveled lane.
- c. Sight distances for each of the roadway speeds will meet the standards of Section 3.2.1 AASHTO: A Policy on Geometric Design of Highway and Streets.
- d. Minimum horizontal offset to structures for roadway design will conform to the Barriers & Clear Zones section of AASHTO: A Policy on Geometric Design of Highway and Streets.
- e. Roadways have shall designed to meet provision for passing a stalled vehicle as per AASHTO: A Policy on Geometric Design of Highways and Streets.
- f. All lane drops and merge lanes are designed to meet the minimum standards following the MUTCD, Advanced Warnings and Taper and in consultation with PANYNJ.

- g. Curve widening will be applied over the length of the horizontal transition curve. The design widths for curve widening will be for both the super elevation runoff length as well as required sight distance per AASHTO: A Policy on Geometric Design of Highway and Streets.
- h. Maintain proper roadway clear zone free of obstruction where possible but as a minimum must comply with AASHTO: Roadside Design Guide. Proper protection shall be provided in accordance with the PANYNJ Roadside and Median Barrier Design Guide for areas where clear zone cannot be met. Protection shall include use of concrete barriers and/or guiderail. Impact attenuators shall be used at gore areas of diverging roadways on-structures and on-grade. On structures fixed objects shall be located behind the structure rail
- i. Per AASHTO: A Policy on Geometric Design of Highway and Streets, Table 3-7 Minimum roadway radii:

R = 86.0' for 20 mph design speed
 R = 154.0' for 25 mph design speed
 R = 250.0' for 30 mph design speed
 R = 371.0 for 35 mph design speed
 R = 533.0 for 40 mph design speed

- i. Per PANYNJ Civil Engineering Design Guidelines, the maximum super elevation shall be 4%.
- j. Per PANYNJ Civil Engineering Design Guidelines, the maximum vertical grade for roadways shall be 5%. Grades greater than 5% must be approved by the PANYNJ Chief Civil Engineer.
- k. Design Vehicles

- a. Airport Roadway Network: 53 Ton Striker 4500 Fire Fighting Truck
- b. Loading Docks: WB 62
- c. Restricted Access Roads: 53 Ton Striker 4500 Fire Fighting Truck

- l. Vertical Clearance

Roadway - 14.5 ft.
 Overhead Sign Structure - 15.5 ft.
 Overhead traffic Signal - 15.5 ft. minimum; 17.5 ft. maximum
 Above Heavy/Light Rail - 13.0 ft. minimum

- m. On-Airport Roadway Widths (Tangent Section)

4 Lanes = 54 Ft. (4-12 Ft. lanes; 2-3 Ft. shoulders)
 3 Lanes = 42 Ft. (3-12 Ft. lanes; 2-3 Ft. shoulders)
 2 Lanes = 30 Ft. (2-12 Ft. lanes; 2-3 Ft. shoulders)
 1 Lane = 21 Ft. (1-15 Ft. lane; 2-3 Ft. shoulders)

- n. Roadway pavement shall be designed in accordance with the PANYNJ Civil Engineering Design Guidelines.

4. Terminal Frontage Roadway Layout

- a. The design speed for the Departure (upper level) and Arrivals (lower level) frontage roadways shall be 20 mph.
- b. Arrivals and Departures frontage roadways shall be 49 feet wide and shall consist of two 10-foot drop-off/pick-up lanes, one 12-foot maneuvering lane, two 12-foot bypass lanes and one 3-foot outer shoulder.

- c. The Ground Level HOV frontage shall be 52 feet wide and shall consist of two 10-foot drop off/pick up lanes, one 12-foot maneuvering lane, a striped 3-foot median, two 12-foot bypass lanes, and one 3-foot outer shoulder.
- d. Arrivals frontage length requirements shall be determined in accordance with the procedures outlined in this document
- e. The Departures frontage roadway length requirements shall be determined in accordance with the procedures outline in this document.
- f. Vertical clearance shall be a minimum of 14.5 feet.
- g. The minimum lateral distance between the terminal face and the right frontage curb shall be 30 feet.
- h. Pedestrian islands shall be a minimum of 30 feet wide.

5. Surface and Structural Parking

- a. Regular Parking Stall Dimensions shall be minimum 8.5 feet by 18 feet (width by length).
- b. Regular ADA Parking Stall Dimensions shall be minimum 8.5 feet by 18 feet (width by length) with at least one 5-foot-wide aisle parallel to each stall. The pedestrian aisle shall be marked and shall be of equal length to the stall.
- c. Van Accessible ADA Parking Stall Dimensions shall be minimum 11 feet by 18 feet with at least one 5-foot side aisle parallel to each stall. The pedestrian aisle shall be marked and shall be of equal length to the stall.
- d. Parking Drive Aisles shall be minimum 24 feet wide for two-way drive aisle, 20 feet wide minimum for one-way drive aisles.
- e. Entry and Exit Plazas
 - 1. Each entrance/exit lane shall be a minimum of 15 feet wide (9-foot travel lane and 6-foot island)
 - 2. Each entrance lane shall be located on a tangent a minimum of 46 feet long
 - 3. Each exit lane shall be located on a tangent a minimum of 54 feet long
 - 4. Entrance/exit plaza tapers shall be a minimum of 1 to 15
 - 5. Each exit lane shall be cash, credit card, E-Z pass and unmanned credit card or pre-paid capable
 - 6. Exit/entrance queues shall not extend onto adjacent roadways or circulation aisles.
 - 7. Controlled entrance lanes typically have a processing rate of 360 vehicles per hour.
 - 8. Controlled cash/credit card exit lanes typically have a processing rate of 110 vehicles per hour.
 - 9. E-Z Pass controlled exit lanes typically have a processing rate of 150 vehicles per hour

6. Garage Requirements

- a. Circulation aisles and ramps shall be a minimum of 24 feet wide
- b. Minimum vertical clearance for parking structures is eight feet (8.0 feet) at typical floors and twelve feet six inches (12 ft. 6in.) for ground floor

- c. Grade for parking structure ramps should range between six percent (6%) and ten percent (10%) without parking and maximum five percent (5%) and preferred three percent (3%) with parking.

7. Landside Signs and Support Structures

- a. Airport signs will allow motorists to safely navigate the airport roadway network while entering, transiting and exiting the terminal area, from local streets and highway corridor. This signage will include guide signs, regulatory signs, warning signs, informational signs, pedestrian wayfinding signs and possibly variable message sign technology.
- b. Roadway, parking and wayfinding signs shall meet the requirements of the MUTCD, PANYNJ Roadway Sign Manual, and the PANYNJ Manual for Pedestrian Signing & Wayfinding.
- c. Lateral and vertical clearances between sign panels and the roadway shall conform to PANYNJ Traffic Engineering Standards.
- d. Roadway signs shall be mounted on a single pole, or on overhead sign structure. Structural design of overhead sign structures shall conform to the latest AASHTO requirements.
- e. At this level of conceptual design, the main focus shall be the location of critical informational and guide signs and not the signs designs.

8. Traffic Signals

- a. Traffic signal locations shall be identified based on the signal warrants specified in the MUTCD.
- b. The traffic signal designs shall be developed using the PANYNJ Traffic Signal Design and Drawing Preparation Guidelines.
- c. At this level of conceptual design, the main focus shall be the location of traffic signal and not the signal design.

9. Roadway Intelligent Transportation Systems (ITS)

- a. The proposed roadway design shall include provisions for ITS work that can be incorporated into the overall Airport ITS Masterplan. The goal of the Masterplan is to have an infrastructure of ITS subsystems designed to provide detection of and responses to changing conditions, through surveillance and monitoring of traffic operations, traffic management tools and motorist information devices.
- b. At this level of conceptual design, the main focus shall be the location and placement of detection and informational devices on the roadway network that will form the ITS infrastructure. These devices include closed circuit television cameras (CCTV), surveillance cameras, vehicle detectors, and variable message signs (VMS).
- c. All work shall comply with the PANYNJ Intelligent Transportation System Design Guidelines.

