ACRP FACT SHEETS

AIRPORT COOPERATIVE RESEARCH PROGRAM

Deicing Practices

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FACT SHEETS

Deicing Practices #1–41, 113–115

ACRP Research Report 14

Deicing Planning Guidelines
and Practices for Stormwater
Management Systems

Second Edition

AIRPORT COOPERATIVE RESEARCH PROGRAM **2020**

Deicing Fact Sheets

These fact sheets are prepared for each of the identified deicing practices. They are organized into five categories: aircraft deicing source reduction; airfield pavement deicing source reduction; deicing runoff containment/collection; deicing runoff treatment/recycling; and deicing runoff system components.

It should be noted that the status of the fact sheets is shown in parentheses relative to the original edition of this guidebook.

It is essential that relevant FAA regulations and requirements are considered when assessing the applicability of the practices and technologies represented in the fact sheets, especially as they relate to safety. FAA's Regulations & Policies website is a comprehensive and up-to-date resource for this information. Practical guidance on which regulations and requirements apply to planning and implementing the types of projects and activities described in the fact sheets may be found in a variety of ACRP publications, for example:

Report 81: Winter Design Storm Factor Determination for Airports
Report 96: Apron Planning and Design Guidebook
Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers
Report 113: Guidebook on General Aviation Facility Planning
Report 114: Guidebook for Through-the-Fence Operations
Report 123: A Guidebook for Airport Winter Operations
Report 125: Balancing Airport Stormwater and Bird Hazard Management

Special note on costs: Where available, specific costs of equipment and other well-defined elements are provided in the fact sheets to give the reader a sense of the magnitude of costs. These estimated cost numbers should not be used for planning purposes without verifying current local costs.

Aircraft Deicing Source Reduction

The purpose of these practices is to reduce the amount of pollutants generated by aircraft deicing activities, either by using products with reduced environmental impacts or by reducing the amounts of deicing products required to achieve and maintain safe flight operations. It should be noted that U.S. aircraft operators must obtain FAA Flight Standards approval for certain proposed source reduction fact sheets prior to selection and implementation.

Fact Sheet 1. Aircraft-Deicing Product Selection (Updated)
Fact Sheet 2. Storage and Handling of Aircraft-Deicing Materials (Updated)
Fact Sheet 3. Proactive Anti-Icing (Updated)
Fact Sheet 4. Blending to Temperature (Updated)
Fact Sheet 5. Forced Air/Fluid Deicing (Updated)
Fact Sheet 6. Infrared Deicing Technology (Retired)
Fact Sheet 7. Physical Removal (Updated)
Fact Sheet 8. Hangared Parking (No Change)
Fact Sheet 9. Hot Water Deicing (Updated)
Fact Sheet 10. Enclosed Deicing Bucket (Updated)
Fact Sheet 11. Enhanced Weather Forecasting (Updated)

Airfield Pavement Deicing Source Reduction

The purpose of these fact sheets is to reduce the amount of pollutants generated by airfield pavement–deicing activities, either by use of products with reduced environmental impacts or by reduction in the amounts of deicing products required to achieve and maintain safe flight operations.

Deicing Runoff Containment/Collection

The role of these fact sheets is to provide methods for isolating, collecting, and containing storm water runoff from deicing activities. In most instances, these practices are implemented to address aircraft deicing runoff.

Deicing Runoff System Components

These technologies represent components of systems that may be implemented in various locations, and serving different purposes, in any given system.

Deicing Runoff Treatment/Recycling

These practices provide alternatives for disposing of deicing runoff that has been collected and contained and is not suitable for controlled discharge to receiving waters.

FACT SHEET 1

Aircraft-Deicing Product Selection

1. Description

Purpose

This practice considers opportunities to use alternative aircraft-deicing products that have a reduced environmental impact, primarily in terms of the biochemical oxygen demand (BOD) found in the freeze-point depressants and aquatic toxicity associated with additives required to meet certification specifications.

Product selection is typically the responsibility of aircraft operators and their contractors.

Technology

All aircraft deicing and anti-icing fluids (ADFs and AAFs) must be certified as meeting the following Aerospace Materials Specifications published by SAE:

- 1424 Deicing/Anti-Icing Fluid, Aircraft, SAE Type I
- 1428 Fluid, Aircraft Deicing/Anti-icing, Non-Newtonian, SAE Types II, III, and IV

Each manufacturer of aircraft-deicing fluids has its own proprietary formulations, the environmental characteristics of which may vary from others. Currently, only ethylene glycol (EG)–based or propylene glycol (PG)–based aircraft fluids are used at a commercial level. Both of these glycols have a relatively high BOD content, with EG having a somewhat lower BOD than PG. The additive packages, which affect primarily the aquatic toxicity of each product, vary more significantly among the formulations. Guidance on the environmental properties is sometimes provided in manufacturer literature for each product, but it is not always consistent or comparable between products.

The fluid manufacturers have been steadily improving their products with respect to aquatic toxicity and elimination of toxic components in the additive packages. Therefore, it is important to get the most current product information on the deicers that are being used or considered.

There are several ongoing efforts to develop ADFs and AAFs with reduced environmental impacts. The Department of Defense's Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) have been funding research into environmentally friendly aircraft deicers since the early 2000s. To date, three ADFs have come out of these programs, none of which has been fully qualified for use. The goal of ACRP Project 02-01 was to identify the sources of toxicity in currently available deicing formulations and develop alternatives with more environmentally friendly profiles. This project was completed in 2008 and, although significant advances were made to improving the understanding of sources of toxicity and fate of deicing fluid components in the environment, additional research is required with respect to developing more environmentally friendly products.

Documented Performance

The U.S. military and some airports have mandated the use of only PG-based aircraft fluids. This bias toward PG-based fluids seems counterintuitive given its BOD content, but other environmental considerations have driven the trend. Specifically, in the 1990s, industry and the military moved away from EG-based fluids because of ethylene glycol's mammalian toxicity and its listing as a hazardous air pollutant subject to release reporting under the Comprehensive Environmental, Response, Compensation, and Liability Act (CERCLA) and the Emergency Planning and Community Right-to-Know Act (EPCRA). For severe cold weather airports, EG-based products are preferred because they allow for use at a larger range of temperatures compared to PG-based fluids. Specifically, lower concentrations of EG are required to achieve the same freeze protection as compared to PG.

Historically, some ADFs and AAFs contained benzotriazoles for corrosion inhibition. These compounds were implicated as a major source of aquatic toxicity in those fluids. However, in recent years the use of triazole compounds has been discontinued in the United States and Europe.

2. Implementation Considerations

Applicability Assessment

The primary key to applicability of this practice is the ability of aircraft operators to purchase and use SAE-certified deicing products based on improved environmental characteristics. Flexibility in this regard will be dependent on site-specific weather and operational conditions, which require specific deicer characteristics, and organizational constraints that may affect procurement practices. Also, any change in deicers must be accompanied by revisions to the aircraft operator's FAA-approved snow and ice control plan.

The potential for benefits from changing aircraft deicers may be evaluated by comparing the environmental characteristics of products currently being used against available alternatives in the context of existing facility-specific environmental concerns.

Where glycol recycling is used or planned, there will be a strong economic motivation for using PG-based fluids because the value of recovered glycol from runoff containing only PG-based fluids is significantly greater than that of a mixed waste stream.

Regulatory Considerations

The primary regulatory considerations regarding this practice are:

1. Choice of alternatives is constrained to SAE-certified products, and
2. Any changes in product use must be incorporated in revised FAA-approved snow and ice control plans as well as associated training and operational activities.

Planning and Design Considerations

Product selection by an aircraft operator is typically conducted through a fluid selection committee composed of representatives from engineering, ground support, flight crew, environmental, and purchasing and begins with identifying certified products that are reliably available in the quantities required and within the time constraints. The identified list of products is then evaluated with respect to logistics, cost, environmental characteristics, operator and industry experience with the products, ground support equipment fleet mix and compatibility with the product, and the need for and timing of employee retraining. Fluid selection must balance a wide range of competing objectives (e.g., supply requirements, environmental) without sacrificing safety. Several air carriers have established “no backsliding” policies for fluid selection to ensure that less environmentally friendly products are not re-introduced into the fluid purchasing system. In addition, to encourage the development of new environmentally friendly fluids, contractual incentives have been written into long-term purchasing contracts to ensure continuous improvement with respect to environmental performance.

Other considerations include the following:

- Airport policies restricting the type of glycol that can be used at that facility.
- Implications to recycling programs that depend on using a PG-based fluid.
- Potential for increased management and reporting requirements associated with EG being regulated under Toxic Chemical Release and CERCLA reportable quantity regulations.
- The logistics of product substitution, which will include consuming or disposing of existing stockpiles of old fluids and cleaning tanks and refilling them with the new product.
- Modifying and distributing deicing plans to reflect the new product and training employees on the new plan and product.
- The environmental characteristics of the product.

Integration with Other Fact Sheets

Product selection can be combined with all other practices. There may be opportunities to reduce the need for collection and treatment through use of deicers with improved environmental characteristics (e.g., lower BOD or reduced aquatic toxicity).

Operation and Maintenance Considerations

For this practice to be effective, the aircraft operator should plan on revising deicing plans to reflect the new product and providing product-specific training to deicing personnel.

With the exception of changes required to the deicing plans, equipment operation and maintenance requirements should not change significantly.

3. Costs

Capital Costs

The only capital costs that might be incurred would be if the new product is not compatible with existing storage and application equipment.

Operations and Maintenance Costs

The primary source of changes to operational and maintenance costs would be differences in cost of the new product compared to the previously used one, including any adjustment for differences in application rates to achieve equivalent performance.

FACT SHEET 2

Storage and Handling of Aircraft-Deicing Materials

1. Description

Purpose

This practice includes protocols or guidelines for the storage and handling of aircraft deicing materials, with the primary purpose of reducing the contamination of stormwater by deicing/anti-icing materials.

Aircraft operators or their deicing contractors are normally responsible for implementation of this practice.

Technology

Specific goals for the storage and handling of deicing/anti-icing materials include maintaining product integrity, using and storing products effectively, and minimizing exposure of the materials to stormwater. Personnel responsible for the storage and handling of these materials should be trained in stormwater pollution prevention and follow protocols and procedures consistent with the airport's stormwater pollution prevention plan (SWPPP) and deicer management program.

To maintain the integrity and effectiveness of deicing/anti-icing materials, they must be stored, handled, and applied in a manner consistent with chemical-specific instructions provided by the manufacturer on the safety data sheet (SDS). Materials with reduced effectiveness may require larger application volumes or frequent reapplication, thus increasing the potential for stormwater pollution.

In general, aircraft anti-icing fluid (AAF) (classified as either a Type II or a Type IV fluid by SAE), has more specialized requirements for storage and handling than does aircraft deicing fluid (ADF) (classified as a Type I fluid by SAE). The high viscosity of AAF may be damaged by improper handling or storage methods, which can potentially reduce the holdover time between applications. Thickeners in AAF may be damaged by ultraviolet light and certain metal ions and thus AAF requires storage in opaque tanks constructed of stainless steel, coated steel, polyethylene, or opaque fiberglass. AAF agents also require careful heating to protect fluid viscosity. Any transfer of deicers through dedicated pipes and pumping equipment should be accomplished according to manufacturers' specifications. Anecdotal information from one airport indicates that piping cannot contain 90° bends because they increase the likelihood of freezing.

Documented Performance

Quantified benefits of establishing storage and handling protocols for aircraft deicing materials have not been explicitly documented or measured. However, airports have reported reduced unexplained glycol releases during transfer and fewer unexplained occurrences of elevated deicer concentrations outside designated deicing areas with the implementation of this practice. Generally, benefits may be expected in terms of decreased deicer discharges to surface water and potentially decreased deicing stormwater management costs.

The success of this practice at an individual airport can be evaluated by comparing the frequency of unexplained or unexpected deicer releases before and after implementing storage and handling practices.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to any airport where aircraft deicing occurs, although larger airports may experience more noticeable benefits because of the volumes of fluids being handled. Airports already may have some type of guidelines in place as a component of their SWPPP or deicer management program plan. Opportunities for improving existing deicing material storage and handling programs will arise where there is a problem with deicer runoff outside of designated deicing areas.

Regulatory Considerations

Storage and handling protocols are frequently incorporated as requirements of SWPPPs and written deicer management program plans and may be explicitly required by National Pollutant Discharge Elimination System (NPDES) permit conditions.

Planning and Design Considerations

The following operational considerations apply when developing protocols for storing and handling aircraft deicing and anti-icing materials:

- Store, handle, and apply deicing and anti-icing materials only within designated contained areas.
- Maintain adequate supplies of spill response equipment and materials in locations accessible to and near areas where spills may occur.
- Provide employee education as appropriate in the following areas: material storage and handling, deicing procedures, spill response and prevention, and stormwater pollution prevention.
- Restrict deicing/anti-icing material storage and handling to trained personnel only.
- Take actions to prevent stormwater runoff onto deicing/anti-icing material storage and handling areas. Block storm drains during material handling operations to prevent runoff of deicing/anti-icing materials.

- Where possible, store deicing/anti-icing materials indoors or in a sheltered area.
- Protect storage containers from damage due to vehicular traffic with bollards or other physical barriers to the extent possible.
- Shield storage containers from jet blast or locate in areas not subject to jet blast.
- Perform and document frequent inspections of storm drains, deicer application equipment, deicer runoff controls, and storage tanks; perform maintenance as required.
- Follow chemical- and product-specific instructions and guidelines recommended by the material manufacturer to maintain the material's integrity and effectiveness.

Several airports have reported that employee training is key to the success of this practice. This importance is illustrated by an anecdotal report that operators were found to be allowing releases from hoses and overfills to enter secondary containment basins without realizing the costs associated with pumping out and disposing of contaminated precipitation in the basins.

The following features should be considered in designing new facilities or upgrading existing facilities, to aid the effective storage and handling of aircraft deicing and anti-icing materials:

- Pavement or flooring characteristics in material storage and handling areas that facilitate cleanup and containment of spills; slope pavement or flooring toward a sump to facilitate fluid collection.
- Clearly designated aircraft deicer/anti-icer storage and transfer areas.
- Secondary containment for aircraft deicing/anti-icing material storage areas.
- Closed-loop recycling system at deicing stations, which could help with collecting spent or spilled deicer for recycling.
- Consolidated glycol storage/dispensing system, which has the potential to reduce spillage caused from transferring the materials between storage tanks and dispensing equipment.

Integration with Other Fact Sheets

This practice would be compatible with any other deicing practices with regard to pollution prevention. Following this practice will reduce overapplication and spillage and ultimately reduce the volume or concentration of deicing runoff that needs to be managed through other deicing practices. Storage and handling protocols may also be tailored to apply to specific deicer management practices, including alternative deicing materials, deicer application methods or equipment (for example, forced air/fluid deicing trucks; see Fact Sheet 5), and deicing stormwater collection and storage practices (for example, glycol collection vehicles; see Fact Sheet 23). Relevant storage and handling procedures and protocols should be considered during the development of standard operating procedures for those practices.

Operation and Maintenance Considerations

Operational requirements associated with this practice include regularly reviewing and updating deicing material storage and handling protocols as necessary prior to each deicing season. Employee training should occur prior to the start of each deicing season.

3. Costs

Costs associated with this practice include both capital and operation and maintenance components.

Capital Costs

Capital costs for this practice may include features added to material storage and handling equipment and areas to reduce spills and prevent contamination of stormwater. These features may include secondary containment for storage tanks or specialized dispensing equipment that reduces the opportunity for spillage during transfer operations.

Operations and Maintenance Costs

Operational costs associated with this practice include educational programs for employees involved in storage and handling of aircraft deicing/anti-icing materials, spill response materials, and performance of regular inspections of storage and handling equipment.

Transfer operations provide an opportunity for inadvertent spills of deicing or anti-icing fluid.

FACT SHEET 3

Proactive Anti-Icing

1. Description

Purpose

This practice involves the application of aircraft anti-icing agents as a preventative measure, potentially resulting in a reduction in the volume of deicing agents required to ensure that aircraft are free of snow and ice contamination prior to take-off.

Implementation of this practice would be the responsibility of the aircraft operators.

Technology

Proactive anti-icing involves the application of anti-icing agents in advance of an anticipated frozen-precipitation event, therefore reducing the adherence of frozen precipitation on the aircraft and facilitating its removal. Aircraft anti-icing fluids (AAFs) are applied in significantly smaller volumes than deicing fluids, potentially resulting in cost savings to the aircraft operators, as well as reduced environmental impact due to glycol runoff.

Documented Performance

According to testing performed by the U.S. Air Force, this practice can reduce the overall volume of glycol-based deicing fluid applied to an aircraft when properly performed prior to the advent of icing conditions (EPA 2000). Proactive anti-icing has been found to be most effective under freezing rain; it is less effective for heavy snow and severe icing conditions.

Several aircraft operators have experimented with the preventative application of anti-icing agents to aircraft immediately after their landing. The purpose of this practice is to prevent the buildup of frozen precipitation while aircraft are at the gate and to reduce the deicing effort needed prior to their departure. Aircraft with short turnaround times generally require less deicing fluid application prior to departure, depending on weather conditions.

The key to proper implementation of this practice is access to accurate weather forecasts. When used with inaccurate weather forecasts, this practice can result in the application of otherwise unnecessary and excessive amounts of anti-icing fluid and deicing fluids needed to remove the AAF.

A drawback of preventative anti-icing is that the application of AAF alone has been found to pose a safety risk to aircraft under certain conditions. If a dry period occurs in place of a predicted frozen-precipitation event, the AAF may dry into a residue, only to be rehydrated and refrozen during subsequent storm

Application of Type IV anti-icer may result in the formation of a residue that poses a potential aircraft safety risk. The application of hot water or heated Type I fluid in the first step of a two-step process for subsequent deicing operations will minimize the formation of these residues.

events. Several aircraft operators have expressed concerns that this refrozen residue can degrade aircraft parts and limit flight controls (EPA 2000). Out of concern for aircraft safety, aircraft that have been anti-iced are often deiced with Type I prior to takeoff in an effort to remove the Type IV residue, even in situations where deicing may not have been otherwise required.

2. Implementation Considerations

Applicability Assessment

This practice would be most applicable for aircraft operators or fixed base operators (FBOs) at airports that typically experience weather conditions during which proactive anti-icing would be an effective alternative or supplement to deicing (freezing rain, for example). Airports that frequently experience heavy snow or severe icing conditions during the deicing season may not benefit as much from a proactive anti-icing program owing to the reduced effectiveness of anti-icing agents in those weather conditions.

Pro-active deicing is more commonly used on cargo aircraft that are typically on the ground for longer periods of time between arrival and departure. Type IV is sometimes applied after aircraft arrive to avoid a buildup and bonding of frozen precipitation while parked on the apron for several hours. This practice can shorten departure delays and potentially reduce the volume of Type I required at departure.

Deicing personnel should also consider whether the coordination of proactive anti-icing and deicing activities for arriving and departing flights would cause significant interference with airport operations or flight delays.

Regulatory Considerations

The FAA requires that an aircraft be clean prior to takeoff in order to meet aircraft safety requirements. If proactive anti-icing is implemented, it must be performed with considerations for aircraft safety and FAA regulations. In many cases, an aircraft will be deiced again prior to takeoff to ensure that all frozen precipitation has been removed and to prevent any buildup of anti-icer residue on the surface of the aircraft. Conservative deicing procedures required to ensure safety have the potential to reduce the documented performance levels of this practice.

Planning and Design Considerations

Aircraft operators and FBOs interested in proactive anti-icing should consider the following in their planning and implementation:

- Identify services or equipment for improving weather-forecasting abilities and thereby the accuracy of proactive anti-icing.
- Develop protocols for identifying conditions appropriate for proactive anti-icing.
- Develop standard operating procedures for proactive anti-icing, including weather forecasting, anti-icing equipment coordination, anti-icing agent application, and scheduling.

Integration with Other Fact Sheets

The success of proactive anti-icing activities can be increased by using specialized weather-forecasting systems and procedures to identify opportunities for proactive anti-icing. Accurate weather forecasts can help aircraft operators and FBOs identify weather conditions during which proactive anti-icing is expected to be more efficient than deicing alone, as well as conditions that will not result in the formation of a harmful residue.

Operation and Maintenance Considerations

Operational requirements associated with this practice include the regular monitoring of weather forecasts to identify weather conditions that would be appropriate for proactive anti-icing. Maintenance requirements for this practice may include removing residue that could form on aircraft from dried anti-icing materials.

3. Costs

Overall costs associated with this practice include the costs for anti-icing materials and equipment, as well as weather-forecasting or -monitoring systems to accurately identify conditions that are beneficial for proactive anti-icing. Potential savings may be achieved where the net cost of all deicers and anti-icers used is reduced.

Capital Costs

The primary capital cost associated with this practice would be for the installation of a specialized weather-forecasting system, if applicable. In some instances, additional deicing equipment may be required to meet air traffic demands.

Operations and Maintenance Costs

Operational costs associated may include additional aircraft anti-icing fluids used and costs associated with subscribing to a specialized weather-forecasting service, and specialized training. Other costs may include the labor and materials costs to remove anti-icing material residue from aircraft. Potential cost savings may be achieved through any reduced use of aircraft deicing fluids.

Reference

EPA. 2000. Preliminary Data Summary: Airport De-Icing Operations. *EPA-821-R-00-016*. From http://www.epa.gov/waterscience/guide/airport/.

FACT SHEET 4

Blending to Temperature

1. Description

Purpose

Blending to temperature is a source reduction practice aimed at reducing the volume of glycol in applied Type I aircraft deicer fluid by optimizing the dilution of Type I concentrate relative to the outside air temperature (OAT). This practice is not applicable to Type II or Type IV aircraft anti-icing fluids.

Aircraft operators or their contract service providers are normally responsible for the implementation of blending to temperature. Implementation of this practice throughout a facility can be facilitated through airport involvement and coordination of efforts.

Technology

Manufacturers of Type I aircraft deicing fluids (ADF) provide dilution charts describing the lowest operational use temperature for a range of mixtures. Many aircraft operators adopt a standard ADF concentrate:water mixture, typically between 45:55 and 60:40, to ensure consistent compliance with FAA criteria and prescribed safety factors under the full range of anticipated OATs. As the OAT rises, the mixture of Type I concentrate can be reduced instead of using a standard mixture. Examples of how blending calculations are conducted are commonly provided with the product literature. Any use of mixtures that can be accomplished below the standard concentration will result in reduced glycol use.

Blending can be accomplished in a variety of ways, from manual mixing of ADF in a deicing truck's tank to the desired concentration, to the use of blending technology that either automates the tank mixture process (for example, blending stations) or provides for "blending on the fly" by adjusting the mix of concentrated ADF and water fed to the deicing application nozzle. Recent developments in equipment technology have made the implementation of this practice more practicable and reliable, both with centralized blending stations and deicing vehicles.

Documented Performance

The success of this practice varies widely with climate and temperature variations. The greatest potential for benefits exists at airports where most deicing is conducted at milder OATs. Because blending to temperature is typically combined with other practices, specific documented performance data is limited. Various individual airport studies, as well as manufacturers' literature suggest savings reductions between about 18% and 65% per season. The potential reduction is greatly influenced by facility specific factors, such as typical winter weather, aircraft mix, and times of day when aircraft deicing is conducted.

Since 2010, large scale evaluations of blend to temperature and forced air/fluid deicing practices have been conducted by several air carriers at two different airports. The results of these studies confirm the potential for significant fluid use reductions compared to standard ADF concentrate:water mixtures. These studies are summarized below.

Side-by-side comparisons of deicer usage were conducted by a major carrier at Anchorage International Airport during the 2010–2013 deicing seasons. During the 2010–2011 deicing season, the volume of both Type I and Type IV deicing fluid was individually tracked for over 254 aircraft deicing operations. Some aircraft were deiced with conventional deicing trucks using ready-to-apply deicing fluid (55:45 Type I concentrate:water) whereas other aircraft were deiced using new technology trucks equipped with both blend to temperature and forced air/fluid capabilities.

The following findings were reported from this study:

- Average reduction in fluid use with trucks equipped with blend to temperature and forced air/fluid technologies compared to conventional trucks was 57% for Type I fluid and 53% for Type IV fluid.
- Although only a portion of the fleet was deiced using the new technology trucks, overall reductions in fluid usage for the entire carrier fleet ranged between 24 and 30% over 2 seasons.

Studies conducted at Minneapolis–St. Paul International Airport during the 2010–2011 deicing season compared trucks equipped with blend to temperature and forced air/fluid technologies to existing conventional technology trucks under similar deicing conditions. Two different new technology trucks were utilized and compared against conventional deicing trucks. A total of 189 individual aircraft deicing operations were evaluated. These data indicated that the new technology trucks reduced glycol consumption by between 34 and 67% compared to traditional deicing trucks.

2. Implementation Considerations

Applicability Assessment

This is an aircraft operator practice, so the first consideration will be the feasibility and acceptability of blending to temperature by the aircraft operators at the facility. The availability of blending technology greatly improves the feasibility of blending to temperature. Decision criteria presented below can be used to assess the potential benefit associated with implementing a blending to temperature practice.

Decision Criteria

A simple screening process can be applied to determine the potential benefit that might be associated with adoption of blend to temperature practices at an airport.

The process involves answering two questions and then entering the results in a matrix, as follows:

What is the average winter temperature? If available, what is the average winter temperature during deicing events?

30–35°F	25–30°F	20–25°F
15–20°F	10–15°F	

What is the average Type I fluid mixture (ADF concentrate : water) applied at the airport (check the one that approximates the closest to actual application strength):

55:45	50:50	45:55
40:60	35:65	30:70

Use Table 1 to assess potential Type I fluid reduction if using blend to temperature. Note, the potential fluid savings shown are for a "generic" fluid containing 88% propylene glycol, and flight safety should be evaluated in all circumstances. The mixture required for the outside air temperature should be confirmed for the specific fluid used. Consideration also should be given to the potential that the aircraft skin temperature may be lower than the outside air temperature.

Regulatory Considerations

There are no specific environmental regulations that apply to this practice, although reduction of deicing agents in stormwater will generally be viewed favorably by environmental regulatory agencies.

Table 1. Potential cost savings by use of fluid blend.

Current Fluid Mix (Type I concentrate:water)	Typical Deicing Temperatures				
	10–15°F	15–20°F	20–25°F	25–30°F	30–35°F
55:45	22%	27%	35%	41%	45%
50:50	14%	20%	28%	35%	40%
45:55	4%	11%	20%	28%	33%
40:60		0%	10%	19%	25%
35:65				7%	14%
30:70					0%

KEY:

Green: Substantial Benefit (>20% fluid reduction possible)

Yellow: Some Benefit (0 – 19% fluid reduction possible)

Gray: No Benefit

Red: Fluid Fails to Meet Temperature Offset Requirements, Flight Safety Concerns, Do Not Use

Values: Potential maximum fluid savings if use blend to temperature compared to current fluid use. Assumes an 18°F offset from outside air temperature. Assumed fluid mix is based on mid-point storm temperature (e.g., for 20 - 25°F deicing temperature, the fluid mix was based on an outside temperature of 22.5°F).

NOTES:

Example: If average fluid mix is 55:45 and average event temperature is 25-30°F, a fluid mix of 30:70 or 35:65 is required resulting in an average savings of 40.9%.
Lowest fluid mix of 30:70 assumed.

Actual fluid reduction is based on frequency of fluid mix preparation and additional safety factor(s) used by carrier in determination of fluid mix.

Safe flight operations under freezing weather conditions is a priority. Per 14 CFR Sections 121.629 and 135.227, the aircraft must be free of frost, ice, or snow adhering to the wings, control surfaces, propellers, engine inlets, or other critical surfaces prior to takeoff. Minimum ground deicing and anti-icing requirements are described in the FAA Advisory Circular (AC) 120-60B as well as the SAE Aerospace Standard (AS) 6285. The use of blending to temperatures requires adherence to SAE AS 6285 and Aerospace Recommended Practice (ARP) 4737 specification that residual Type I ADF on aircraft surfaces following deicing must have a freezing point at least 10°C (18°F) below the OAT or aircraft skin temperature. This is commonly referred to as the freezing point buffer. All deicing operations must be compliant with the above regulations to ensure safe flight operations.

In addition, the practice must be adequately described in an aircraft operator's FAA-approved snow and ice control plan.

Planning and Design Considerations

The following factors should be considered in planning implementation of the blending to temperature practice:

- Standard mixtures currently being used by aircraft operators;
- Distribution of air temperatures during periods of aircraft deicing;
- Suitability to aircraft fleet mix and operations;
- Availability of specialized blending equipment and land/space requirements, if any;
- Availability of water for blending;
- Plans for glycol recycling, which can be undermined by the decreased concentrations of glycol in deicing runoff; and
- Effective training and quality assurance program.

Airports may encourage this practice through environmental awareness programs and may go as far as providing central glycol storage and dispensing stations with automated blending equipment.

Blending may be considered in conjunction with centralized deicing systems; however, consideration must be made for infrastructure, such as a water supply, to support blending mixtures at the deicing facility.

Implementation may be constrained by the requirements of various air carriers. For example, fixed base operators (FBOs) may elect to use a standard conservative blend on all aircraft because individual contracts with different carriers specify unique glycol blends.

Experience at Detroit Metropolitan Wayne County Airport (DTW) highlights the competing objectives of glycol recycling and blend to temperature programs. Specifically, implementation of blend to temperature deicing operations at DTW resulted in a 36 to 43% decrease in mainline Type I fluid usage compared to a base year. This resulted in a reduction in the amount of glycol captured for recycle and increased the amount of stormwater discharged to the sanitary sewer thereby increasing airport cost (Wagoner et al. 2013).

Integration with Other Fact Sheets

Blending to temperature may be used in conjunction with most other practices in the source reduction, containment/collection, conveyance/storage, and treatment disposal categories. It is commonly used in conjunction with forced air/hybrid deicing technology. As noted earlier, integration with glycol recovery may be counterproductive because of reduced glycol concentrations in runoff. For airports with glycol recycling operations, collection set-points need to be evaluated to identify optimum collection criteria that balance collection of high strength stormwater for glycol recycling with low strength stormwater collection and disposal costs.

Operation and Maintenance Considerations

As noted above, all deicing operations must be conducted in compliance with available specifications and advisory circulars and must ensure that the aircraft is free of all frozen contaminants adhering to the wings, control surfaces, propellers, engine inlets, or other critical surfaces prior to takeoff.

The most significant operational consideration is how blending can be efficiently accomplished without affecting aircraft safety or operations. For example, it will be important to take care in managing trucks with various concentrations to ensure that the proper concentration is applied to the aircraft. Each facility and situation will present a unique set of opportunities and constraints in this regard.

Where blending stations or blend-on-the-fly truck-mounted equipment is used, the added complexity of the technology will increase maintenance requirements. Specifically, maintenance personnel will require training in the operation and maintenance of each system. Based on discussions with various air carriers, concerns with each system consist of the following. For truck-mounted equipment, maintenance technicians will require specialized training for the equipment. Due to the seasonal use of the equipment, recurring training may be required. For stationary blending systems, a management plan must be developed to allow for reblending of fluids as OAT changes throughout the day and from day to day. Further, additional tankage may be required to allow for storage of fluids which require re-blending.