10. Future Transit Right of Way

- a. The terminal roadways shall be coordinated with any PANYNJ conceptual layout of a future transit system.

Appendix A – PANYNJ Airport Planning Standards Guidelines for Public Terminal Restrooms

GUIDELINES FOR PUBLIC TERMINAL RESTROOMS

Restrooms play an important role in airport facilities for passenger and staff convenience and passenger perceptions regarding their overall experience at an airport. Passengers and staff should be provided with adequate toilet facilities near all main waiting zones and workplaces.

In an effort to provide the highest level of customer experience, the Port Authority has developed the following planning guidelines to provide airports with public restrooms that balance the needs and expectations of travelers, the efficiency of airport operations, and the costs of building and managing these spaces. These guidelines should be used when renovating, replacing or new construction of restroom facilities.

This document does not supersede the requirements of any applicable code and/or regulation. Any conflicts between the requirements in this document and the applicable codes shall be directed to the Aviation Planning Division for resolution. It is the responsibility of the designer to ensure the conformity of the proposed plans with the most current version of all codes and regulations.

Restroom requirements include the quantity of lavatory fixtures needed to accommodate the expected numbers of occupants. Dimensional criteria based on area per fixture and circulation, and spatial guidelines for restroom layout are used to derive the restroom space program.

This manual does not provide restroom finishes, materials and color palette guidelines. Future versions of this document may include these parameters.

1. References

Port Authority airports, LaGuardia and John F. Kennedy International Airports (LGA and JFK, respectively) in New York City are subject to the provisions of the New York City Plumbing Code. Stewart International Airport (SWF) in New Windsor, New York, and Newark Liberty International Airport (EWR) in Newark, New Jersey, are subject to the New York State Building and Plumbing Codes and the International Building Code New Jersey Edition, respectively. The codes provide a basis for construction type identification and fixture sizing.

The following documents and references provide additional guidelines and best practices for planning and designing terminal restrooms:

- a. ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design
- b. Port Authority Pedestrian Signing and Wayfinding Airport Standards Manual
- c. Americans with Disabilities Act (ADA) Standards for Accessible Design
- d. Others (to be finalized)

2. Restroom Requirements and Locations

- a. Fixtures Needed Calculation – Methodology Guidelines

The toilet fixture counts within each men and women toilet room should be calculated based on the function and occupancy of the terminal area. The table below indicates the bases for determining the requirements for restroom fixtures from the New York City Plumbing Code, the New York State Building and Plumbing Codes and the International Building Code New Jersey Edition.

		Restroom Criteria as per Plumbing Codes		
Planning Criteria Ratios	Units	New York State Plumbing Code	New York City Plumbing Code	International Building Code, New Jersey
Male / Female	Ratio	50%/50%	50%/50%	50%/50%
Fixture: Male	Ratio	1:500	1:500	1:500
Fixture: Female	Ratio	1:500	1:500	1:500
Sinks: Male	Ratio	1:750	1:750	1:750
Sinks: Female	Ratio	1:750	1:750	1:750
Service Sinks: Restroom	Ratio	1:1	1:1	
Maximum Distance to nearest Restrooms	Feet	300	300	

Table A1: Restroom Criteria as per Plumbing Codes

While local building codes should always be consulted, recent industry research shows that building codes only provide minimum requirements. To provide exceptional customer service, code minimums have proven to be inadequate at Port Authority airports.

For this reason, the Port Authority requires the use of the methodology and principles explained in the following pages which were developed based on the latest recommendations from ACRP²²⁰ for the

²²⁰ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

planning and design of public terminal restrooms. The Port Authority's objective is to provide well-appointed restrooms that provide adequate space for belongings and circulation, ample circulation space, accommodations for individuals with special needs, and highly maintained facilities.

To meet the projected passenger demand requirements, airport restroom sizes must be calculated based on the portion of the terminal they serve: airside concourse, terminal pre-security area, and terminal post-security area. Their number and locations also depend on the planning concept used for concessions: centralized departure concessions versus distributed concessions (within boarding areas/concourses).

For terminals with departure concessions distributed within the boarding area/concourses, restroom requirements should be calculated separately for the two following functional areas:

- Airside concourses (post-security)
- Terminal-landside (pre-security)

Terminal landside restrooms are typically located within the major terminal areas such as check-in, baggage claim, and pre-security concessions areas.

For terminals providing a centralized post-security concession area, additional restroom requirements should be calculated for that particular space:

3. Terminal-centralized departure concession area (post-security)

The following process should be used to determine the minimum number of restroom modules and fixtures needed for each one of the three main functional areas:

a. Airside concourses calculation

Calculations for restroom requirements on airside concourses must be based on the number of gates available and the design aircraft on each gate.

Step 1: Determine Peak Passenger Capacity

Peak passenger capacity (design passengers) is calculated using the following formula:

$$\begin{aligned} \text{Design Passengers} = & \text{Load Factor} \times (\text{Number of ADG-II gates} \times \text{ADG-II Design Aircraft Seats} \\ & + \text{Number of ADG-III gates} \times \text{ADG-III Design Aircraft Seats} \\ & + \text{Number of ADG-IV gates} \times \text{ADG-IV Design Aircraft Seats} \\ & + \text{Number of ADG-V gates} \times \text{ADG-V Design Aircraft Seats} \\ & + \text{Number of ADG-VI gates} \times \text{ADG-VI Design Aircraft Seats}) \end{aligned}$$

The following minimum planning standards are provided for the load factor and seats per aircraft values for restroom calculation at all Port Authority airports:

Port Authority Minimum Standards	
Load Factor	90%
Seats per Aircraft	
ADG-II (Regional Jets)	76 seats
ADG-III	190 seats
ADG-IV	240 seats
ADG-V	400 seats
ADG-VI	550 seats

Table A2: Port Authority Minimum Standards

Notes:

- A load factor of 90% is given as a minimum at the time this manual was written. However, the Port Authority may require the use of a higher load factor on a per-project basis, based on the specific traffic characteristics of the studied airport and terminal.
- Any proposed adjustment of design aircraft seat values based on the expected fleet mix must be submitted to the Port Authority for review.
- As a standard method, the Port Authority requires the use of design aircraft seats values for the calculation of restroom requirements in airside concourses. This approach will typically produce the conservative case (all gates used). During the planning stage, this value may be compared to the design peak hour (typically resulting from the Design Day Flight Schedule) to gauge effects on total calculated fixtures. Methodologies, based on the peak hour passengers, can be provided to the Port Authority for comparison purposes, in addition to the standard method given by the Port Authority. However, peak hour calculation and simulation methodologies shall not be used to reduce capacity and space requirements calculated through the standard method presented in this manual.

Step 2: Determine Peak 20-minute Passenger Demand

Peak 20-minute passenger demand is calculated using the following formula:

$$\text{Peak 20-Minute Passenger Demand} = \text{Design Passengers} \times \text{Peak 20-Minute Factor (\%)}$$

The Port Authority requires the use of a Peak 20-minute Factor between 50% and 60%, as per the latest recommendations from ACRP²²¹.

²²¹ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

Step 3: Determine Total Number of Men's and Women's Fixtures

First, calculate the design factor, which will be used to determine the required fixture count:

$$\text{Design Factor} = \text{Peak 20-Minute Passenger Demand} \times \% \text{ Using Restrooms (utilization)}$$

The Port Authority requires the use of a Utilization Factor of 60%, based on the latest recommendations from ACRP²²² and observations at PANYNJ airports.

As per ACRP Report 130 guidelines, the men's fixture count is used for base calculations. The men's recommended fixture count is determined as follows:

$$\text{Men's Fixtures} = \text{Design Factor} \times \text{Male \%} / 13$$

Note: When the passenger gender mix is unknown, assume a Male% ratio of 50%. The peak 20-minute male passenger ratio (13) is based on an average 1.5-minute male dwell time at a fixture.

The women's recommended fixture count is determined as follows:

$$\text{Women's Fixtures} = \text{Male Fixtures} \times \text{Female Increase Factor}$$

Note: The Port Authority requires a Female Increase Factor of 25% or more, based on the latest recommendations from ACRP²²³ and observations at PANYNJ airports.

Step 4 (for international terminals only): Additional Restrooms for Sterile Area

For international terminals, the following restroom requirements must be provided for international arrival passengers deplaning the aircraft and going through the CBP/FIS area:

Federal Inspection Services (FIS):

$$\text{Total Male Fixtures} = \text{Total International Deplaning (arriving) Peak-Hour O\&D Passengers} \times \text{Fixtures Ratio}$$

Note: When the passenger gender mix is unknown, assume a Male% ratio of 50%.

The Port Authority requires the use of the following "Fixtures Ratio", as per the latest recommendations from ACRP²²⁴: 1 fixture per 70 PHP for first 400 passengers + 1 fixture per 200 PHP in excess of 400 passengers.

$$\text{Total Women Fixtures} = \text{Total Male Fixtures} \times \text{Female Increase Factor}$$

The Port Authority requires a Female Increase Factor of 25% or more, consistent with the latest recommendations from ACRP²²⁵.

In terms of locations, the terminal planner/architect must follow the latest US Customs and Border Protection Technical Design Standards. In particular, restroom facilities shall not be located within the Sterile Corridor System (SCS) and should be as near to the FIS as possible. Restroom locations should be

²²² ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

²²³ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

²²⁴ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

²²⁵ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

provided at both levels of inspection: (1) primary processing/queuing and (2) secondary processing and inspection area.

4. Terminal Landside calculation (pre-security)

Landside restrooms are typically located within the major terminal areas such as check-in, baggage claim, and concessions areas. Calculations are based on the total peak-hour Origin & Destination (O&D) passenger demand (PHP) and the visitors of those passengers.

Visitor ratios are typically provided with airport survey data, compiled by the airport or its planning consultant, and should be used to calculate the total visitor demand when available. However, if this information is unknown, an increase factor of 20 percent for well-wishers (WW) and 30 percent for meeters and greeters (M&G) should be used as a typical industry-wide planning standard²²⁶.

For terminal facilities with enplaning/deplaning passenger processing functions (such as check-in/baggage claim, respectively) on separate levels, utilizing the associated visitor ratios with their respective passenger processing functions is appropriate:

WW + enplaning passengers and, M&G + deplaning passengers

For terminal facilities with check-in, baggage claim and arrival hall/meeters & greeters area functions on a single level, a visitor ratio, comprising the average of the WW and M&G ratios, is more appropriate.

Step 1: Determine Design Passenger Demand

Multi-level Facility:

Check-in:

**Design Demand = Total Enplaning (departing) Peak-Hour O&D Passengers
x WW Ratio (Port Authority Minimum Standard: 1.20)**

Arrivals Hall / Meeters & Greeters Area:

For Domestic Facility (includes the domestic baggage claim):

**Design Demand = Domestic Deplaning (arriving) Peak-Hour O&D Passengers
x M&G Ratio (Port Authority Minimum Standard: 1.30)**

For International Facility:

**Design Demand = International Deplaning (arriving) Peak-Hour O&D
Passengers x M&G Ratio (Port Authority Minimum Standard: 1.30)**

Single-Level Facility (domestic only):

**Design Demand = Total O&D (enplaning/deplaning) Peak-Hour Passengers
x Visitor Ratio (Port Authority Minimum Standard: 1.25)**

²²⁶ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

Step 2: Determine Number of Fixtures

The quantity of fixtures for males is determined through the following formula:

$$\text{Total Male Fixtures} = \text{Design Demand} \times \text{Fixtures Ratio}$$

The Port Authority requires the use of the following “Fixtures Ratio”, as per the latest recommendations from ACRP²²⁷: 1 fixture per 70 PHP for first 400 passengers + 1 fixture per 200 PHP in excess of 400 passengers.

Once the quantity of fixtures for males is determined, use the female increase factor used in the airside calculations.

$$\text{Total Women Fixtures} = \text{Total Male Fixtures} \times \text{Female Increase Factor}$$

Note: The Port Authority requires a Female Increase Factor of 25% or more, as per latest recommendations from ACRP²²⁸.

Fixtures per location per level should then be distributed. As per ACRP guidelines, a fixture count of six per gender is the minimum recommendation to use for any facility type. Restrooms should be located in proximity to the major passenger processing functions such as check-in, baggage claim, security screening, meeter/greeter areas, GTC locations, and major landside concessions nodes. This should be studied carefully as some locations may exhibit lines during peak passenger demand. As a result, a higher percentage distribution for those areas may be required.

Design should consider capacity demands for terminals with integrated multi-modal ground transportation centers (GTCs)—such as taxi, limousine, rail. For such designs, a ground access or curb-front survey would provide valuable passenger modal splits. Enplaning passengers utilizing the GTC, depending on location, should have access to restroom facilities prior to arriving in the check-in hall.

As stated in ACRP Report 130 “Keep in mind that landside and airside restrooms accommodate a different mix of users. While both are visited by travelers and airport employees, landside locations are also frequented by meeters and greeters as well as, in some airports, transportation chauffeurs.” Airport planners should aspire to simultaneously plan to achieve a high level of service and customer satisfaction, while taking into consideration finishes and hardware that can withstand a higher probability of wear and tear from a wide spectrum of non-traveling and traveling patrons.

5. Terminal – centralized departure concession area (post-security)

The development of centralized departure concession areas has become an increasing trend at US airports. For this reason, the Port Authority requires the submittal of a restroom requirements analysis for that particular space, when included in a terminal development (or redevelopment) program.

Due to the variety of parameters involved in the planning of a centralized concession area, the Port Authority requires all developers to provide the following information as part of the restroom requirements analysis for that particular area:

²²⁷ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

²²⁸ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

- O_1 : Maximum Occupancy calculated for the Terminal Airside Concourses
- F_1 : Total Number of Fixtures (men and women) calculated for the Terminal Airside Concourses
- O_2 : Maximum Occupancy calculated for the Centralized Concession Area
- F_2 : Total Number of Fixtures (men and women) calculated for the Centralized Concession Area
- R_{Occ} : O_2 / O_1

The Port Authority requires that a consistent ratio is maintained throughout the entire terminal secure area (post-security) to provide passengers with convenient access to restroom facilities. In order to ensure quality of service, the calculated number of fixtures for the Centralized Concession Areas (F_2) must exceed minimum fixture count of the following formula:

$$F_2 > R_{Occ} \times F_1 - 5\%$$

Designers should consider providing additional restroom facilities for areas with higher passenger dwell times.

6. Planning Considerations for Restroom Location

The guidelines for placement of toilet and support rooms are as follows:

- Restroom facilities should be evenly and conveniently distributed throughout the main public areas with a maximum walking distance of 300 feet to a restroom.
- Each location (restroom module) should include; men, women, family rooms and a janitor's room for maintenance and clean-up storage. These four (4) rooms should always be grouped together and the respective entry points should be adjacent to each other so that they are visible to the passengers.
- Circulation in rooms with larger numbers of fixtures should be laid out in a loop to avoid dead-end conditions.
- In airside concourses, restrooms should be conveniently distributed along the passenger circulation corridor.
- In the terminal headhouse, restrooms should be located in proximity to and on the same level as major passenger processing functions; such as check-in, baggage claim, security screening, meeter/greeter areas, GTC locations, and major landside concessions nodes.
- Restroom locations should be visible from major passenger circulation areas.
- Restrooms in high activity areas, such as a concourse or terminal building, should always be available for passengers' use.
- Restrooms near bars and restaurants may experience higher utilization and dwell times; and should be considered for designing restrooms in such areas.