Where blending is incorporated into a hydrant ADF delivery system, the operation and maintenance of separate service lines for the deicing fluids and water must be considered, along with other equipment and facilities that may be required.

3. Costs

It is difficult to assess the capital costs of blending-to-temperature practices because most industry information contains total system or facility-wide costs rather than those of a particular facet of the system. Supporting evidence of substantial operations and maintenance savings does exist. For example, an airline-sponsored study at a large hub airport concluded that savings of up to $2.5 million per year for the airport could be realized if blending-to-temperature mixtures were used. Similar analysis at another airport in 2008 indicated savings of over $1M for a single (major) carrier through blend to temperature technologies. Modeling of blending to temperature at two airports in 2012 and 2017 indicates airport-wide fluid savings of 27 to 30% with this practice, under relatively optimal climatological conditions (that is, deicing conducted primarily at temperatures between −2°C and more than 0°C). If sufficient data on capital cost expenditures and changes in deicer use over a variety of weather conditions can be obtained, a life-cycle cost analysis can be useful in supporting decision making.

ADF manufacturers provide specific guidance on blending to their products to different outside air temperatures.

Reference

Wagoner, B., R. Husen and J. Lewis. 2013. "Impacts of Blend-to-Temperature Deicing at DTW." Presentation given at the 2013 ACI-NA/A4A/RAA Deicing and Stormwater Management Conference.

FACT SHEET 5

Forced Air/Fluid Deicing

1. Description

Purpose

Forced air/hybrid deicing reduces and, in some instances, eliminates the volume of aircraft deicers required to deice an aircraft by using a high-velocity stream of air to mechanically dislodge and remove snow and ice. In "hybrid deicing," aircraft deicing fluid (ADF) is added to the air stream to aid in breaking loose snow and ice from aircraft surfaces.

This practice is normally implemented by aircraft operators or their contract service providers.

Technology

Forced air/fluid deicing employs specialized equipment to deliver high-pressure air and controlled Type I ADF mixtures to the aircraft surface. Some designs allow the use of air in applying Type IV anti-icing fluids, although certification tests on the equipment/fluid combination are required prior to use in this manner.

Forced air systems are often an optional item on larger, standard deicing vehicles and fixed boom configurations and, in some cases, can be installed as a retrofit. Some systems utilize a high-pressure air flow, while others are based on delivering large air volumes at low pressure. In some designs, nozzle arrangements deliver a columnar air stream that can be maintained over an extended distance to lengthen the effective reach of the stream. In all cases, the air stream may be warmer than ambient air because of the heat of compression. SAE Aerospace Information Report (AIR) 5633 describes forced air technology including equipment, safety, operation, and methodology.

Documented Performance

A Transport Canada–sponsored study evaluated forced air deicing systems in cleaning contamination from an aircraft test wing (APS Aviation Inc. 2000). The following study findings were reported:

- The increase in wing skin temperatures from forced air deicing (and, to a lesser degree, from fluid injected air) was less than observed with the standard application of heated ADF. This led to a significantly reduced time interval until refreezing occurred.
- The use of forced air alone was unable to free ice from the test-wing surface, in part because the heat of the air stream was insufficient to melt through the ice. An air/fluid combination melted the ice but required more than twice as much time as a standard nozzle to clean the wing.

Table 1. Reported percent glycol reduction by user type.

User Type	Reduction	Note
Aircraft operator	85%	Predominantly ideal conditions
Contract operation	65%	Midwestern airport with centralized deicing pads
Medium hub airport	46–67%	Range reflects seasonal comparisons with varying weather
Large hub airport	10–20%	Long-term modeling evaluation using 30 years of weather data

- In tests to remove dry snow, the air/fluid combination and the standard fluid nozzle cleaned the test wing in about the same time, but the air/fluid combination used about 80% less fluid.
- The short time-to-refreeze following forced air deicing precludes its use as a one-step deicing process and undermines its suitability as the first-step in a two-step deicing process.

Reported experience indicates that performance in field operations is difficult to quantify with confidence and varies with the type of freezing precipitation. The technology has been found to be most effective under dry/powdery snow conditions and least effective in removing ice that has bonded to the aircraft surface. Table 1 summarizes reported glycol reduction from facilities where this technology was found to be practicable. These results may be significantly better than what can be expected under less than ideal conditions. Reports on low effectiveness are generally not quantified in part because interest in the technology disappears when it is found to not meet the aircraft operator's needs.

Aircraft operators who have adopted this technology cite the following reasons for the decision:

- The time required to clean an aircraft of snow can be reduced under certain conditions by properly trained personnel. In contrast, several air carriers have indicated that for quick-turn aircraft (e.g., aircraft with short gate turn-around times), the use of forced air is not operationally practical. However, for aircraft that remain overnight and may accumulate a significant amount of contamination, forced air/fluid deicing technologies were found to be very effective and significantly reduced ADF usage as long as there was adequate time to deicing the aircraft.
- A significant reduction in ADF usage over conventional trucks is possible under certain types of weather conditions, such as dry snow and frost.
- The potential source reduction benefits of the technology can assist facilities and airports with maintaining compliance with stormwater regulations.

There may be additional operational efficiencies due to the decreased frequency in refilling deicing fluid tanks.

2. Implementation Considerations

Applicability Assessment

Forced air systems are not approved for use as a one-step deicing process, or for the first step of a two-step deicing process unless the system has been tested and shown to be satisfactory. The SAE International G112E Equipment Subcommittee (2015) has established a test procedure for this purpose.

Forced air systems can be very effective in cleaning contamination from aircraft surfaces as a pre-step to standard fluid deicing, speeding up the deicing process and significantly reducing the amount of fluid needed to produce a clean aircraft.

The key factor in evaluating potential applicability of this technology is the type of winter precipitation commonly encountered. The technology is well-suited to dry, powdery snow, and least effective where icy conditions and heavy wet snow predominate.

A practical consideration is the age of existing deicing equipment. Equipment may not be scheduled for replacement for several years, thus reducing the near-term feasibility of changing to forced air/hybrid application technology.

Regulatory Considerations

There are no specific environmental regulations that apply to this practice, although increased air emissions may be an issue at some airports.

The adoption of forced air/fluid deicing requires that it be described in an aircraft operator's FAA-approved snow and ice control plan.

Planning and Design Considerations

The following success factors need to be considered prior to pursing a forced air/fluid deicing system:

- Climate suited to the technology's strengths, including whether the majority of deicer use is during powdery snow and frost events.
- Extensive operator-training program.
- Maintenance staff training.
- Phased procurement as part of regular deicing-truck replacement schedule.

Integration with Other Fact Sheets

Forced air/fluid deicing can be integrated with virtually all of the other source reduction practices, with the exception of hangared parking (Fact Sheet 8). Significant reduction in the use of deicing fluids may undermine the economic viability of recycling programs.

Operation and Maintenance Considerations

The added complexity of the air blowers and delivery system will increase maintenance and repair requirements relative to conventional deicing vehicles or deicing booms.

Specialized operator training is critical to the effectiveness of this practice. The techniques are significantly different from conventional deicing trucks and require more time to develop and maintain proficiency. It may be difficult for operators to maintain a high level of proficiency where local weather conditions result in infrequent use of the technology.

Noise due to the high air stream velocity may necessitate hearing protection for operators and for nearby ground service personnel.

If used to remove non-adhered cold dry snow, it is important to ensure that the air stream is cold enough to avoid melting of the snow. The surfaces must be checked after cleaning to ensure that no snow has melted and refrozen, adhering to the wing.

Operational efficiencies may result due to increased time intervals between deicing fluid resupply, in particular for deicing vehicles/equipment with deicer fluid tanks. Similarly, operational efficiencies can be realized by using forced air systems to remove accumulated snow versus physical/mechanical removal methods, and the opportunity for damage to the aircraft is minimized.

3. Costs

Capital Costs

The initial capital investment for forced air/fluid deicing is dependent on the costs associated with the specialized equipment purchase. Anecdotal information from users of this technology indicates that the incremental cost associated with the forced air option on a deicing truck is in the neighborhood of $100,000, including a recommended enclosed cab feature.

A life cycle cost comparison of standard deicing trucks vs. force air/fluid trucks may be useful in evaluating the feasibility of this technology. Such a comparison should include capital costs for equipment and annual deicer use costs, along with changes in deicer use over one or more seasons to account for a representative variety of weather conditions.

Operations and Maintenance Costs

Additional maintenance costs may be expected because of the increased complexity of the machinery. Increased fuel consumption is required to operate the air blowers. However, aircraft operators have reported that overall the incremental cost of this technology above conventional equipment may be recovered in savings from reduced deicer usage within several seasons. Additional savings may be achieved through reductions in departure delays.

References

APS Aviation Inc. 2000. *Safety Issues and Concerns of Forced Air Deicing Systems*. Transport Canada, November.

SAE G-12e Equipment Subcommittee. 2015. Forced Air or Forced Air/Fluid Equipment for Removal of Frozen Contaminants. Aerospace Information Report (AIR) 5633.

FACT SHEET 6

Infrared Deicing Technology

This fact sheet has been retired.

FACT SHEET 7

Physical Removal

1. Description

Purpose

This practice provides the opportunity to reduce the volume of aircraft deicers used in wintertime operations by physically (mechanically) removing snow or ice from aircraft. Manual methods of snow removal are useful in certain circumstances and can be used as long as safety is not compromised.

Physical removal techniques are the responsibility of the aircraft operator or its contracted service provider.

Technology

Physical removal of snow or ice involves manual labor and brooms, ropes, and brushes to remove accumulated snow from an aircraft. Hot-air-blast deicing systems may also be used. This practice requires that care be taken to avoid damage to the aircraft during the process of physically removing snow and ice.

Typically, after snow or ice has been physically removed, deicing or anti-icing fluid will need to be applied to an aircraft to remove any remaining frozen contamination, and to provide adequate holdover time prior to its takeoff.

A description of devices and associated procedures available to remove contamination is available in Transport Canada document TP 14052—Guidelines for Aircraft Ground-Icing Operations (http://www.tc.gc.ca/CivilAviation/publications/TP14052). This document describes the safe use of brooms, ropes, and scrapers, and touches on the use of portable forced-air-heaters to remove frost.

There is a separate set of technologies that serve to physically remove frozen precipitation during flight. "Boot" deicing systems, often used on smaller propeller aircraft, employ inflatable pneumatic or hydraulic boots, installed on the leading edge of aircraft wings, to crack and dislodge ice from the aircraft. Other mechanical means that have been evaluated on an experimental basis include electrical resistive heating on small aircraft (heating mats applied to the surface of the aircraft). These technologies have no impact on the use of deicing fluids.

Documented Performance

The performance of physical removal techniques is very site-specific, depending on factors such as the type of precipitation and the aircraft fleet mix.

Anecdotal reports indicate that manual approaches to removing contamination are effective in particular circumstances, such as pre-deicing removal of large amounts of snow during early morning hours before operations start-up and removing small accumulations of dry cold non-adhered snow, thereby avoiding the need for fluid deicing.

2. Implementation Considerations

Applicability Assessment

Physical removal is most successful with loose precipitation (e.g., dry powdery snow) and smaller aircraft with horizontal surfaces that can be easily accessed by ramp personnel. Larger aircraft and those with high wings present serious access and safety issues that make physical removal impractical or unsafe. Protruding sensors or antennae on the surface of an aircraft also may make physically removing precipitation impractical.

Items that should be evaluated prior to considering physical removal techniques include the size and configuration of the aircraft, the timeliness required prior to departures, traffic volumes, availability of suitable personnel, and the frequency of dry powdery snow.

Physical removal is more likely to be applicable at general aviation airports due to the smaller size of the aircraft involved. Aircraft operators may consider this process in conjunction with anti-icing protection to reduce the use of aircraft-deicing fluid.

Personnel performing mechanical deicing require training to ensure that they use proper equipment and methods to maintain safety and not damage the aircraft.

Regulatory Considerations

The primary regulatory consideration for the implementation of the physical/mechanical removal practice is incorporation into the aircraft operator's FAA-approved snow and ice control plans. Safety guidelines related to labor (exposure to the elements, working under slippery conditions, etc.) should also be considered.

Planning and Design Considerations

The following factors should be considered in planning for physical removal:

- Frequency of snowfall that is subject to efficient physical removal.
- Size and configuration of aircraft.
- Staffing and labor requirements.
- Time requirements associated with physically removing snow or ice.
- Number of aircraft requiring the service at peak departure times.
- Suitable equipment to provide personnel with safe access to aircraft surfaces.
- Provision of training and equipment to avoid damage to highly sensitive and often fragile sensors, antennas, vortex generators, and other aircraft surface features.

Integration with Other Practices

Physical removal techniques may be employed prior to the application of aircraft deicing or anti-icing fluids to reduce the total amount of fluid required. In those cases, applicable practices (containment/collection, conveyance/storage, and treatment/disposal practices) can be implemented to further reduce the discharge of deicing agents into the stormwater system.

Operation and Maintenance Considerations

The primary operational considerations are worker safety and ensuring that no damage is incurred to the aircraft during the physical removal process.

Because manual methods of snow removal may be very time consuming, their application must be compatible with flight departure schedules.

3. Costs

The equipment costs to accomplish manual removal of snow from aircraft is relatively modest and generally would be covered under operating costs. Equipment purchases would be limited to brooms, ropes, brushes, and access ladders. Labor costs are the primary component of operation and maintenance costs.

Reference

Transport Canada. 2018. Accessed, February 26, 2019. http://www.tc.gc.ca/CivilAviation/publications/TP14052

FACT SHEET 8

Hangared Parking

1. Description

Purpose

Hangared parking seeks to reduce or eliminate the volume of aircraft deicers applied by avoiding accumulation of snow or ice on the aircraft. This practice is normally implemented by aircraft operators or their contract service providers.

Technology

The application of this practice does not rely on technology. Hangared parking simply avoids exposing an aircraft to snowfall, freezing rain, etc., until just prior to its departure. Anti-icing may still be required to protect the aircraft from snow or ice accumulated during taxiing from the hanger to takeoff.

Documented Performance

The net reduction in deicer usage that can be achieved through this practice varies with climate, precipitation type, and characteristics of the aircraft operations. During periods of winter precipitation, this practice requires the application of anti-icing fluids to an aircraft to avoid snow or ice accumulation prior to the aircraft's takeoff.

2. Implementation Considerations

Applicability Assessment

The size of aircraft, the timeliness of departures, traffic volume, and the amount of suitable and available hangar space should be assessed prior to relying on hangared parking as an alternative to deicing operations. Where operations permit, and adequate space is available, aircraft can be moved into hangars to warm up and melt off any freezing precipitation in advance of a scheduled departure. Generally, this practice is not suited to passenger or cargo operations where aircraft are loaded outside.

Smaller general aviation airports are more likely to implement hangared-parking alternatives due to the size of the aircraft involved. In addition, military installations are more likely to have hangar space for aircraft, especially smaller fighters.

Regulatory Considerations

The primary regulatory considerations concern FAA requirements and constraints on location and configuration of structures on the airfield.

Where significant taxiing to and from hangar locations is required, there may be regulatory concerns related to increased air emissions.

Planning and Design Considerations

The following factors should be considered in hangared parking:

- Availability, location, and adequacy of existing hangar space.
- Aircraft size.
- Nature of aircraft operations.
- Loading operations (indoor or outdoor requirements).
- Space for and cost of new hangar construction.

Integration with Other Practices

Not applicable.

Operation and Maintenance Considerations

Standard hangar space operation and maintenance need to be considered for this practice.