The terminal planner/architect should take into account the following recommendations from ACRP in order to determine the optimal restroom locations²²⁹:

- "Historical observations indicate deplaning (arriving) passengers produce the greatest demand for the concourse restroom locations. Because most passengers on short-haul domestic flights will wait to use the restroom facilities until arrival, it is important to provide adequate capacity

²²⁹ ACRP Report 130, Guidebook for Airport Terminal Restroom Planning and Design, 2010

to serve these arriving passengers. This is especially important where near simultaneous flights arriving on adjacent gates will produce a surge effect on the restrooms located nearby.”

- “Observations also indicate that arriving passengers typically use the first restroom location they pass between their arrival gate and baggage claim or a connecting gate. Passenger behaviors suggest this is true even if queues are present and another location may be only a short distance away (passengers are likely uncertain how far away the next restroom is located). Due to these passenger tendencies, a good planning rule, as stated in ACRP Report 25, is to provide fewer restroom locations but with larger capacities. It is also recommended that restroom modules be placed adjacent to major concession nodes within airside concourses.”

For the location of restrooms within the sterile area at International Terminals, the planner/architect must follow the latest US Customs and Border Protection Technical Design Standards. In particular, restroom facilities shall not be located within the Sterile Corridor System (SCS) and should be as near to the FIS as possible. Restroom locations should be provided at both levels of inspection: (1) primary processing/queuing and (2) secondary processing and inspection area.

7. Spatial Components

The following section defines the minimum design intent for the placement and design for toilet facilities within the Terminal Area.

a. Restroom Module

Each restroom module should always include the following elements:

1. Men’s room, with the following components:
 - Sink / lavatories area
 - Coat & Baggage Storage area
 - Toilet stalls (standard, wheelchair-accessible, and ambulatory stalls as per ADA and applicable code requirements)
 - Urinal Area
 - Floor drain(s) in a level floor
2. Women’s room, with the following components:
 - Sink / lavatories area
 - Coat & Baggage Storage area
 - Toilet stalls (standard, wheelchair-accessible, and ambulatory stalls as per ADA and applicable code requirements)
 - Floor drain(s) in a level floor
3. Each restroom module should provide, at a minimum, one family room, signed with the men's and women's handicap symbols. For restrooms with large number of fixtures an additional family room should be provided. (Criteria Pending).
4. Janitor’s room, with easy access to the plumbing chase.

Where possible restroom layout shall provide for the ability for the restrooms to be partially closed for cleaning or maintenance and still maintain public use to 50% of the fixtures.