Operational considerations in utilizing hangared parking include the practicality of ground movement of aircraft to and from the hangars. Long taxi distances will increase fuel consumption and air emissions and potentially complicate airfield ground traffic management. It is also important to ensure that taxi routes are maintained so hangared aircraft do not become stranded in an area that is not a high priority for being cleared of snow during storm events.

3. Costs

Assuming hangared space is already available, there are few, if any, capital costs associated with implementing this practice. On the other hand, if hangar space is required, the associated capital investment will be relatively high, along with traditional operations and maintenance costs. In most instances, it will be cost-prohibitive to provide new hangar space for commercial aircraft.

Operating costs will vary with the specifics of the site. Reduced deicer usage will represent a reduction in operating costs, while additional labor required for moving aircraft in and out of the hangar and increased fuel consumption will increase operating costs. Maintenance costs will be largely associated with maintenance of the hangar and associated equipment.

Aircraft such as F-16 Fighting Falcons are protected from the elements inside the hangar.

Smaller airports such as the Fort Collins–Loveland Municipal Airport can more easily implement this practice due to costs and size of the hangar space.

FACT SHEET 9

Hot Water Deicing

1. Description

Purpose

Hot water deicing provides a specific opportunity to reduce or eliminate the volume of aircraft deicers applied by using hot water for deicing operations in lieu of deicer agents.

Aircraft operators or their contract service providers are normally responsible for the implementation of this practice.

Technology

Hot water deicing requires the appropriate technology to heat and distribute the water at the prescribed temperature (at least 60°C or 140°F). Normally, this can be accomplished using conventional fixed or truck-mounted deicing equipment.

Hot water deicing is conducted as a two-step process: using a hot water spray to remove frozen material and then applying anti-icing fluid before the water has a chance to freeze.

Documented Performance

The success of this practice varies widely based on the suitability of the climate, with factors such as ambient temperature and wind speeds affecting the performance. Because this practice by itself does not provide holdover protection, it is employed as the first of a two-step process—being followed by the application of anti-icing fluids.

2. Implementation Considerations

Applicability Assessment

The primary factor determining applicability of this practice is local weather during the deicing season. Under relatively mild winter weather conditions, it has been successfully implemented by aircraft operators at a range of commercial airports.

Regulatory Considerations

The requirements for conducting hot water deicing are described in SAE's Aerospace Recommended Practice (ARP) 4737. The rules limit hot water deicing to ambient air temperatures above –3°C (27°F), specify a minimum application temperature of at least 60°C (140°F), and require that it be followed by application of an anti-icing fluid.

There are no environmental regulations that directly apply to this practice.

Planning and Design Considerations

The primary planning consideration is practicality of aircraft operators adopting hot water deicing under the ambient weather and operational conditions.

The procedures controlling the use of hot water must be very stringent because its application is dependent entirely on heat for protection against freezing. For this reason, this practice is recommended for use only at locations where there is supervision and dedicated deicing staff who are trained and proficient in its use.

Integration with Other Practices

Physical removal techniques may be used prior to using hot water deicing. In addition, practices associated with detecting the presence of snow or ice can be integrated with hot water deicing, such as aircraft ice detection sensors, enhanced weather forecasting, and ice detection and information systems. Forced air/fluid deicing (see Fact Sheet 5) may also be integrated with hot water deicing.

Because concentrations of glycol in runoff will be reduced with hot water deicing, this practice may undermine glycol recovery efforts (Fact Sheet 41).

Operation and Maintenance Considerations

Because existing deicing equipment can be used for implementing hot water deicing, the primary consideration will be how to integrate using hot water into overall deicing operations while ensuring safety and compliance with all FAA requirements.

Special care is needed to guard against the following operational risks:

- Decrease in ambient temperature below the accepted guideline during the deicing activity.
- High wind conditions that quickly rob heat from the treated surface.
- Freezing of inadequately protected deicing equipment plumbing following the deicing activity.
- Inadequate labeling and checking of deicer tank contents, leading to misunderstanding of strength of fluid being applied. Tanks/trucks containing water should be clearly labeled such that the operator and pilot understand that the first step in a deicing operation is being conducted with hot water only and requires a second step for application of an anti-icing fluid.
- Dangerous icing of ramp surfaces in the absence of freeze point depressant.

3. Costs

Where existing deicing equipment can be used or adapted for use, capital investment for hot water deicing would be negligible.

Cost savings from reduced deicing fluid use would be realized during operations.

FACT SHEET 10

Enclosed Deicing Bucket

1. Description

Purpose

This practice addresses the concept that equipment operators working in a comfortable environment and protected from the elements will be more efficient in their deicing usage and practices.

Aircraft operators or their contract service providers are normally responsible for the implementation of this practice.

Technology

Enclosed deicing buckets augment standard deicing trucks or booms. They consist of a weather-proof and climate-controlled enclosure for the deicing operator controls.

Documented Performance

There is currently no quantitative data on the performance of enclosed buckets in reducing deicer usage or improving the efficiency of deicing operations. However, it has been observed that equipment operators tend to be more conscientious and efficient during the application process when protected from the environment and from exposure to deicing fluid. Protection from back spray also encourages deicing closer to the aircraft, which may reduce overspray and increase efficiency.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to any aircraft-deicing operation, but implementation is typically accomplished in conjunction with replacement of deicing trucks or boom-mounted equipment.

Regulatory Considerations

There are no known regulatory requirements for enclosed deicing buckets. However, there are federal codes for exposure control and personal protective equipment related to the handling of propylene glycol, ethylene glycol, and other deicing agents. Chemical goggles, hand gloves, and clean body protection (rain suits) are required for handling of glycol; 29 CFR 1910.134 describes respiratory protection requirements for airborne exposure (specifically for ethylene glycol). Enclosed deicing buckets can reduce or eliminate some of those requirements.

Planning and Design Considerations

The primary factor to be considered in planning for enclosed deicing buckets is procurement of the equipment as part of regularly scheduled deicing vehicle replacement.

Integration with Other Practices

Enclosed deicing buckets are compatible with other practices and can be used with forced air/fluid deicing (see Fact Sheet 5), hot water deicing (Fact Sheet 9), and blending to temperature (Fact Sheet 4) source reduction practices.

Operation and Maintenance Considerations

The operation and maintenance considerations for enclosed deicing buckets do not add significantly to the standard operation and maintenance for deicing vehicles.

3. Costs

Most deicing equipment manufacturers offer enclosed buckets as an optional item for deicing vehicles, which increases the initial capital investment. However, anecdotal evidence suggests that savings in deicing fluid usage from more efficient application may offset this difference. The cost difference between open and enclosed buckets is demonstrated in Table 1.

Table 1. Typical equipment costs.

Equipment	Cost ($)
Standard 2,200-gal open bucket deicing vehicle	220,000
Standard 2,200-gal enclosed bucket deicing vehicle	245,000

FACT SHEET 11

Enhanced Weather Forecasting

1. Description

Purpose

This practice involves the use of advanced weather forecasting systems to improve the accuracy of deicing and anti-icing material application, as well as for the preparation and operation of deicing practices.

Airports, aircraft operators, or deicing service providers may be responsible for implementing this practice.

Technology

Enhanced weather forecasting utilizes real-time weather forecasting to improve the efficiency of deicing and anti-icing practices by giving pilots and airport operators relevant qualitative and quantitative information on the potential for wintertime precipitation. This real-time forecasting may assist in improving the efficiency of deicing and anti-icing practices. For example, if snowfall is classified as dry then an airport operator may be able to sweep snow from airfield pavement without the need for deicer application.

Different technologies have been developed and implemented at several airports to achieve improved weather forecasting.

The Weather Support to De-Icing Decision Making System (WSDDM) uses regional area Doppler radars, surface weather stations, and snow gauges situated in terminal areas to measure weather characteristics. The National Center for Atmospheric Research (NCAR) developed an integrated display system that uses this information to depict accurate, real-time “nowcasts” of snowfall rate and moisture content plus current temperature, humidity, and wind speed and direction. FAA AC 150/5200-30 Airport Winter Safety and Operations provides a discussion of this system, and its safety and operational benefits. SAE International Aerospace Standard AS #5537 provides guidelines for the components and configurations that define the four versions of the WSDDM system.

A second technology provides forecast services ranging from terminal forecasts to written or oral system route briefings. Terminal forecasts are short-term, 18-hour forecasts of ceilings, visibilities, winds, and weather in or near airports, all of which dictate weather restrictions on arriving aircraft. If airport conditions improve earlier than originally forecasted, an amendment is issued as soon as possible. Route system briefing forecasts provide weather conditions over longer periods and over larger areas than the terminal forecasts. Briefings consist of a written summary of weather features and events that are likely to impact aviation operations. Generally, they include a discussion of the pertinent weather features forecasted to affect the route system during the next 8 to 24 or 48 hours. Potential weather trouble spots including timeframes and impacts are identified as specifically as possible. These reports are intended for use by systems operation controllers and others who work with the various components of flight operations.

A third technology has been implemented that involves the collection of weather data during aircraft climb-out, top of climb to descent and during the descent. Specifically, in partnership with NOAA, one air carrier has installed technology to allow the real-time reporting of temperature and wind speed as well as a sensor to collect water vapor data on select aircraft. This data is collected at variable intervals through all phases of the flight (e.g., more frequent data collection is conducted during climb-out and descent compared to top of climb) and transmitted in real time to NOAA/NWS. NOAA/NWS utilizes the data to increase the accuracy of their forecast models that are publically available. Further, the collection of wind, temperature, and water vapor profiles from ground surface to top of climb above an airport allows granular differences in temperature profiles to be examined, which facilitates the forecast of the type of winter precipitation expected. To date, over 100 aircraft have been equipped with this technology.

Documented Performance

The performance of this practice has not been directly measured. If used successfully, this practice can optimize the selection of deicing or anti-icing materials and methods for a particular deicing event. When used in conjunction with other deicing practices, enhanced weather forecasting may also improve the accuracy of practice selection, coordination, and operation, thereby potentially reducing concentrations or discharge volumes of deicer- or anti-icer-impacted stormwater.

A limitation associated with this practice is that forecasts are often inaccurate, even with advanced weather systems and equipment; however, short-term forecasts are improving. Deicing personnel are tasked with making real-time deicing decisions that are conservative with respect to aircraft safety. As such, deicer application rates may not be significantly decreased because of enhanced weather forecasts.

2. Implementation Considerations

Applicability Assessment

This practice would be applicable to any airport or aircraft operator that performs aircraft or pavement deicing because it can improve the accuracy of deicer or anti-icer application rates and methods. The practice could be especially beneficial at airports with deicer management systems and deicer application practices that could be optimized by more-accurate weather forecasts.

Accurate weather forecasts can help identify weather conditions that are optimal for alternative deicing methods such as forced air deicing, tempered steam, hot water deicing, proactive anti-icing, and deicer blending to temperature. Weather forecasts can also improve the preparation and coordination of deicer containment and collection equipment, including deicer collection vehicles and catch basin inserts. Airports with fewer operations may not realize significant benefits when compared to the costs for installation and operation. Medium and large airports in northern climates are more likely to achieve the most benefits from this practice.

Regulatory Considerations

The primary regulatory consideration for this practice is complete compliance with all FAA requirements for effective deicing and safe flight operations.

Planning and Design Considerations

Airports, aircraft operators, and deicing service providers interested in enhanced weather forecasting as a practice should consider the following in their planning and implementation:

- Identify the service or equipment that can provide enhanced weather-forecasting services that best meet the needs of the airport and aircraft operators. Consider the following:
  - Capital and operational cost for each service or equipment; and
  - Types and accuracy of forecasts provided through each system and their applicability to existing airport deicing procedures and practices.
- Determine how enhanced weather forecasts will be incorporated into standard operating procedures for deicing/anti-icing and deicer management.
- Develop protocol for identifying weather conditions that are appropriate for existing deicer or anti-icer application methods and deicer management practices.
- Develop a training program for employees that will be using the weather-forecasting system.

Integration with Other Practices

The success of many deicer application and deicer management practices may be enhanced by more-accurate and relevant weather forecasts. Enhanced weather forecasts may enable an airport or aircraft operator to identify opportunities for using alternative deicing practices, including alternative deicing materials and application equipment. Accurate weather forecasts can help identify weather conditions that are optimal for alternative deicing methods such as forced air/fluid deicing (see Fact Sheet 5), hot-water deicing (Fact Sheet 9), proactive anti-icing (Fact Sheet 3), and deicer blending to temperature (Fact Sheet 4). Weather forecasts can also improve the preparation and coordination of deicer containment and collection equipment, including deicer collection vehicles (Fact Sheet 23) and catch basin inserts (Fact Sheet 33).

Operation and Maintenance Considerations

Operational requirements associated with this practice depend on the technology employed. If a service provider is used, the primary operational issues will be incorporating the information into standard operating procedures and training of personnel. If the technology is to be operated by the airport or aircraft operator, regular maintenance of equipment associated with sensors and forecasting technologies will be required, as prescribed by the manufacturer.

3. Costs

Costs associated with this practice consist of the costs of the weather-forecasting service or system as well as the time for the airport/airline staff to interpret the data.

Capital Costs

Capital costs include installation of specialized weather-forecasting equipment onsite. Costs may be significant if the airport or aircraft operator chooses to own and operate the instrumentation. Using a forecasting service will entail no capital costs if dedicated instrumentation is not required.

Operations and Maintenance Costs

Operational costs may include costs associated with subscribing to or accessing a specialized weather-forecasting service, or costs for maintenance of onsite enhanced weather-forecasting sensors and equipment.

FACT SHEET 12

Holdover Time Determination Systems

1. Description

Purpose

Holdover Time Determination Systems (HOTDS) record measurements of winter conditions at airports at pre-determined intervals. HOTDS compute a precipitation rate for any weather condition, enabling the calculation of a single-value de/anti-icing fluid holdover time for any combination of fluid, ambient temperature, precipitation type and precipitation rate. The holdover time (HOT) information can then be relayed electronically to crews in the flight deck for their use in HOT decision making in winter operating conditions.

The result of this practice is optimized selection of deicing/anti-icing fluid selection by flight crews and derivation of site-specific holdover times, resulting in potential cost savings, environmental benefits, operational efficiencies, and safety enhancements.

HOTDS programs are currently available. HOTDS systems that utilize liquid water equivalent to estimate HOT were pilot tested in 2013–2014 and numerous systems have been implemented worldwide since then.

Technology

Deicing/anti-icing fluid HOT table values have been established as a function of specific precipitation rate and ambient temperature. However, the current tools employed by flight crews to assess the intensity of winter precipitation, Aviation Routine Weather Reports (METAR), and visibility tables, are subjective, inaccurate, and contain no quantitative data.

HOTDS employ sensors that measure the three parameters required for fluid HOT determination: rate of precipitation, type of precipitation, and ambient temperature. The result of each combined measurement of these parameters is a scientific holdover time for any given aircraft deicing fluid or aircraft anti-icing fluid. A more-precise assessment of fluid HOT enables optimal fluid usage that is consistent with actual measured onsite weather conditions and flight safety requirements.

A HOTDS was tested at Montreal-Trudeau International Airport from November 2003 to April 2008. The system records precipitation type, precipitation intensity, ambient temperature, and wind speed every 10 minutes and calculates updated HOTs based on the measured weather and aircraft deicing fluid (ADF) holdover time databases. The holdover time databases are fluid-specific and represent the same information used to prepare conventional holdover timetables. Calculated holdover times are displayed on the PC and can then be transmitted to the flight deck and ground crews.