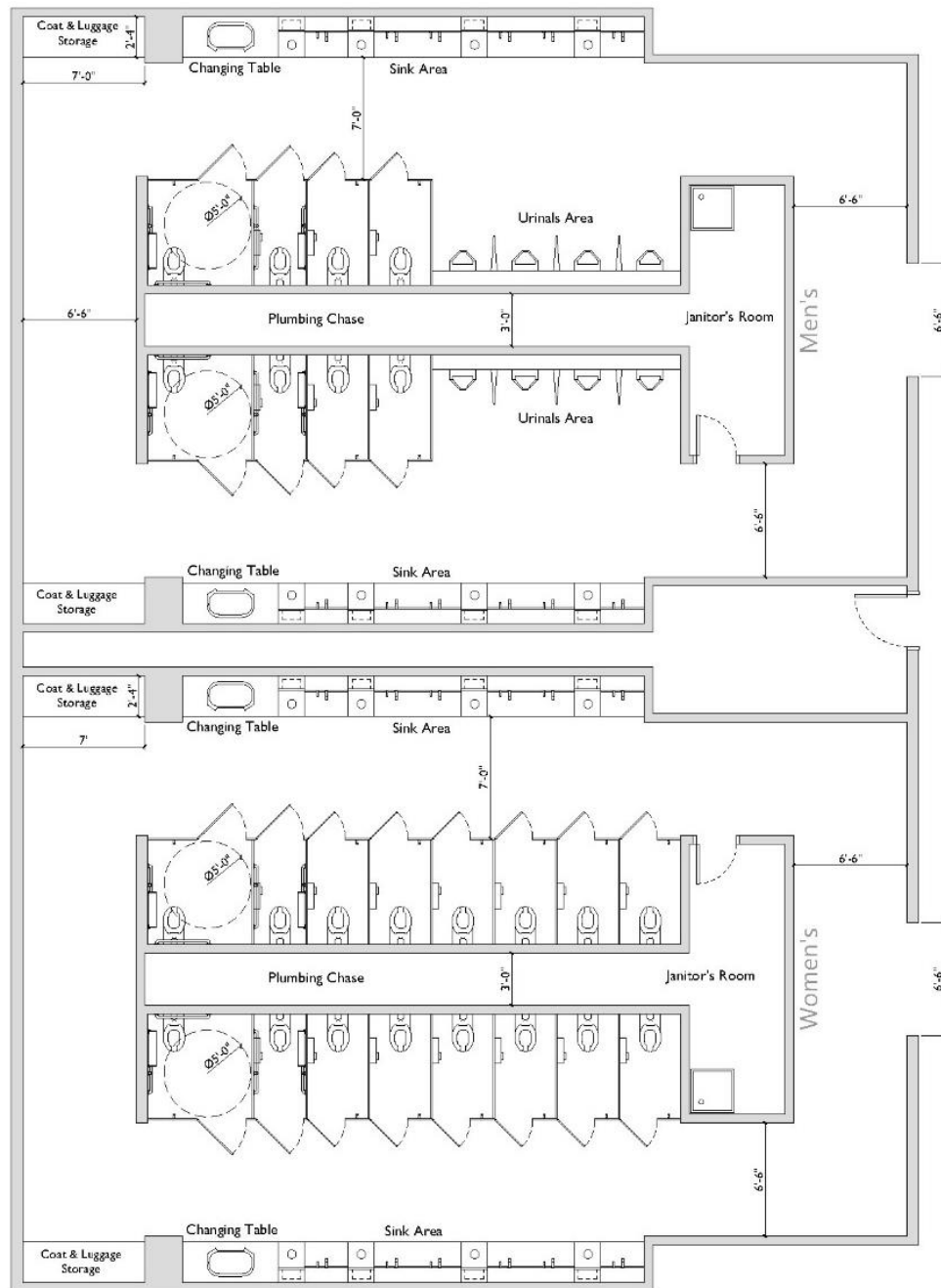


Figure A1: Sample of a Restroom Module

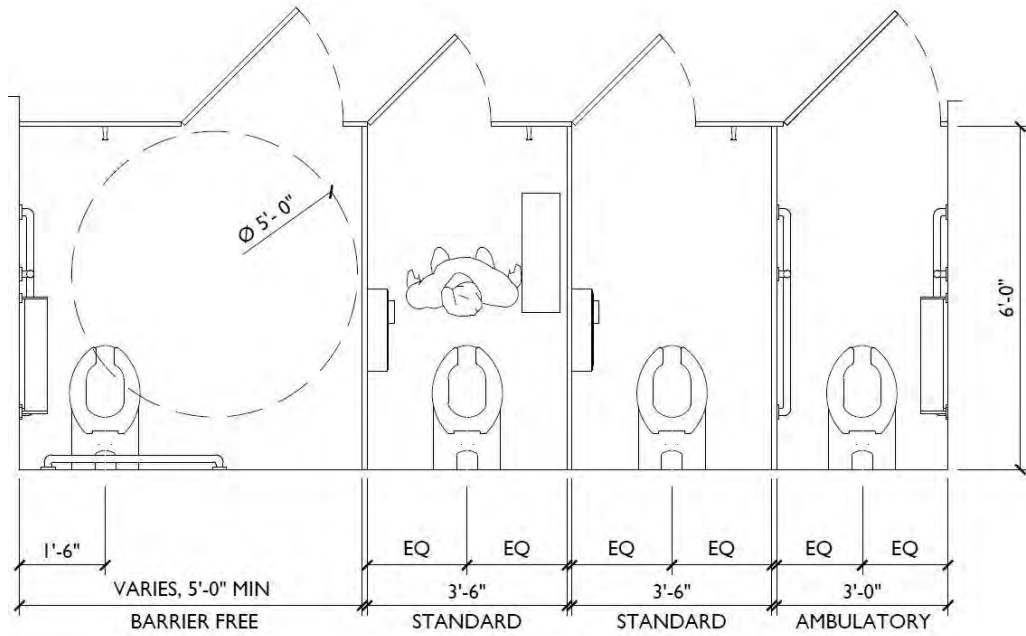


Figure A2: Sample of a Toilet Stalls (standard, wheelchair-accessible, ambulatory)

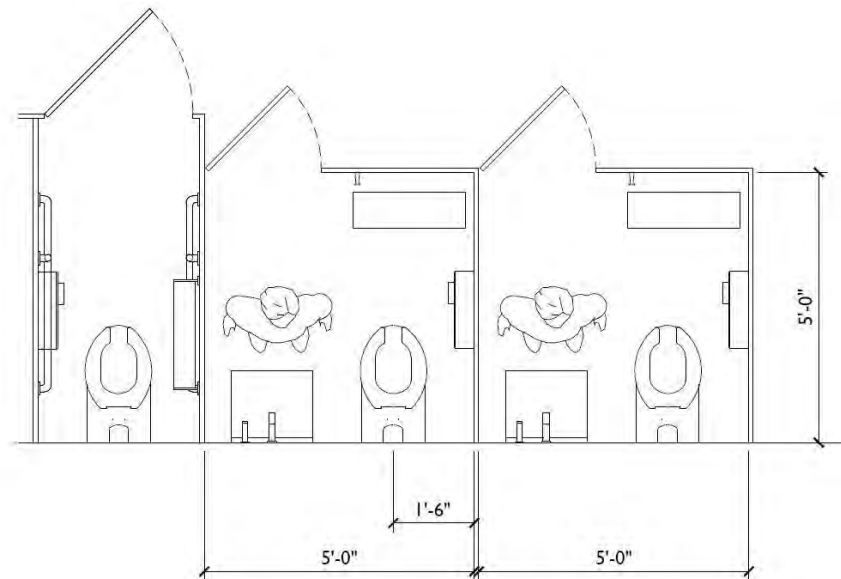


Figure A3: Sample of a "1-stop" Toilet Stall

It is recommended that consultants review the feasibility of 1-stop toilets within the restroom module and implement where possible to enhance customer experience. 1-stop stall layout should utilize standard ceiling mounted stall partitions and include a sink and toilet.

b. Entry Point / Signage

The guidelines for entry points are as follows:

1. The entries into the toilet rooms must be a minimum width of 6'-6" (7' is preferred).
2. All entry points should be designed as open entryways without doors. Size of vestibule width should be increased in relation to size of toilet room.
3. Entries should be designed to prevent line-of-sight from the public areas into the toilet areas.
4. The finishes at eye level in the transition area should reinforce the overhead exterior signage package to confirm a passenger is headed into the correct room. An additional "verification" sign should be installed farther into the entry to confirm the restrooms gender.
5. Restroom identifiers (Men/Ladies/Families) shall be clear and visible and consistent with the Port Authority Pedestrian Signing and Wayfinding Airport Standards Manual.
6. Refer to Port Authority Pedestrian Signing and Wayfinding Airport Standards Manual standards for additional guidelines on signs.
7. Provide dynamic signage to inform passengers of alternate restroom locations and cleaning/maintenance schedules.
8. Provide customer feedback interface or other means to report restroom concerns in real time.
9. Refer to ADA guidelines and Universal Design Guidelines for entry opening standards.



Figure A4: Sample Restroom Entrance

c. Sink Area / Lavatories

The guidelines for toilet room lavatories are as follows:

1. Consider using solid surface material public restroom sinks. All sink surfaces should be self-draining to prevent water ponding.
2. Countertops shall be a solid surface material with matching backsplash on all attached walls. The backsplash shall be a minimum of 6" high. All flat counter top surfaces should be located above or away from sinks to minimize water splashing onto them.



Figure A5: Sample Custom Solid Surface Sink

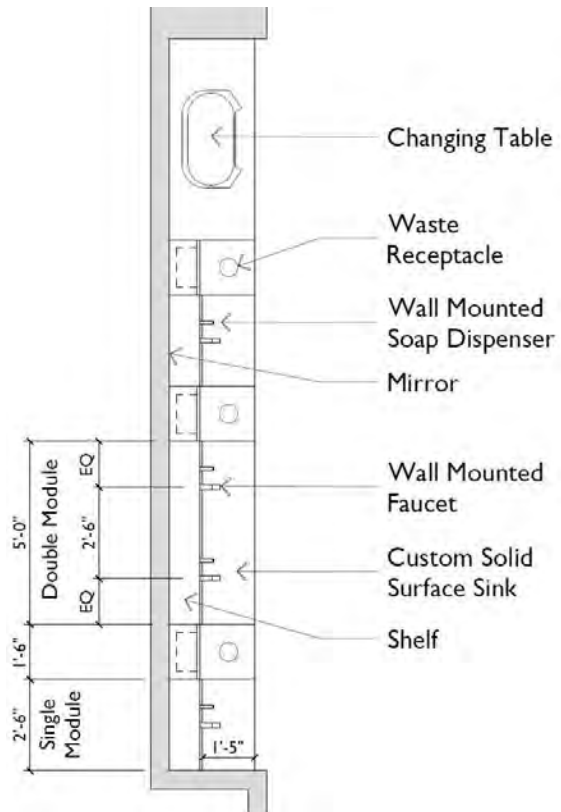


Figure A6: Sink Area / Lavatory Sample Layout

3. Sinks shall be arranged in groupings of two or single lavatory fixtures.
4. Provide a large wall mirror in front of the lavatories between built-out wall pilasters.
5. An 8" diameter trash opening with a 4" (minimum) drop shall be located in the countertop at each pilaster below the surface mounted paper towel dispenser.
6. Trash receptacle (12" minimum wide) shall be in a lockable under counter cabinet.
7. A surface mounted center pull paper towel dispenser should be located on the center pilaster above the trash receptacle opening with clear visibility to meet ADA requirements.
8. Provide water faucet and soap dispenser at each sink
9. Provide a built in 12" deep shelf behind the sink to offers a dry place for belongings.

d. Coat & Baggage Storage Area

The guidelines for the coat & baggage storage area are as follows:

1. Areas should be provided for customers to stow their bags and coats while utilizing restrooms.

2. These areas should be conveniently located, in close proximity to lavatory/sinks area and urinals area (for men's room). Visibility is a necessity and passengers should be able to see their belongings from both the urinals and sink areas.
3. Each area should include the following elements:
 - Passengers should be able to hang their coats/jackets and any other items.
 - Areas for baggage storage should consider ease of storage, cleaning and security.

e. Toilet Stall and Partitions

The guidelines for toilets are as follows:

1. The doors of standard stalls should open out. While out-swinging stall doors may result in being opened onto a passerby, their benefits outweigh this hazard by providing a clear space for individuals to maneuver themselves and their belongings with the door in any position. Having the resting position of stall doors be a position that is a few inches open allows users to readily see if the stall is occupied. Such a practice would eliminate the need for "occupied/vacant" indicators, many of which are problematic because they use the colors red and green, respectively, which prohibits those who are color-blind from deciphering the indicator.
2. Toilets shall be wall hung, white, vitreous china, siphon jet, elongated bowl, with white open-front plastic "contoured" seat without cover. Include proper wall mount chairs/hangers and plumbing chase.
3. Toilets will receive automatic flush controls: they will be mounted on the back wall with the auxiliary flush button no more than 44" AFF.
4. All restrooms shall have sanitary seat covers available.
5. All stall doors must have door locks or latches.
6. All stalls shall be equipped with heavy duty clothes hooks.
7. All stalls shall have built in 10"-12" deep shelf for small bag items.
8. All restrooms shall be equipped with an adequate number of trash receptacles to meet peak traffic flow.
9. Paper products shall be provided in adequate supply to meet peak traffic flow.

The guidelines for toilet partitions are as follows:

1. Partitions shall be ceiling hung with extensions to the floor only as needed for panel stabilization.
2. Partition shall extend from 12" AFF to 78" AFF for privacy.
3. Latches should be easy sliding bars and shall be ADA compliant.
4. Standard toilet stalls shall have a minimum clear dimension of 3'- 6" wide and 6'- 0" deep to provide enough room in front of the toilet to maneuver carry-on luggage.
5. Provide a self-closing door for ADA accessible toilet stalls.

6. Standard toilets shall have water closet centered within the stall. For ADA accessible toilet stalls, centerline of water closet must be between 16" and 18" from the partition.
7. Provide a coat hook on partition side panel, opposite the door swing, to prevent panels and doors from becoming dented. Install hook at a minimum height of 60" AFF to prevent theft of items. Coat hooks must be heavy duty and tamperproof, without face screws.

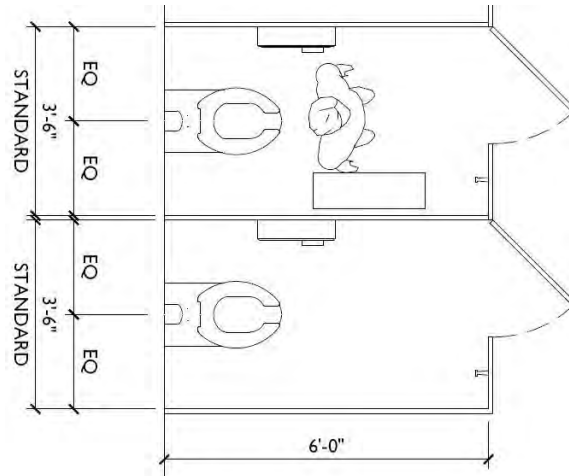


Figure A7: Standard Toilet Stall Layout

f. Ambulatory and Wheelchair-Accessible Stalls

The guidelines for ambulatory toilets are as follows:

1. As per International Building Code requirements, any restroom with six or more toilets / urinals shall be equipped with an ambulatory stall in addition to the required wheelchair-accessible compartment. An ambulatory stall has grab bars on both sides to provide assistance for those with impaired mobility such as the elderly, someone with a broken leg, stroke victims, etc. (see Figure A8).
2. ADA Standards require an ambulatory stall to have a clear width between 35"-37" and clear length of five feet. Provide an additional foot in length to accommodate carry-on baggage. In addition, this is the same depth as the accessible stall (see Figure A9), which simplifies restroom layouts.
3. The door of the handicapped and ambulatory stalls should open out.

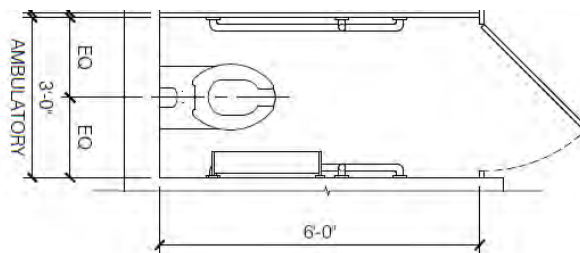


Figure A8: Ambulatory Toilet Stall Layout

The guidelines for Wheelchair-Accessible toilets are as follows:

1. The handicapped accessible stalls and all associate accessories shall be located at end of the row and comply with all applicable codes.
2. Height of accessible toilets and all fixtures shall meet the requirements set forth in the Americans with Disabilities Act (ADA).

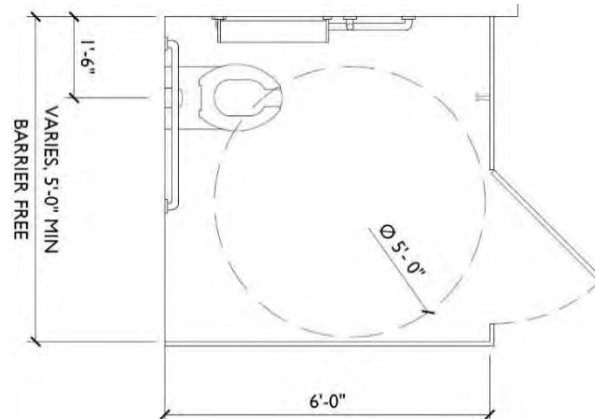


Figure A9: Wheelchair-Accessible Toilet Stall Layout

g. Urinal Area

The guidelines for urinals are as follows:

1. Urinals shall be white, vitreous china, wash out type, wall hung with a large tapered elongated bowl rim.
2. Urinals shall be mounted minimum of 3'-6" on center to provide adequate room with 24" privacy partitions installed between each urinal
3. Flush controls shall be automatic; they will be mounted on the back wall with the auxiliary flush button no more than 44" AFF.
4. Provide a 10"- 12" deep built-in small bag shelf in the vicinity of the urinal mounting surface. ADA urinal will have lower shelf and lower flush assembly.

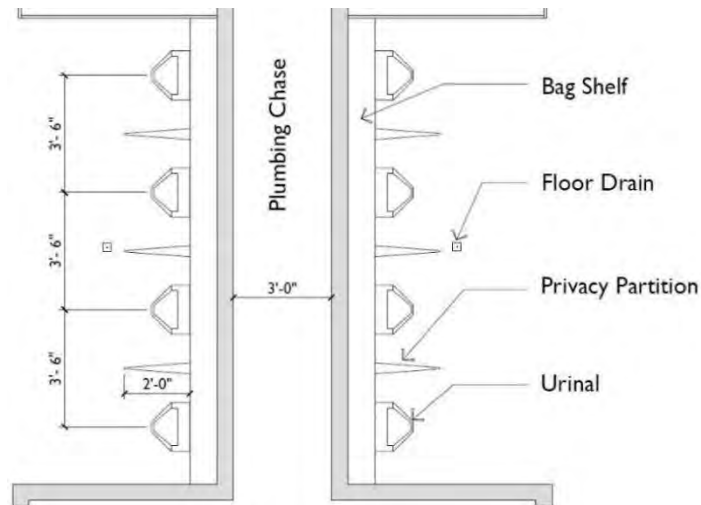


Figure A10: Urinal Area

h. Family Rooms

The Family Rooms should always contain the following:

1. One (1) lavatory counter
2. One (1) handicapped toilet
3. One (1) diaper changing station
4. Each door shall be equipped with kick plates and door hardware and equipped with a corridor lock function (locked from the inside only). Considerations should be given for controlled access to best service our customers.
5. Floor drain in a level floor