The manufacturer of the HOTDS tested in Canada has demonstrated compliance with the minimum requirements established by Transport Canada. [Other HOTDS products include a liquid water equivalent system (LWES) developed by the National Center for Atmospheric Research.] An LWES is an automated weather measurement system that determines the Liquid Water Equivalent (LWE) precipitation rate in conditions of frozen or freezing precipitation. Because the water absorption capabilities of each deicing fluid are known, the amount of precipitation expressed as the liquid water equivalent can be used to determine if the applied fluid is saturated and no longer effective or if it is not saturated and providing protection. Specifically, the LWE rate is used by the HOT system with the appropriate endurance time (ET) regression equations and regression coefficients specified in an FAA-approved current database to determine HOT. Operational demonstrations of LWES were conducted in 2013–2015 by FAA, and AC 120-112, Use of Liquid Water Equivalent System to Determine Holdover Times or Check Times for Anti-Icing Fluids, was published in 2015. These systems are currently being tested at numerous locations throughout the United States and Canada.

Documented Performance

A HOTDS was tested at Montreal-Trudeau International Airport over five winter seasons. Over 2,500 data points were collected with the system during this period in nearly 100 natural precipitation events, spanning the full range of ambient temperatures and precipitation types. Data from the HOTDS were compared to data collected using historical rate measurement procedures and human weather observations, and the correlation was excellent. In summer 2008, the HOTDS demonstrated compliance with the Minimum Performance Specifications and Quality Assurance Requirements established by Transport Canada for use of HOTDS outputs in Canadian air operations (see later section on Regulatory Considerations).

An operational assessment of the HOTDS was also performed at Montreal-Trudeau International Airport from 2004 to 2006. The objective of this work was to compare actual flight crew decisions in winter operating conditions to optimal fluid decisions that would be made if HOTDS were available. The results indicated that flight crews selected to employ thickened Type IV fluids in conditions that did not warrant their use in 27% of all departures. An additional 4% of all departures took off with exceeded HOTs. In the winter of 2007–2008, testing was conducted at Montreal-Trudeau airport to determine if a single location precipitation sensor can reliably report precipitation conditions for the entire airport (See *ACRP Report 45: Optimizing the Use of Aircraft Deicing and Anti-Icing Fluids*). Data was collected at locations separated by distances ranging from 4,200 to 13,300 ft. These data indicated that a single HOTDS positioned at a central location at an airport with a small surface area would likely be sufficient to provide accurate information for the entire airport. However, it was noted that at some airports such as Denver International Airport, the distances from a central location to a departure runway may exceed 16,000 ft. To address this deficiency, tests were conducted at three additional airports in 2008–2009. Airports selected for this study were Mirabel Airport, Denver International Airport, and Syracuse Hancock International Airport.

The conclusion from this second study was that differences in HOTs for snow can be significant and are a function of distance between data collection location. These differences can be greater for airports impacted by lake-effect snowfall. Differences in HOT generated from different sites begin to impact the operation when the sites are separated by midrange distances (7,017 to 13,390 ft) and have a definite impact at long separation distances (27,800 to 28,500 ft). However, these differences in the calculation of HOT over a large airport were not considered an obstacle to further development of HOTDS. Recommended approaches for large airports for consideration were installation of multiple HOTDS or development of a safety factor for incorporation into the HOTDS calculation.

A demonstration program was conducted by a major carrier to demonstrate the accuracy and reliability of system interfaces for LWES. The project was a joint carrier effort and indicated the following benefits: reduction in the need for Type IV anti-icing application in very light or light snow, extended fluid effective time, and elimination of the need for a pre-takeoff contamination check. In addition, use of LWES simplified pilot decision-making and eliminated the need for holdover tables.

2. Implementation Considerations

Applicability Assessment

The potential cost savings, environmental benefits, operational efficiencies, and safety enhancements associated with this practice make it potentially applicable to most airports and aircraft operators subjected to winter precipitation conditions and the use of fluid holdover timetables.

The benefits associated with the implementation of this practice will vary largely by the size of the operation, and therefore the capital and operating costs of this practice may limit its practical use to medium- and large-size airports and operations characterized by severe winter weather.

Regulatory Considerations

Transport Canada and the FAA develop and publish the deicing/anti-icing fluid HOT tables on an annual basis, and both organizations regulate the usage of the information by air carriers in their respective countries. The shift to automated generation of deicing/anti-icing fluid HOT data will therefore require regulatory oversight and approval.

In December 2007, Transport Canada issued regulatory approval for use of HOTDS in Canadian air operations. As part of the regulatory approval process, Transport Canada developed Minimum Performance Specifications and Minimum Quality Assurance Requirements for HOTDS. A HOTDS manufacturer must demonstrate adherence to the minimum requirements prior to being approved by Transport Canada. Subsequently, Transport Canada has made regulatory exemptions to Standard 622.11, which authorizes air operations to use HOT generated by HOTDS using best-fit power law equations and regression coefficients as part of their ground icing operations program.

The FAA has published the AC 120-112, Use of Liquid Water Equivalent System to Determine Holdover Times or Check Times for Anti-Icing Fluids. This document describes the submittals required for authorization to use LWES. Authorization of a specific air operation to use LWES as part of ground deicing operations is through FAA Flight Standards Service (AFS). Similarly, Chapter 27, Section 5 of the Flight Standards Information Management System provides guidance of the approval process for the use and implementation of LWES.

Planning and Design Considerations

The following planning and design considerations need to be examined when implementing this practice:

- Airport siting of the HOTDS so that the system will provide outputs that are representative of conditions experienced by aircraft on the airfield.
- Determination of the desired data provision cycle time, which may affect the number of HOTDS systems that are ultimately required.
- Space requirements for the physical installation of the system hardware.
- Development of data communication pathways for system information (data link, radio frequencies, wireless modems, etc.).

Integration with Other Practices

HOTDS technology can be integrated with most practices, including all fluid-related practices. The combination of real-time weather measurement from the HOTDS and enhanced weather forecasting tools have been found to be extremely useful to airports and aircraft operators.

Operation and Maintenance Considerations

Operational and maintenance requirements associated with this practice are not yet available because it has not been tested over the long term.

Some operational considerations, such as how the HOT information from the system will be employed by flight crews, will need to be examined in detail. Testing by the air carriers has indicated that training programs for flight crews to ensure the transition from paper tables to electronic information is essential, as well as the need for calibration, maintenance, and verification programs for the HOTDS hardware, to ensure the validity of the system outputs.

3. Costs

Overall costs associated with this practice are not yet fully defined, as the technology has yet to be fully implemented in an operational environment.

Capital Costs

Capital costs for this practice are not fully defined but are likely to consist primarily of costs of the installation, the location, as well as the hardware and software. Alternatively, capital costs of the installation may be incurred by a service provider who will sell the service to the airport/aircraft carrier community.

Operations and Maintenance Costs

Operational costs will be uncertain until the technology has been fully commercialized but are likely to include costs for personnel to oversee system operation and monitor results as well as costs for maintaining and testing the weather-monitoring equipment.

FACT SHEET 13

Aircraft Deicer Use Tracking

1. Description

Purpose

This practice provides for accurately quantifying and tracking the volumes of aircraft deicers and anti-icers used in wintertime operations. Accurate deicer use information can be critically valuable in understanding aircraft-deicing practices, supporting analysis and design of deicing management systems, and complying with environmental requirements.

Tracking aircraft deicer use is never intended to promote unsafe or inadequate aircraft-deicing practices or conflict in any way with FAA-approved snow and ice control plans, which always take precedence.

Aircraft deicer use tracking is typically the combined responsibility of the aircraft operator (or its contracted service provider) and airport staff who track use across the entire facility.

Technology

Various methods may be used to track aircraft deicer use, depending on the availability of data from existing record-keeping and the nature of information needs driving the tracking effort. The simplest and most common approach involves manually extracting the information from deicing truck logs and entering it into a spreadsheet to facilitate management, tracking, and simple analysis of the data.

At the other end of the spectrum, where a high degree of accuracy or resolution is required, electronic instrumentation can be installed on deicing equipment to monitor and record use and even communicate it to a deicing dispatcher.

Documented Performance

There is no quantified description of the performance of this practice, and tracking deicer use is not by itself expected to affect rates of use or impacts to stormwater. Instead, tracking provides a basis for understanding and demonstrating the relationships among weather, airport operations, deicer use, and environmental impacts. Airports and aircraft operators have reported using detailed aircraft deicer application data for a wide range of purposes, including evaluating different deicing application technologies, quantifying deicer loading under different weather and operational conditions, assessing the performance of collection practices, and understanding the fate and transport of deicers.

2. Implementation Considerations

Applicability Assessment

This practice is applicable where quantitative information on aircraft deicer use is needed to support effective deicing runoff assessment, planning, design, and management. The complexity of the approach should be closely matched to the facility-specific data needs. Examples of factors that affect complexity include frequency and resolution of reporting (seasonal, monthly, weekly, daily, by aircraft), accuracy of reporting, spatial resolution (whole airport, by drainage area, by gate), and fluid type and concentration.

Regulatory Considerations

FAA AC 120-60 requires that deicing crews communicate details of each aircraft deicing to the flight crew. The following details are to be included and an example tracking form is shown in Table 1.

- Fluid type (e.g., Type I, Type II, Type III, or Type IV).
- Fluid–water mix ratio by volume for Types II, III, and IV. Reporting the concentration of Type I fluid is not required.
- Start time (hours and minutes) of the final fluid application.

Table 1. Deicing tracking form example.

STATION DEICING/ANTI-ICING FORM

DEICING PROVIDER/VENDOR ______________________ **STATION** ____________

	FLIGHT DATE	AIRCRAFT REGISTRATION NUMBER	WEATHER CONDITION AT TIME OF DEICING	OUTSIDE TEMPERATURE IN °C	TYPE I FLUID FREEZE POINT IN °C	NOTE THE ______% GLYCOL MIXTURE ☐ TYPE II ☐ TYPE IV	SPECIFY LOCAL START TIME OF FINAL FLUID APPLICATION	SIGNATURE OR EMPLOYEE NUMBER OF THE PERSON CONFIRMING THAT THE AIRCRAFT IS FREE OF CONTAMINANTS AND ALL REQUIRED INSPECTIONS, INCLUDING AIRCRAFT SPECIFIC, HAVE BEEN COMPLETED
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								
9.								
10.								
11.								
12.								

**ESTABLISH VERBAL COMMUNICATION WITH FLIGHT CREW PRIOR TO DEICING.
THE INFORMATION IN COLUMNS WITH BOLD OUTLINE MUST BE COMMUNICATED TO FLIGHT CREW
AFTER DEICING AND/OR ANTI-ICING HAS BEEN COMPLETED**

Source: FAA AC 120-60A, *Ground Deicing and Anti-Icing Program*

Compliance with this requirement may facilitate more complete tracking of deicer usage, including volumes of deicers applied.

There are no generally applicable environmental regulatory requirements for aircraft deicer use tracking. However, certain National Pollutant Discharge Elimination System (NPDES) permits for deicing discharges require some level of use reporting, and some permitting programs, such as the Multi-Sector General Permit, have tiered requirements based on annual aircraft deicer use.

Planning and Design Considerations

The following factors should be considered in planning for tracking aircraft deicer use:

- Tracking and reporting complexity should be chosen to produce data sufficiently accurate, representative, and complete to meet the intended use of the data.
- Taking advantage of existing aircraft deicer use recording activities provides a way to minimize additional burden.
- Clear explanation and communication of the need for tracking will facilitate cooperation by aircraft operators and their contractors.
- Reporting and tracking can be made easier using web-based reporting forms and software.
- Accountability for accurate and complete reporting will help minimize data gaps and errors.
- A simple quality assurance practice is the inclusion of end-of-season reconciliation checks to ensure agreement between deicers on hand at the beginning of the season, purchased during the season, reported used, and on hand at the conclusion of the season.

Integration with Other Practices

Aircraft deicer use tracking can support the implementation, performance assessment, and refinement of a wide range of other practices.

Operation and Maintenance Considerations

Operational requirements associated with tracking aircraft deicer use are related to the methods of record-keeping and reporting. Primary considerations include the following:

- Employing commonly used software for data entry, management, and analysis.
- Building the tracking and reporting system around practices already in place—for example, compliance reporting required by FAA AC 120-60B.
- Minimizing data entry steps.
- Automating quality assurance checks.

Maintenance requirements consist of managing the database and generating tracking reports. In those rare instances where electronic tracking instrumentation is employed, some level of routine maintenance of that equipment should be expected.

3. Costs

The primary costs will be associated with both aircraft operator and airport staff time required for reporting and tracking activities. The magnitude of this effort will be a function of the incremental effort beyond that required by existing AC 120-60 reporting activities, the number of reporting entities, the complexity of the data being reported, and the types of data analyses and summary reporting required.

Capital costs for electronic instrumentation to measure, record, and report aircraft deicer use can be substantial. As of 2017 the cost ranges from $15,000–$20,000 per deicing truck for an instrumentation package that includes flow count and telemetry.

FACT SHEET 14

Aircraft Reduced Operations

1. Description

Purpose

This practice involves reducing or eliminating deicer usage by curtailing flight operations during winter precipitation events. Reduced aircraft operations are the responsibility of aircraft operators.

Technology

Aircraft operators' decisions regarding flight operations prior to and during winter storm events are driven by technologies used to evaluate potential storm paths and fleet planning and recovery.

Documented Performance

There is no documented quantitative information on the performance of reduced aircraft operations in reducing deicer usage or deicing runoff discharges. However, reductions in both usage and discharges would be reasonably expected with reduced operations.

2. Implementation Considerations

Applicability Assessment

Reducing flight operations to reduce deicer usage and runoff has very limited applicability. In the general aviation and corporate flight communities, flight operations are flexible, and flights are often delayed or cancelled to avoid flying in winter weather. Certain military aircraft operations are also discretionary and may be scheduled around the weather.

With the increased use of enhanced weather prediction technologies, many commercial passenger air carriers may proactively cancel or reroute flights to avoid stranding aircraft and passengers at an airport. These decisions are based on weather forecasts and potential for system-wide impacts to the carrier. Because these decisions are weather-based, and each storm event presents a different set of characteristics, the decision to cancel flights cannot be associated with a particular or predictable design storm.

This practice may be impractical for aircraft that operate on strict set flight schedules, operate on demand, or involve emergency services.

Regulatory Considerations

Where applicable, there are no regulatory considerations involved in reduced flight operations.

Planning and Design Considerations

Aircraft operators' operational practices during winter storm events have changed significantly in recent years and airports should consider and evaluate how changes made by their operators may affect the airport and its infrastructure needs. The following factors should be considered in planning for reduced operations:

- Relative contribution of anticipated reduction in deicing to improved environmental compliance.
- Flexibility of flight operations.
- Acceptance by aircraft operators.
- Loss in revenue or other economic impacts from reduced flight operations.

Integration with Other Practices

This practice can be integrated with other deicing practices. Where reduced flight operations are feasible and result in reduced deicer usage, this practice should reduce requirements for collecting, storing, and treating deicing runoff.

Operation and Maintenance Considerations

Not applicable.

3. Costs

Costs will be associated with lost revenues or other lost opportunities associated with delayed or cancelled flights.

FACT SHEET 15

Tempered Steam Technology

This fact sheet has been retired.

FACT SHEET 16

Airfield Pavement–Deicing Product Selection

1. Description

Purpose

This fact sheet considers opportunities to employ alternative pavement-deicing products that have a reduced environmental impact, primarily in terms of biochemical oxygen demand (BOD) and aquatic toxicity found in the freeze point depressants (and in a few cases, the aquatic toxicity associated with additives) required to meet certification specifications.

Product selection is typically the responsibility of airports and their contractors.

Technology

Prior to 1990, glycols and urea were the primary airfield pavement deicers used at airports. Since then, alternative pavement-deicing products that have lower BODs and no issues with ammonia toxicity or nutrient enrichment have been introduced to the market. This transition has been, in part, in response to the U.S. EPA's 2012 Effluent Limitations Guidelines and New Source Performance Standards for the Airport Deicing Category for airport deicing (see Regulatory Considerations). These products are available in both solid and liquid forms.

Potassium acetate-based airfield pavement deicers are supplied as a liquid and can be applied either alone or as a wetting agent in conjunction with granular deicing materials to improve efficiency. Other available liquid deicers use potassium formate or polyol as the freezing point depressant.

Sodium acetate and sodium formate are supplied in granular and prill form. Generally, manufacturers recommend applying these materials with liquid pavement deicers to improve adherence to an ice-covered surface and prevent the solid material from being blown off the pavement. Granular products with irregular and sharp surfaces may be less susceptible to drift by wind or jet blasts than prill products.

Ongoing research and development results in the continual improvement of existing products. These efforts are being driven by both environmental considerations and materials compatibility issues, especially as they relate to catalytic oxidation of aircraft carbon brake components.

Documented Performance

Product selection offers the opportunity to reduce loadings of BOD and ammonia (and possibly toxicity, although the research is ongoing) associated with airfield

Table 1. Chemical oxygen demand of common airfield pavement deicers (ACRP Web-only Document 3).

Pavement Deicer	COD (mg/kg)
Potassium acetate (liquid)	315,000
Sodium acetate (solid)	700,000
Sodium formate (solid)	242,000

deicing while providing the necessary operational and safety performance. The most common example of success from this practice is found in the experience of numerous airports where replacing urea with another certified airfield pavement deicer has eliminated problems with excessive ammonia concentrations in stormwater discharges.

The potential benefits of this practice at an individual airport will depend on the pavement deicer(s) currently in use, and the alternative products that are both available and meet all operational performance requirements. Table 1 provides representative chemical oxygen demand content for pavement deicing products. BOD and toxicity information for individual products may be found in the manufacturers' literature.

2. Implementation Considerations

Applicability Assessment

This practice is potentially applicable at any airport where airfield pavement-deicing agents are employed. The key to applicability will be the benefits that might be achieved by changing to an alternative product. Applicability will be greatest where airfield-deicing runoff is an environmental compliance concern and a change in pavement deicers offers the potential to significantly reduce pollutant loads while maintaining necessary performance.

Regulatory Considerations

In 2012, the U.S. EPA issued the Effluent Limitations Guidelines and New Source Performance Standards for the Airport Deicing Category (40 CFR Parts 9 and 449). This rule states that existing and new primary airports with 1,000 or more annual jet departures must use non-urea deicers or meet effluent limitations for ammonia.

Another primary regulatory consideration in product is that all materials used for airfield deicing must be certified as conforming to SAE's specifications, described in AMS 1431 (solids) and AMS 1435 (liquids).

Planning and Design Considerations

The following factors should be considered before selecting the airfield-deicing product:

- Deicing products currently being used at the airport.
- Operating requirements, especially effective temperature range.
- Regulatory mandates and constraints regarding airfield-deicing materials.

- National Pollutant Discharge Elimination System (NPDES) permit language describing pavement-deicer requirements.
- Environmental characteristics of alternative airfield-deicing materials.
- Environmental impacts of primary concern and the relative contribution by airfield-deicing runoff.
- Compatibility of current and alternative pavement deicers with aircraft components and airfield infrastructure.
- Modifications may be necessary to the airport's Snow and Ice Control Plan. Guidance to assist airport operators develop a snow and ice control plan is provided in AC 150/5200-30D, Airport Winter Safety and Operations.

Guidance on the characteristics and proper handling and application of individual airfield-deicing materials are provided in manufacturer literature for each product.

Integration with Other Practices

Product selection may be integrated with most other source control practices, such as storage and handling and application of airfield-deicing materials (see Fact Sheet 17). Product selection that reduces airfield runoff pollutant loading may result in reduced needs for collection and treatment where this loading source is a significant compliance concern.

Operation and Maintenance Considerations

Deicing products may require specific storage and handling protocols to maintain their integrity and effectiveness. For example, some solid pavement deicers are hydroscopic and will cake if stored incorrectly. Product-specific requirements and instructions are typically provided by the manufacturer.

3. Costs

A representative range of costs typically associated with commercially available airfield-deicing products is provided in Table 2.

The primary environmental characteristics of potential concern are oxygen demand and toxicity.

Potassium formate liquid pavement deicer is used at some airports in northern Europe, but its use is limited in the U.S. market.

Table 2. Range of unit costs for commercially available airfield-deicing products (Circa 2017).

	Costs ($)		
Deicer	Bulk	Tote	Drum/Bag
Potassium acetate	5.50–6.50/gal	6.00–7.00/gal	7.00–9.00/gal
Sodium acetate	1,700–1,800/ton	1,800–2,100[a]	1,800–2,600[b]
Sodium formate	1,300–1,400/ton	—	1,700–1,800/ton

Note: Costs were provided by commercial deicer manufacturers.
[a]Per 2,205 lbs.
[b]Per pallet of 40 55-lb. bags.

→ **SOURCE REDUCTION**
Containment/Collection
System Components
Treatment/Recycling

FACT SHEET 17

Storing and Handling of Airfield Deicing/Anti-Icing Agents

1. Description

Purpose

This practice provides a means of preventing deicing and anti-icing agents from coming into contact with stormwater during their storage and handling prior to being applied.

Proper storage and handling of pavement deicing materials is normally the responsibility of any member of the airport community who uses these products.

Technology

Good housekeeping techniques, proper physical site usage, structural controls, regular maintenance, and the training of staff are typical activities related to storing and handling pavement deicers.

To maintain the integrity and effectiveness of pavement deicing materials, they must be stored, handled, and applied in a manner consistent with chemical-specific instructions provided by the manufacturer on the safety data sheet (SDS). Materials with reduced effectiveness may require larger application volumes or frequent reapplication, thus increasing the potential for stormwater pollution.

Documented Performance

There is no quantitative data available on the performance of this practice. Generally, benefits may be expected in terms of decreased deicer discharges to surface water and potentially decreased deicing stormwater management costs.

The success of this practice at an individual airport can be evaluated by comparing pavement deicer consumption (rather than application) rates before and after implementing storage and handling practices. Any such comparison must, of course, consider comparability of weather conditions.

2. Implementation Considerations

Applicability Assessment

This practice is applicable to virtually any facility where airfield deicing materials are stored or handled prior to application.

Regulatory Considerations

Good housekeeping practices, including the proper storage and handling of deicing materials, are typically required under a National Pollutant Discharge Elimination System (NPDES) industrial stormwater permit as an element of an airport's Stormwater Pollution Prevention Plan.

Planning and Design Considerations

The following factors should be considered in planning for storing and handling airfield deicing/anti-icing agents:

- Specific NPDES permit language describing requirements for storage and handling of these materials.
- Volume of deicing/anti-icing materials to be stored.
- Packaging of the deicing products (e.g., bulk, super-sacks, totes, or tanks).
- Methods used for transferring deicing materials to the application vehicles.
- Opportunities to upgrade existing facilities or construct new facilities for improved storage and handling.
- Indoor storage may offer an opportunity to incorporate heating of solid pavement deicers to enhance their effectiveness.
- Cost of storage and handling options.

Key approaches to storing and handling these products include the following:

- Store materials indoors or under cover, if possible.
- Store containers of material away from direct traffic routes to prevent accidental spills.
- Keep floors and ground surfaces clean and dry by using brooms, shovels, vacuum cleaners, or cleaning machines.
- Routinely inspect containers and tanks for leaks.
- Take actions to prevent stormwater run on to deicing/anti-icing material storage and handling areas. Block storm drains during material handling operations to prevent runoff of deicing/anti-icing materials.
- Provide a means of preventing spilled deicing materials from entering storm drain inlets.
- Clean areas following deicing/anti-icing material transfers.
- Maintain adequate supplies of spill response equipment and materials in accessible locations near operations.
- Emphasize the importance of these practices through personnel training.
- Restrict deicing material storage and handling to trained personnel only.
- Perform and document frequent inspections of storm drains, deicer application equipment, deicer runoff controls, and storage facilities; perform maintenance as required.
- Follow chemical-specific instructions and guidelines recommended by the material manufacturer to maintain the material's integrity and effectiveness.

Integration with Other Practices

This practice is compatible with all other deicing practices where pavement deicing materials are involved.

Operation and Maintenance Considerations

Operation and maintenance requirements related to materials' storage and handling are normally part of a facility's industrial NPDES compliance program. Deicing/anti-icing materials may require specific storage and handling protocols to maintain their integrity and effectiveness. These product-specific instructions are typically provided by the manufacturer. For example, solid materials require storage and handling that prevents clumping or dusting, either of which decreases effectiveness.

3. Costs

Capital and operation and maintenance costs depend on the amount of deicer materials to be stored and the locations and configurations of transfer areas. Higher costs will be incurred when covering or containing large loading/unloading areas is needed.

FACT SHEET 18

Pavement Deicer Materials Application Technology

1. Description

Purpose

This practice provides the opportunity to reduce the volume of pavement deicing materials (PDMs) used in wintertime operations by facilitating efficient and optimum application of PDM.

PDM application techniques are generally the responsibility of the airport operator or its contracted service provider.

Technology

The simplest approach to efficient PDM application involves training and maintenance. Training airfield maintenance staff in appropriate techniques and application rates required to maintain safe operations, and operators in the importance of disposing of excess deicers appropriately avoids unnecessarily exposing PDM to stormwater. Routine calibration and maintenance of PDM equipment ensures that application rates are accurately set.

Enhanced weather-forecasting systems (Fact Sheet 11) can also improve the efficiency of deicing practices by airport operators. The quantitative information on the potential for freezing precipitation can help determine appropriate PDM application.

An increasingly common technology is the use of onboard computers to control application rates, with settings “locked out” of driver control to maintain consistent rates for the prevailing weather conditions.

One of the more advanced technologies for PDM application management integrates information from runway detection sensors and application vehicles. All runway clearing and deicing vehicles are equipped with GPS telemetry that transmits location and rate of runway deicer application to a central monitoring and logging system. Airfield maintenance staff can monitor the vehicles’ operations, along with runway and air temperatures in real time, and the information is stored in the system. Monitoring data are used to decide how much additional deicing is required. Additional benefits of this technology include the ability to detect when equipment is not operating to specifications (e.g., flow rates in booms, spreaders), providing in the event of an incident a detailed record of exactly where pavement deicers were applied.

Documented Performance

The performance of PDM techniques is site-specific, depending on factors such as the type of precipitation and the deicing mix. Up to 20% reduction in pavement chemical use has been reported by the Munich International Airport with the use of the most sophisticated telemetry and control systems (H. Pawlik, personal communication).

2. Implementation Considerations

Applicability Assessment

Sophisticated PDM application technologies are more likely to be applicable at facilities that regularly encounter ice and snow conditions and use significant quantities of PDM. The justification for this specialized equipment should be evaluated on a facility-specific basis.

Personnel performing pavement deicing require training to ensure that they use proper equipment and methods to maintain safety. Training should also include techniques for ensuring appropriate application rates and avoiding overuse or waste.

Regulatory Considerations

The primary regulatory consideration for the implementation of this practice is its incorporation into an airport's ice and snow control plan. Safety guidelines related to labor (exposure to the elements, working under slippery conditions, etc.) should also be considered.

Planning Considerations

The following factors should be considered in planning for efficient PDM application:

- Frequency of ice or snowfall that is subject to use of efficient pavement deicing techniques.
- Size and configuration of airfield.
- Staffing and labor requirements.
- Time requirements associated with removing snow or ice.
- Costs for deicing application technology.

Integration with Other Practices

Mechanical methods, such as plows, brushes, blowers, and shovels for snow removal may be employed prior to the application of PDMs to reduce the total amount of fluid required.

Operation and Maintenance Considerations

The Stormwater Pollution Prevention Plan (SWPPP) for the airport typically requires the practicing for deicing/anti-icing practices. Generally, approaches for inspection or training, operation considerations, and contingency responses are provided.

Maintenance requirements vary with the type of equipment selected to use for pavement deicing application. Maintenance is either the responsibility of the airport operator or the contracted service operator.

3. Costs

Capital Costs

The most advanced control systems have capital costs that include vehicle and airfield telemetry packages, along with a control system and associated software. Costs for a complete package at a medium to large airport can range from $500,000 to more than $1,000,000.

Operations and Maintenance Costs

Labor and equipment maintenance costs are the primary components of operation and maintenance costs and depend largely on facility-specific details.

Depending on the type of enhanced weather forecasting system employed, reported annual operating costs for small, medium, and large airports nationwide can range from $2,400 to $8,400.

Reference

Pawlik, H. 2018. Personal communication, Mr. Pawlik is with Flughafen München GMbH (http://www.munich-airport.de/de/consumer/index.jsp).

FACT SHEET 19

Heated Pavement

1. Description

Purpose

Heated pavement provides a means of deicing airfield pavement using heating elements to minimize or eliminate the use of pavement deicing chemicals. Although this technology has been used on bridges and to some extent at overseas airports, it is in its development stage for U.S. aviation applications.

Technology

The concept behind heated-pavement systems is that pavement surface temperatures are maintained above the freezing point of water, thus preventing accumulations of snow and ice from bonding with the pavement. Accomplishing this could facilitate the mechanical removal of frozen precipitation from paved areas, and reduce the need for chemical deicing and anti-icing agents.

There are two primary methods of heating pavement: hydronic and electric. Hydronic heating uses either geothermal energy or a boiler to heat a liquid that is directed through pipes situated beneath the pavement surface. Electrically heating pavement is done by placing a series of electrodes between two layers of pavement. The base layer of pavement is traditional while the top layer is conductive. This can be accomplished by embedding conductive materials, such as steel shavings or carbon fibers, in the pavement. An electric current is then applied that allows heat to spread evenly through the top surface.

Documented Performance

Research within the United States has been ongoing for several years. An area of electrically heated pavement is currently being tested at the Des Moines International Airport while a hydronic pavement section is being tested at the Greater Binghamton Airport. Tests reveal that both methods are effective at melting snow although very rapid snowfall may be best removed with traditional equipment.

Both the hydronic and electric systems can be tailored for their environment to meet the desired level of performance. Pipe spacing can be varied in hydronic systems, while the spacing of electrodes or the composition of the conductive concrete can be modified in electric systems to meet the needs of the specific application. Turning on the heating system to allow the pavement to warm before snowfall occurs has been shown to be more effective than more intense heating once snowfall has commenced.

2. Implementation Considerations

Applicability Assessment

Because this technology is still in the development and testing phase, this practice is unlikely to be applicable to airports at this time.

Regulatory Considerations

In March 2011, the FAA published AC 150/6370-17, Airside Use of Heated Pavement Systems. This publication provides guidance and design considerations for electric and hydronic systems while also specifying construction standards for heated pavements projects. Similar to other ACs, this guidance is not mandatory by nature but must be met by projects using federal funding under the Passenger Facility Charge or Airport Improvement Programs.

Planning and Design Considerations

A fundamental consideration is that installing a heated pavement system in existing pavement will require demolition and replacement of the pavement. For this reason, it may be difficult to justify a heated pavement system unless it is installed as part of a new pavement or pavement rehabilitation project.

For each system, the location, available power sources, pavement characteristics and drainage characteristics should be considered. Hydronic systems require pipes to carry the heated liquid and are not compatible with most asphalts types because compression of the asphalt during construction may damage the pipes. Because storm water collection may overly saturate surrounding areas or potentially interrupt traffic, a detailed estimate of melted runoff and how it will be stored and/or removed from the operations area must be included in a heated pavement design. Modifications may also be necessary to the airport's Snow and Ice Control Plan. Guidance to assist airport operators develop a snow and ice control plan is provided in AC 150/5200-30D, Airport Winter Safety and Operations.