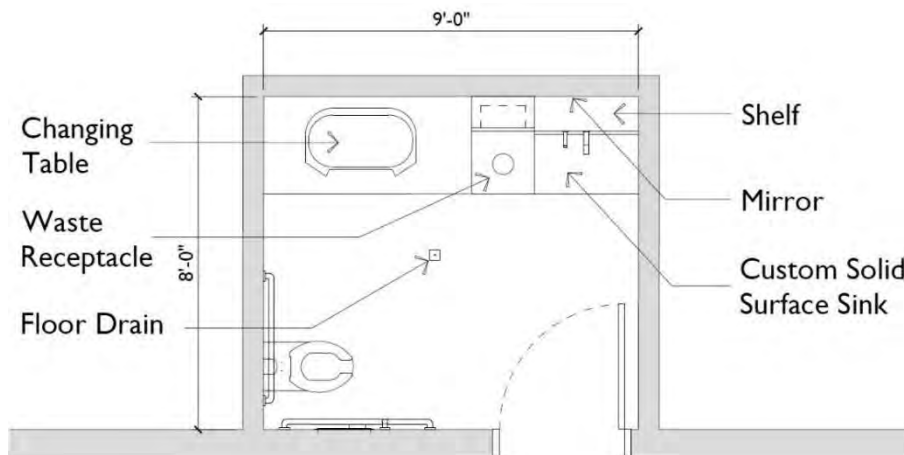


Figure a11: Family Room Layout

i. Janitor's Room

Provide a janitor's room adjacent to multi-stall toilet rooms. The room shall include the following minimum amenities: (See Figure A12)

1. Mop/Slop sink.
2. Hose bib over a floor mounted mop sink with protective surfaces around mop sink as required by code.
3. Mop hangers.
4. Storage shelving (for cleaning, maintenance, customer use supplies and operations)
5. Floor drain.
6. Access door to plumbing chase.
7. The entrance door shall be equipped with kick plates on the push side of the door.

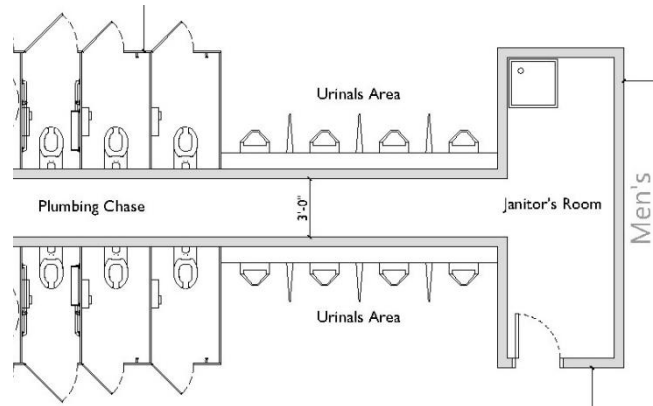


Figure A12: Janitor's Room Layout

j. Plumbing Chase

1. Finishes / fixtures must ensure easy cleaning process
2. Service chases shall be provided behind all fixture walls and be a minimum of 3'-0" clear from the inside face of the metal framing. This will provide ease of maintenance and minimize restroom closures for service.
3. 2'-0" wide (minimum) lockable service door shall be provided at each chase.
4. Floor drains and hose bibs are required in all chase areas.
5. Pipe elevations should be designed and organized to all fit into the chase. Ideally the waste piping should slope toward the chase door and a cleanout should be provided above the spill line to allow for easy access and the ability to clean out that piping as needed. Enough space should be provided at the chase entry to allow the door to close when someone is working at that end. This conceals maintenance personnel from public view."

8. Restroom Accessories

Each Restroom shall receive the required toilet accessories to serve the needs of a public toilet. This section will determine the quantities and locations of specific accessories.

The guidelines for toilet room accessories are as follows:

- a. A restroom stall shall include the following minimum partition mounted toilet accessories:
 1. One (1) stainless steel jumbo toilet tissue dispenser with capacity to hold two (2) toilet tissue rolls. (each side for partition type dispensers)
 2. One (1) toilet seat protector dispenser
 3. One (1) feminine product receptacle. (Women's only.)
- b. All toilet accessories are to be commercial grade and vandal resistant.
- c. All similar type of restroom accessories should be selected from the same manufacturer to keep continuity and uniform appearance.
- d. Grab bars are to be 1-1/2" diameter stainless steel, 18 gauge, Type 304, brushed satin finish with peened gripping surface.
- e. Grab bars are to be mounted using concealed plates, without exposed fasteners; concealed anchors are to be used for each specific wall type.
- f. Soap dispensers should be provided adjacent to each sink.
- g. Soap dispensing system should consider bulk dispensing systems to minimize service maintenance.
- h. A recessed 12-gallon waste receptacle shall be mounted at each door location.
- i. Each toilet room shall include a minimum of one (1) baby changing station.
- j. Provide a full-height dressing mirror out of the main circulation path.

9. Guidelines for Improved Passenger Experience

- a. General Requirements
 1. Considerations in terms of lighting:
 - Indirect lighting
 - Natural lights
 - Overall experience

The following sections address different locations for task lighting.

2. Entry

Lighting at the entries should accent signage that designates wayfinding. Lighting levels should not be too bright (or dim) such that users have a hard time transitioning visually from the adjacent area into or out of the restroom.

3. Sink Area

Lighting at the sink should be oriented to provide even vertical illumination (from the sides) onto the face, but somewhat softly to avoid glare into the eyes. Lighting from above the mirror can supplement the vertical lighting but should not be the sole source as it casts shadows that make a person's face look

tired and gaunt. Vertical lighting should be evenly balanced on both sides of the face. Lighting integrated within mirrors works well to keep the walls clear of clutter and surfaces that collect dust.

4. Toilet Stalls

Lighting at the utility wall or over the toilet stalls will offer a clean and crisp appearance. Consider providing indirect lighting.

b. HVAC

To improve quality of space by elimination odor and increasing air quality. Consider engineered ventilation systems that minimize recirculation of air, introduce fresh air in to the space, increase air changes per hour as well as applications of odor eliminating systems.

c. Entry points / Signage

Using an iconic façade and entry on restrooms throughout the airport would help travelers to recognize and supplement identifying signs. Designer should consider bold colors, text, or graphics to help identify gender.

d. Other design items to be considered:

- Floor Surfaces
- Wall Surfaces
- Ceiling Surfaces
- Lighting / Electrical
- Corner Guards and Edge Protection Profiles

e. Artistic Design / Environmental Graphics Feature

The Artistic Design / Environmental Graphics Feature criteria supports the PANYNJ's program to maintain and upgrade, as required, public restrooms within the PANYNJ's stewardship to a "World Class Level of Service" consistent with industry best practices and in order to enhance our customer's experience, with immediate effect, all current, future restroom renovations, and new construction must include at least one artistic design feature including, but not limited to texture, color, material, and other possibilities that enhance the physical and psychological qualities of the space and offer customers a memorable experience.

All proposals are subject to a review and approval process, by committee, managed by the Port Authority. The following sixteen Evaluation Criteria are the minimum level of performance for any submission. The Port Authority is open to recommendations that set a new premise for creative expression, innovation, and technical breakthroughs, while meeting or exceeding all criteria and safety considerations. Any submission that does not conform to these minimum criteria will not be considered nor approved.