Integration with Other Practices

Research is being conducted to pair heated pavements with hydrophobic coatings or phase change materials (PCM) to aid in repelling water and prevent ice from forming. Although hydrophobic coatings are very effective at shedding water, they currently lack the durability to withstand use by aircraft and SRE equipment. Similarly, PCM may assist in preventing ice during initial snow conditions but is not effective during sustained cold temperatures. Therefore, although both of these technologies may one day be paired with heated pavements, further development is needed before they are implemented.

Operation and Maintenance Considerations

Not applicable at this time.

3. Costs

Cost for each of these systems can vary based on design and technology used, and more systems will need to be operational before detailed cost information can be gathered. Hydronic systems tend to cost more to install but are generally less expense to operate. Electronic systems tend to reverse this trend. A 2014 study based on existing data showed that the average cost to install a hydronic system was $70 per square foot compared to the electronic heating at $37 per square foot. Once installed, operation and maintenance costs were shown to be $1.30 per square foot for hydronic systems and $1.69 for electric systems. It should be noted that the cost to operate and maintain hydronic systems can vary considerably based upon the type of heating employed (e.g., geothermal heating versus a boiler system).

Costs associated with these technologies are expected to decrease over time as research continues. Therefore, these prices should be seen as a 2014 benchmark that will evolve over time.

FACT SHEET 20

Airfield Deicers—Physical Removal

1. Description

Purpose

This practice provides the opportunity to reduce the volume of airfield deicers used in wintertime operations by physically (mechanically) removing snow or ice from the airfield in lieu of using deicing products for this purpose.

Technology

Physical removal of snow or ice involves using mechanized brooms and plows to remove accumulated snow from airfield pavement. Additional information on snow removal equipment, best maintenance, and management practices is found in *ACRP Report 123: A Guidebook for Airport Winter Operations*.

Under certain circumstances, especially in the case of dry snow, deicing products will not need to be applied to the airfield after the snow has been physically removed. Even when chemical deicing is needed after physical removal, less will be required to achieve safe operating conditions than would otherwise be the case.

Documented Performance

The performance of physical removal techniques is very site-specific, depending primarily on the type of precipitation encountered.

2. Implementation Considerations

Applicability Assessment

Physical removal is commonly conducted prior to application of pavement deicing products and is widely applicable as a standard practice for airfield snow and ice removal. It is most successful in reducing the need to apply deicing products where loose dry precipitation, such as dry powdery snow, is involved.

Regulatory Considerations

There are no environmental regulatory considerations associated with this practice. Implementation must be consistent with all applicable FAA policies and approved airfield snow and ice control plans.

Planning and Design Considerations

Airports commonly employ physical removal procedures to make their use of deicing products more efficient. This fact sheet provides recognition that these typical procedures reduce the amount of deicing fluids applied and can therefore be considered as a source reduction practice.

Modifications may be necessary to the airport's Snow and Ice Control Plan. Guidance to assist airport operators develop a snow and ice control plan is provided in AC 150/5200-30D, Airport Winter Safety and Operations.

Integration with Other Practices

Physical removal techniques are commonly employed prior to the application of deicing products to reduce the total amount of product required.

Operation and Maintenance Considerations

The primary operational consideration is ensuring aircraft safety.

3. Costs

Capital costs for physical removal are limited to purchasing brooms and plows. Labor costs are the primary component of operation and maintenance costs. However, because these practices are typically performed at airports regardless, there are no "new" costs in considering this action as a practice.

FACT SHEET 21

Centralized Deicing Facilities

1. Description

Purpose

This practice provides a means of concentrating deicing activities in one or more centralized deicing locations so that containment areas and runoff volumes are minimized.

Technology

Centralized deicing facilities can be simple aprons with drainage infrastructure that allows isolation and collection of deicer-laden runoff, or technologically advanced facilities with electronics that monitor everything from aircraft positioning to glycol concentrations in the runoff collection system. The complexity of each facility depends on the airport's or airlines' situation, and the sophistication required to meet operational and environmental needs.

Documented Performance

Centralized deicing facilities have the highest reported performance of available glycol collection practices. Because deicing activity is consolidated into one or more relatively confined areas, runoff volumes are reduced, and relatively high concentrations of deicer-laden runoff may be collected. This feature is important when considering recycling of glycol in the runoff as well as certain biological treatment technologies.

Airports employing centralized deicing facilities report repeatable seasonal collection performance in the range of 35–80% of glycols applied at the facilities.

2. Implementation Considerations

Applicability Assessment

Site-specific factors significantly affect the practicality of this practice. Centralized deicing facilities can vary from small apron or gate areas retrofitted with trench drains or asphalt curbs and frac tanks, to sophisticated off-gate facilities with queuing control, fixed deicing booms, blending to temperature, pumps, and recycling facilities. A key characteristic is that the facility provides an area where deicing activities are concentrated, and runoff can be isolated. Each airport and airline must assess its needs and determine if one or more centralized deicing facilities is appropriate.

The following factors are considered in determining whether a centralized deicing facility is a potentially suitable practice:

- Operational considerations such as peak hour traffic flow, gate availability, aircraft size, typical weather conditions, etc., will present opportunities and constraints. For example, it may not be economically feasible to construct a facility with the capacity to accommodate a large number of aircraft launched during a relatively short departure window. Conversely, if the flow of arrivals and departures is impeded by the availability of open gates, it may be beneficial to move deicing operations to a centralized facility, potentially reducing delays.
- The amount of site preparation required to construct a centralized deicing facility will affect cost. Large amounts of earthwork and drainage infrastructure may make the initial capital investment too large to justify the benefits of a centralized facility.
- Site-specific issues such as available area, drainage infrastructure, prevailing wind conditions, and jet blast will determine if a centralized deicing facility will fit within the confines of the airfield.
- Centralized deicing facilities may be established on existing aprons or gate areas if the areas are already graded favorably for collecting and containing deicing runoff. It may be feasible to deice smaller, regional jet–type aircraft at a centralized deicing facility while continuing to allow larger aircraft to deice at the gate.

Regulatory Considerations

Siting requirements for centralized deicing facilities are outlined in FAA Advisory Circular 150/5300-14C. Centralized deicing facilities must also comply with the requirements of FAR Part 77, Objects Affecting Navigable Airspace, runway and taxiway safety area and object free area criteria, as well as terminal instrument procedures (TERPs) surfaces such as precision obstacle free zones and W, X, and Y obstruction clearance surfaces. In accordance with FAA Environmental Handbook 5050.4B, a centralized deicing facility must not incorporate storage tanks or lagoons that may attract waterfowl.

Typically, the driving factor in considering centralized deicing is compliance with stringent environmental regulatory requirements in the airport's NPDES permit. The decision to employ this practice to satisfy those requirements is made through a site-specific evaluation of alternatives, rather than a specific requirement for deicing pad technology as a compliance condition.

Planning and Design Considerations

FAA AC 150-5300-14C, Design of Aircraft Deicing Facilities, provides guidance in planning and designing centralized deicing facilities and remote aircraft deicing facilities. There are separate chapters on sizing and siting the deicing facilities, designing aircraft deicing pads (i.e., positions), aircraft access and vehicle service roads, and water quality mitigation.

The following factors should be assessed in planning and designing a centralized deicing facility:

- Consider departure rates and local conditions to determine the number of deicing positions needed.
- Consider aircraft fleet mix and queuing area in determining the size of the deicing facility. General guidelines require 2 acres per each medium or large aircraft. Aircraft movement simulation software may support the location, queue, and size of the deicing facility.
- Consider proximity of candidate locations to predominant takeoff runway(s).
- Evaluate existing taxiways to and from the facility and the potential for additional taxiways to ensure efficient movement of aircraft.
- Incorporate drainage designs that capture deicer-laden runoff and segregate deicing runoff from "clean" runoff to minimize runoff volumes for treatment and disposal. Considerations should include overspray, wind dispersion and jet blast, grading, inlet locations, and underdrains.
- Consider optimum method for deicing using either fixed-boom deicing equipment or deicing trucks.
- Consider orientation of deicing pad so aircraft are positioned with leading edge of wing into the predominant wind direction to minimize the use of deicing fluids.
- Allow sufficient capacity for spent deicer-laden runoff storage under design storm conditions. *ACRP Report 81: Winter Design Storm Factor Determination for Airports* provides guidance for selecting appropriate design storm conditions.
- Ensure all structures, including support buildings, tanks, and lighting, comply with FAR Part 77 imaginary surfaces.
- Allow sufficient room for a support building, if desired. A clear view of the deicing positions is needed from the control room.
- Consider an automated/integrated deicing facility management system to facilitate operation and data reporting of deicer usage.
- Consider aircraft guidance lighting and marking to help pilots navigate into each deicing position.
- Consider space requirements for aircraft to bypass other aircraft parking positions to facilitate traffic movement and avoid back-ups.

Finally, consideration should be given to the possibility that a centralized deicing facility in combination with some properly contained gate deicing might provide an optimal solution.

Integration with Other Practices

Centralized deicing facilities may incorporate virtually any source control practice.

Centralized deicing facilities are often implemented on a limited scale and operated in conjunction with other collection/containment practices. These facilities may be used just for heavy snow events while defrosting or light deicing continues at the terminal gates or freight ramps.

Because centralized deicing tends to result in the collection of concentrated runoff, it can facilitate recycling programs and increase the applicability of certain biological treatment technologies.

Operation and Maintenance Considerations

Operational requirements associated with centralized deicing facilities can be quite extensive, depending on the sophistication of the facility and local conditions. Some facilities are operated by the tenant airlines, whereas others are run by the airport through a private operator or using airport employees.

Maintenance requirements also vary with the degree of sophistication, but at a minimum include annual maintenance of diversion valves and pumps, inspection/repair of pavement joints, and cleaning of the deicing runoff collection and storage system. Fixed booms are disassembled and serviced annually.

3. Costs

Capital Costs

The largest components of capital costs associated with centralized deicing facilities include site preparation and excavation, paving and drainage infrastructure, and containment facilities. Additional costs include the deicing delivery method (fixed booms or truck-mounted deicers), as well as the glycol delivery piping costs and costs for a building to house the mixing/blending equipment and the truck-mounted deicing vehicles. Representative reported capital costs for centralized deicing facilities are shown in Table 1. These costs are presented in 2016 dollars. It should be noted that each facility is unique to the context within which it is designed, and the facilities are often constructed as part of larger airfield projects. It would be inadvisable to estimate costs for a new pad based on the data in the table.

Table 1. Examples of capital and O&M costs for centralized deicing facilities.

Location	Capital* ($M)	Annual O&M* ($K)
Akron-Canton, OH	12	250
Atlanta, GA	9.9	98
Baltimore, MD	37	980
Cincinnati, OH	40	610
Cleveland, OH	55–61	4.3
Dallas-Fort Worth, TX	122	No data
Dayton, OH	28	370
Detroit, MI	98	1,800
Fairbanks, AK	7.0	18–24
Hartford, CT	41	610–730
Pittsburgh, PA	51	~ 850–1,300

*All costs are approximate.

Operations and Maintenance Costs

Reported operating costs for centralized deicing facilities are shown in Table 1. These costs are presented in 2016 dollars. These costs typically include land and/or facility leases; labor; taxes; insurance and overhead; electricity, water, and gas utilities; and potentially a surcharge fee to the airport for the applied fluid, similar to a fuel flowage fee.

Typical Centralized Deicing Facility

Containment of flows in underdrains is often required to intercept glycol-laden runoff that has infiltrated through seams and cracks in the pavement surface of a deicing pad.

FACT SHEET 22

Apron Collection Systems

1. Description

Purpose

This practice provides a means of collecting deicer-laden runoff from terminal and freight apron surfaces by modifying existing drainage infrastructure or installing new conveyance infrastructure to allow deicing runoff to be diverted to containment and storage.

Technology

Apron collection systems for deicing material control generally use conventional collection technology with special features to separate deicing runoff from ordinary stormwater. Watertight standards that are similar to sanitary sewer technology are applied to reduce infiltration or dilution of the collected material and to prevent exfiltration of the collected material into the ground and potentially the groundwater. Some form of diversion valve technology (see Fact Sheet 31) is used to separate deicing from non-deicing runoff. Other surface runoff technologies may be used to promote effective containment and collection of spent deicing materials.

Documented Performance

A wide variety of airports have implemented apron collection systems, either as a stand-alone collection approach or in combination with other collection practices, especially glycol collection vehicles (see Fact Sheet 23). Reported collection performance data from these facilities show a high level of variability, with collection efficiencies that range from about 20% to almost 70% of applied glycol. The performance is dependent on local conditions, especially the weather during deicing events and the configuration of drainage infrastructure. The reported data suggests that long periods of consistently cold weather support higher collection efficiencies.

2. Implementation Considerations

Applicability Assessment

The primary considerations in evaluating the potential applicability of apron collection are the configuration of existing apron drainage, especially storm sewers, and the ability to store and treat the deicing runoff that will be collected.

Drainage configurations will define the size of the area collected and opportunities for implementing diversions. Ideally, the drainage system will provide opportunities to divert deicing runoff with minimal dilution from non-deicing areas through surface runoff or converging storm sewer lines. Apron renovation or new construction projects may offer opportunities to incorporate optimized apron collection features, such as isolation of deicing drainage areas from non-deicing areas, placement of inlets close to deicing positions, and installation of diversions at optimal locations.

Because apron collection tends to involve larger areas of pavement than more-targeted collection practices, the volumes of deicing runoff collected tend to be greater, and the concentrations of deicers in that runoff tend to be lower. Adequate storage, coupled with a suitable treatment practice, must be available for apron collection to be a practical option.

Regulatory Considerations

The placement and configuration of apron drainage features must comply with FAA requirements for taxiways and aircraft aprons (FAA AC 150/5300-13A, Airport Design). Apron drainage features must also comply with runway and taxiway safety area and object-free-area criteria, as well as terminal instrument procedure surfaces such as precision obstacle-free zones and W, X, and Y obstruction clearance surfaces.

Planning and Design Considerations

FAA AC 150/5320-5D, Airport Drainage Design, provides general guidance in planning and designing apron collection systems. Separate sections are included on sizing facilities and drainage and collection methods. The goal of the apron collection system for deicing runoff control is to maintain as much of the deicing runoff in the system as possible and reduce the loss of material to uncontrolled areas. The following factors should be considered in planning and designing an apron collection system to achieve this goal:

- Consider the geometry of the system. For simple retrofits, look for nodes where diversions can be installed to isolate subdrainage networks that serve the deicing areas with minimal inflow from nondeicing areas. For major apron renovation or new construction, a drain layout that reduces the surface travel distance for deicing runoff improves the potential for capture. Do not locate the drain under the aircraft if fueling operations are planned for the deicing position.
- For larger deicing areas, consider segmenting the surface drainage to minimize dilution during limited deicing operations.
- Consider slope and surface roughness to reduce the loss of fluid off of the apron containment area due to jet blast.
- Seal pavement joints to reduce infiltration and deicing runoff loss through the pavement section.
- Consider the potential for infiltration and exfiltration in existing collection systems during design. Slip lining collection pipes or grouting pipe joints may be needed to reduce infiltration into a collection system that increases the volume of water stored and treated, or exfiltration that can undermine collection performance and potentially contaminate groundwater.