Please note: It is the Port Authority's intention that in the next iteration of the Tenant Construction and Alteration Process (TCAP) Manual, this process will be removed from the Airport Planning Standards and be covered in the TCAP Manual.

f. Evaluation Criteria

	Evaluation Criteria	Evaluation Criteria Detail
A.	<i>Objectives</i>	
1.	Enhance the physical and psychological qualities of the space and offer customer a memorable experience.	
2.	Theme based to allow individual installations to work collectively and add a sense of space.	
3.	Attractive and inspiring design that engages travelers.	
B.	<i>Location</i>	
4.	Strategically located to be highly visible	How well does the feature location promote exposure to maximum numbers of traveling public.
5.	Contribute to passenger orientation and intuitive way finding.	Does the feature assist with passenger orientation or does it detract from intuitive wayfinding.
C.	<i>Design and Color</i>	
6.	Design to evoke positive passenger experience.	Does the feature provoke a unique, original, positive, and memorable experience.
7.	Incorporate regional character and culture.	Are regional character and cultural elements prominently featured in the design.
8.	Use of colors, patterns, textures and imagery to providing uplifting and cheerful space.	How well do the selected colors, materials, textures, and imagery contribute to improve ambiance.
9.	Design and color schemes to be considerate of locations within terminal.	Does the design and color scheme respond to different installation locations within terminal, i.e., pre-security vs. post security and arriving vs. departing areas.
10.	Feature to work in concert with lighting sources and levels. Incorporate day light where possible.	Does the installation take advantage of natural day light opportunities? Do the proposed lighting fixtures, lighting levels, and light sources complement features location, colors, materials, and textures.

	Evaluation Criteria	Evaluation Criteria Detail
D.	<i>Materials and Installation</i>	
11.	Materials and installation shall be durable and easy to clean.	Are the materials and finishes durable and easy to clean? How well are the selected materials expected to stand up to high volume of passenger traffic. Do the proposed finishes and materials require special cleaning agents or procedures.
12.	Compatibility of materials and finishes to promote unified design.	How well are the selected materials and finishes work together to enhance the design concept and promote a unified appearance. For installation at existing facilities, with minimal changes, how well do the proposed material and finishes work with existing finishes.
13.	Modern timeless design using warm, inviting and light-colored finishes	Will the design be fresh and relevant over the expected life span of the feature? How well do the proposed materials contribute toward creating an inviting, pleasing, and well-lit space.
14.	Minimize ecological impact by incorporating environmentally friendly and sustainable practices	Are the selected materials and installation procedures environmentally friendly and in line with sustainable practices.
E.	<i>Ease of Installation</i>	
15.	Installation duration	What is the installation duration of proposed feature? Can it be installed off hours without taking the restroom out of service. Is the concept compatible with phased installation to help minimize restroom down time.
16.	Standard installation procedures	Can the feature be installed by a general contractor? Does the installation require any nonstandard tools or procedures.

Table A3: Evaluation Criteria for Restroom Artistic Design / Environmental Graphics Feature

g. Submittal Requirements

Refer to Port Authority of New York and New Jersey Tenant Construction and Alteration Process (TCAP) for complete list of required documents. Submissions shall include, but not be limited to:

PANYNJ TAA Documents	PANYNJ TAA Submittal Documents and a letter of intent articulating scope of work, anticipated budget, and anticipated duration. Certifications of all specialized trades. Asbestos report where required.
Architectural drawings	Site Plan, Summary of Applicable Codes and ADA / Universal Design integration, Demolition Plans with proposed barrier locations, Floor Plans, Reflected Ceiling Plans, Section, Elevations, Finish Plans and Schedules, MEP Drawings as required. (Phasing plans where applicable)
Specification	Technical specifications for all materials and installation methods
Architectural Renderings and illustrations	Rendering with multiple views to clearly describe the design concept
Finish Boards and material samples	Finish boards, samples and manufacturers literature of all major finishes. Samples to be clearly coded and coordinated with plans and rendering.

Table A4: Submittal Requirements for Restrooms Artistic Design / Environmental Graphics Feature

Appendix B – List of Acronyms and Abbreviations

A4A: Airlines For America
AASHTO: American Association of State Highway and Transportation Officials
AC: Advisory Circular
ACRP: Airport Cooperative Research Program
ADA: Americans with Disabilities Act
ADG: Aircraft Design Group
ADPM: Average Day of the Peak Month
ADRM: Airport Development Reference Manual
AIT: Advanced Imaging Technology
AL: Alarm Line
ANSI: American National Standards Institute
APHIS: Animal and Plant Health Inspection Service
APM: Automated People Mover
ASL: Automated Screening Lanes
AT: Advanced Technology
ATCT: Airport Traffic Control Tower
ATO: Airline Ticket Office
ATR: Automated Tag Readers
AVS: Alternate Viewing Station
AVS: Alternate Viewing Station
AWDPM: Average Weekday of the Peak Month
BHS: Baggage Handling System
BIM: Building Information Management
BIT: Baggage Inspection Table
BLS: Bottle Liquid Scanner
BSO: Baggage service office
CAD: Computer Aided Design
CAGR: Compound Annual Growth Rates
CBIS: Checked Baggage Inspection System
(US)CBP: (United States) Customs and Border Protection
CBRA: Checked Baggage Resolution Area
CDG: Checkpoint Design Guide
CL: Clear Line
CTA: Central Terminal Area
DDFS: Design Day Flight Schedules
DHS: Department of Homeland Security
EBS: Early Bag Storage
EDS: Explosives Detection System
EQA: Equivalent Aircraft
ETD: Explosives Trace Detection
FAA: Federal Aviation Administration
FEMA: Federal Emergency Management Agency
FIS: Federal Inspection Services
GSE: Ground Service Equipment
HOV: High Occupancy Vehicle

Port Authority of NY & NJ

HSC: High Speed Conveyor
HVAC: Heating, Ventilation, and Air Conditioning
IATA: International Air Transport Association
ICAO: International Civil Aviation Organization
ICC: International Code Council
ICS: Individual Carrier System
ITS: Intelligent Transportation Systems
KCM: Known Crewmember
LAN: Local Area Network
LEO: Law Enforcement Officer
LOS: Level of Service
MAAP: Million Annual Air Passengers
MARS: Multi-Aircraft Ramp System
MDR: Manual Diverter Roller
MEP: Mechanical, Electrical, Plumbing
MUP: Make-Up Positions
MUTCD: Manual on Uniform Traffic Control Devices
NFPA: National Fire Protection Association
NYCDOT: New York City Department of Transportation
NYPD: New York Police Department
O&D: Origin and Destination
O&M: Operations and Maintenance
OOG: Out-of-gauge
OOS: Out of Spec
OS: Oversize
OSR: On Screen Resolution
PA: Port Authority
PA: Public Address
PANYNJ: Port Authority of New York and New Jersey
PBB: Passenger Boarding Bridges
PCA: Preconditioned Air
PFSP: Potential Fuel Spill Point
PGDS: Planning Guidelines and Design Standards
PRM: Passengers with Reduced Mobility
PSR: Private Screening Room
PWC: Potable Water Cabinets
QAD: Quality Assurance Division
RBS: Risk-based Security
RFID: Radio Frequency Identification
RIDS: Ramp Information Display System
RL: Re-insert Line
RSR: Restricted Service Road
SIDA: Secure Identification Display Area
SOP: Standard Operating Procedure
SSCP: Passenger Security Screening Checkpoints
TAA: Tenant Alteration Application
TAF: FAA Terminal Area Forecasts

TDC: Travel Document Check
TNC: Transportation Network Companies
TOS: Tail of Stand
TRB: Transportation Research Board
TSA: Transportation Security Administration
TSD: Technology Services Department
TSO: Transportation Security Officers
UEC: Universal Encoding Console
ULD: Unit Load Device
UPS: Uninterruptible Power Supply
USDA: US Department of Agriculture
UV: Ultraviolet
VDGS: Visual Docking Guidance Systems
VIP: Very Important Person
VSU: Vertical Sortation Units
WAN: Wide Area Network
WTMD: Walk-through Metal Detector