- Consider service vehicle routes and taxi lanes when designing surface flow paths to avoid tracking deicing runoff out of the collection system.
- Use single- or multiple-grate inlets for simple construction and low maintenance.
- Consider trench drains in low points when necessary to meet minimum surface grade requirements. Avoid using trench drains to create drainage divides on slopes.
- Require watertight inlets and drain structures and pipe penetrations.
- Require watertight pipe material and joints.
- Provide periodic trench flow check material to control subsurface flow in pipe bedding material.
- Provide underdrains for controlling deicing fluid and stormwater infiltration and high groundwater. Allow diversion of the underdrains to the deicing fluid collection system.
- Design the system using control equipment that is suited to the system objectives and the capabilities of the operations staff.

Integration with Other Practices

Apron collection systems can be implemented alone or in combination with other collection practices. Glycol collection vehicles (Fact Sheet 23) may be used to collect concentrated deicing runoff, to support recycling for example, with the apron collection system serving to contain the more dilute runoff. Apron collection system features may be used in managing the melt-off from deicer-laden snow and in providing spill control capabilities.

Operation and Maintenance Considerations

Operational and maintenance requirements associated with an apron collection system vary significantly depending on the sophistication of the system. The requirements are significant in a system that includes pumping, diversion valves, monitoring, and storage in addition to conveyance to a treatment or recycling process. In areas with winter weather that fluctuates between freezing precipitation and rainfall, manually operated systems will require a higher level of attention and operation. A gravity flow system may have requirements as modest as periodic observation and annual flushing.

Most apron collection system elements are underground and should be designed with low maintenance in mind to avoid excavation, repair, and replacement costs and the costs of surface restoration and disruption of airfield operations.

Apron collection systems may be operated by the tenant airlines (e.g., a freight apron operator, the dominant air carrier, or largest fixed base operator), or by the airport through a private operator or using their own employees. Each facility needs to consider the best method of operating the apron collection system with the interests of all users in mind.

Pavement joints on the apron surface need to be inspected annually. Any joints showing signs of defective sealant should be resealed, and any cracks in the pavement should be sealed to reduce migration of the deicing runoff into the subsurface drainage.

3. Costs

Capital Costs

The capital costs for apron collection systems using existing infrastructure and surface drainage techniques can be very low. Larger aprons require underground drains and piping and may become significantly costlier. If mechanical control and monitoring are required, the capital cost of conveyance facilities can be even higher.

Operations and Maintenance Costs

Though it may have a high capital cost, a large pipe gravity conveyance system can have relatively low operation and maintenance costs. Mechanical systems add significantly to the O&M costs because of the more complex nature of the facilities, the need for monitoring and data collection, and the ability to develop and implement control strategies.

FACT SHEET 23

Glycol Collection Vehicles

1. Description

Purpose

This practice provides for active collection of aircraft deicing runoff from pavement surfaces using specialized vacuum-type collection vehicles.

Technology

Collection vehicles are commonly referred to by a variety of names, including sweeper-vacs, glycol recovery vehicles (GRVs), and mobile collection units. Collection vehicles may be used for removing spent aircraft deicing fluid from the pavement virtually anywhere that aircraft are deiced, and vehicles can have access. Glycol collection vehicles are often used in conjunction with other, passive collection practices.

There are two basic design approaches in commercial glycol collection vehicles: truck chassis or trailer mounted. The truck chassis designs are adaptations of 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. Wash bars and multi-stage separation systems to improve glycol removal from the vacuum air stream provide improved collection efficiency. 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 takeoff from the tow vehicle, typically a tractor.

Documented Performance

Glycol collection vehicles can be operated to collect as much aircraft deicing runoff as possible, or to just target the most concentrated runoff, depending on the objectives of the collection program. Performance data on glycol collection vehicle operations from several airports report recovery between approximately 20 and 50% of glycol applied in the collection area on an annual basis. The upper end of this reported range should be considered as reflecting optimal conditions.

The overall effectiveness of glycol collection vehicles varies based on the number of vehicles used relative to the areas and deicing activities served, and whether they are used in conjunction with other collection methods, such as apron collection systems (see Fact Sheet 22), central deicing facilities (Fact Sheet 21), automated diversion valves (Fact Sheet 31), etc.

2. Implementation Considerations

Applicability Assessment

Vehicle-based glycol collection is generally well suited to situations where the following conditions are present:

- Aircraft deicing is conducted at various locations around the airfield.
- Collection of relatively high-concentration runoff is desired.
- Catch basins and storm sewer inlets can be blocked to prevent deicing runoff from entering the storm sewer prior to collection.

Other considerations include the following:

- Mobile glycol collection will increase the volume of vehicular traffic around gates and apron areas, and may impact the ability of aircraft to access gates on time.
- Some temporary ponding of deicing runoff on the apron surface may occur. Coordination of collection operations will minimize the occurrence of this ponding.
- To the greatest extent possible, apron surfaces should be cleared of snow and heavy slush prior to mobile collection activities to avoid clogging the machinery. This can be a significant operational constraint on the effectiveness of this practice.
- Adequate staff must be available to operate the collection vehicles, open and close the catch basin valves, and manage the collected runoff.
- It is essential to maintain close communication and coordination between the glycol collection vehicle operators, aircraft deicing crews, and ramp coordinators.

Regulatory Considerations

There are no direct regulatory considerations associated with operation of glycol collection vehicles, other than compliance with all regulations regarding airside vehicle operations.

At some facilities, there may be concerns over increased air emissions.

Planning and Design Considerations

Glycol collection vehicles work best where deicing runoff remains on the ramp surface and is accessible for collection. As such, the following must be considered in developing an implementation plan:

- The capacity of the collection vehicle will be dictated by the amount of deicing fluid used at the facility during peak deicing events. Generally, larger capacity vehicles are more efficient, while smaller vehicles are able to operate in more confined areas.
- Some method of blocking storm sewer inlets to keep deicing runoff on the surface prior to its collection is essential to optimal performance. The most reliable methods involve mechanical blocks installed within the inlets. Rubber mats may be used, but these are prone to being picked up by the collection vehicle and displaced by jet blast and prop wash. Consider safety concerns related to ponding of deicing runoff on the ramp before it is collected.

- Pavement surfaces and joints must be maintained in good condition because the collection vehicle vacuum can suck up loose pavement and joint material.
- Stations for transferring collected runoff from the collection vehicles to storage should be located close to the collection areas to minimize transit distances.
- Solids collected with the deicing runoff must be managed and disposed of appropriately.
- Provisions are required for efficient transfer of the collected runoff from the vehicle to storage. On-board pumps can be used to transfer runoff to aboveground tanks. An in-ground sump with a heavy grate can be used for rapidly offloading collection vehicles equipped with a dump body design.
- Collection vehicles are prone to clogging with snow and slush and require a relatively clear surface for optimal effectiveness. Coordination with snow removal operations and operator training will minimize the impact on collection operations.
- The cost-effectiveness of collection vehicles depends significantly on the costs of purchasing and operating the collection vehicles being less than the costs saved in downstream deicer management (conveyance, storage, treatment).

Integration with Other Practices

Glycol collection vehicles may be combined with block-and-pump systems (Fact Sheet 24), apron collection (Fact Sheet 22), and centralized deicing pads (Fact Sheet 21). Often, this is done to target runoff from defrosting operations or to intercept high-concentration runoff. The relatively high concentrations that can be collected facilitate reduced storage requirements and support recycling.

Operation and Maintenance Considerations

Effective operation of glycol collection vehicles requires trained staff and close coordination with aircraft-deicing operations. Vehicle operators need to be available at all times when aircraft deicing is conducted, and especially when heavy events occur. Staffing of glycol collection vehicle programs can be by airport staff or use contractor personnel. Training and supervising operators is key to success with this practice. Typically, a designated coordinator who tracks aircraft schedules and deicing operations as well as directs the operations of the collection vehicles will result in optimum performance.

The maintenance of the collection vehicles is similar to other ground-based vehicles.

3. Costs

Capital Costs

Glycol collection vehicle costs depend on the type and capacity of vehicle. Purchase prices for purpose-built vehicles in 2018 range between $100,000 and $430,000. Lease plans are often offered by glycol collection contractors, either alone or as part of a program package.

Less-expensive alternatives may be suitable for some applications. Retrofit kits are available for certain street sweepers to adapt them to glycol collection. These kits are significantly less expensive than purchasing a new piece of machinery, although performance may not equal that of a vehicle that has been specifically designed for deicing runoff collection.

Operations and Maintenance Costs

Operating costs depend on the size and frequency of use of the vehicle.

FACT SHEET 24

Block-and-Pump Systems

1. Description

Purpose

This practice provides a means of intercepting deicing stormwater near the source. Implementation and operation of this practice is typically the responsibility of an airport, but tenants may consider implementation within their leasehold.

Technology

The primary objective in block-and-pump systems is to intercept deicing runoff close to the source, often using existing storm sewers for temporary inline storage. This approach facilitates cost-efficient collection of runoff and can improve the economy of glycol treatment/recovery systems. Block-and-pump systems are often supplemented with glycol recovery vehicles (GRVs) to collect a higher concentration deicing runoff.

Drainage blocks, consisting of valves (see Fact Sheet 31) or inflatable sewer plugs, are installed within the drainage infrastructure to prevent concentrated deicing stormwater from discharging to surface water through the drainage system. Upstream of the blocking mechanism, detention is provided in the form of pipe storage, surface flooding, or storage within other drainage structures. Deicing stormwater is collected periodically using pumps or GRVs and transported elsewhere for treatment or processing. Blocking mechanisms are generally opened or removed during non-deicing periods to allow normal drainage of nonimpacted stormwater.

Documented Performance

The performance of a block-and-pump system for preventing the discharge of deicing stormwater depends upon the effective operation of the drainage blocks and collection of deicing runoff during deicing events.

There are little available performance data specific to block-and-pump installations, but the practice is popular among smaller airports. Twenty-one airports (15% of those surveyed) reported to EPA that they use such a system. Of those airports reporting, all but seven were small-hub or nonhub-type airports.

2. Implementation Considerations

Applicability Assessment

The following factors should be considered when considering a block-and-pump system as part of a deicing stormwater management system:

- Block-and-pump systems can typically be easily deployed and quickly operational. This practice is often a precursor to more-advanced collection systems.

- Block-and-pump systems may provide a means for collecting relatively high concentrations of spent aircraft deicer in applications where other high-concentration practices (e.g., deicing pads, GRVs) are not practicable.
- Block-and-pump systems are more favorable if the size of the drainage area and complexity of the storm sewer system are relatively low.
- A significant level of coordination may be required to operate and maintain the block-and-pump system to avoid interference with airport operations.
- Inflatable sewer balloons can be simple and effective as blocks but require secure anchoring within the storm sewer system. Balloons may require replacement after 2–4 seasons.
- Drainage blocks may need to be custom fabricated for individual drainage systems.
- Ponding areas should be easily accessible by collection equipment to avoid interference with airport operations.
- Block-and-pump systems may cause flooding during heavy precipitation and impede safe aircraft operation.
- Effectiveness of block-and-pump systems is directly affected by pavement or drainage system cracks (leaks points), drainage area size, porous storm sewers, pipe material (e.g., corrugated metal), and the potential transport of deicer to other areas by vehicles that pass through ponded areas.

Regulatory Considerations

Block-and-pump systems will not generally require permits; however, they should be operated in compliance with any National Pollutant Discharge Elimination System (NPDES) (or equivalent) surface water discharge permit and FAA regulations. Ponding has the potential to interfere with airport and aircraft operations, and FAA AC 150/5320-5c, Surface Drainage Design recommends that ponding above apron catch basin inlets be limited to a depth of 4 inches. Standard operating procedures should establish upset conditions for the removal of drainage blocks when a potential for hazardous flooding occurs. OSHA regulations regarding confined space entry may be applicable where entry into the sewer system is required for installation or maintenance.

Planning and Design Considerations

The following factors should be considered in planning to implement a block-and-pump system:

- Identify potential locations in the drainage system where blocks would be most effective for capturing deicer runoff, and which would not cause significant upstream surface ponding or interference with airport operations.
- Develop standard procedures for preparing, inspecting, monitoring, operating, and maintaining the block-and-pump system, including upset conditions.
- Estimate time intervals and staffing required to operate, inspect, and maintain the system during and between deicing events.
- The collection location should be accessible by recovery vehicles or vacuum trucks, if applicable. The offloading location should be similarly convenient.

- This practice requires that joints or cracks in the pavement and within the drainage infrastructure be sealed to prevent infiltration or exfiltration. Because storm sewers are typically not designed to be watertight, frequent pumping of collected stormwater will minimize losses to exfiltration. The integrity of the block-and-pump system can be directly examined through regular visual inspections and/or tightness testing.

Integration with Other Practices

Commonly, a block-and-pump system is operated in conjunction with GRVs (see Fact Sheet 23) or a tanker truck with pumps, which collect the deicing stormwater that builds up behind the drainage block during deicing events. GRVs can also be used in conjunction with block-and-pump systems to collect higher concentration runoff.

Operation and Maintenance Considerations

Operational requirements associated with a block-and-pump system include the manual operation of the drainage blocks, periodic testing of the ponded stormwater, pumping the collected deicing stormwater, and hauling it to storage and treatment. Operational protocols should be defined for quickly removing drainage blocks to avoid flooding the apron during significant rain events. Maintenance tasks associated with block-and-pump systems include regular inspections of the systems to ensure proper operation, removal of debris that may interfere with drainage block operation, repairs to maintain watertight seals, and replacement of worn sewer balloons and valve parts.

3. Costs

Overall costs associated with block-and-pump systems depend upon the type of system employed, the number and size of drainage blocks required, the type of collection equipment selected, and the need for modifications to the existing drainage system to maximize effectiveness.

Capital Costs

Capital costs for block-and-pump systems may include drainage blocks, pumps or other collection equipment, vehicles for transport, additional detention structures, and modifications to the existing drainage infrastructure. Other initial costs may include repairs to existing infrastructure and surrounding pavement to ensure an adequate watertight seal.

Operations and Maintenance Costs

Operational cost items for block-and-pump systems include labor associated with operating the blocking and collection mechanisms, transportation of collected fluid, and monitoring and analysis. At some airports, sewer balloons are removed at the end of each deicing season and reinstalled at the beginning of the next.

Maintenance costs may include the following:

- Repairs to seals within drainage infrastructure and surrounding pavement;
- Regular inspection of the block-and-pump system;
- Repairs to maintain proper system operation; and
- Periodic replacement of sewer balloons, if used.

Sewer balloons may be installed almost anywhere there is access to the storm sewer.

FACT SHEET 25

Airfield Drainage Planning/Design/Retrofit

1. Description

Purpose

The primary purpose of airfield drainage design is to divert stormwater from airfield operations areas in order to provide a safe and stable surface for movement of aircraft and support equipment. A secondary purpose is to reduce stormwater contaminants before they are discharged to the surface water system. For cold-weather airports, the most significant contaminant is uncollected spent deicing fluid. Considering the unique aspects of deicing runoff in the airfield drainage design process can improve overall control efforts.

Technology

Most existing airfield drainage systems benefit from some passive control of deicing materials in stormwater. Mass balance monitoring at various airports shows significant losses of deicers between point of application and stormwater discharge, and published research demonstrates that substantial biodegradation occurs on apron surfaces, even at low temperatures (Revitt and Worrall 2003). Degradation of deicers in runoff can be enhanced by applying basic stormwater management principles, such as increasing the time that the materials remain in the system and controlling the conveyance surfaces that the deicing contaminants are exposed to. Systems that maintain drainage on the ground surface and maximize contact with vegetation and soil are expected to get the greatest removal benefit, while systems that promote rapid drainage with hard ditches and conduits are likely to get the least.

There are two processes that work to control stormwater contaminants: (1) biological reduction, which uses bacteria and nutrients in soil and vegetation to break down dissolved organic materials such as deicers, and (2) filtration in soil and vegetation, which intercepts suspended material in stormwater. Filtration is most applicable to non-deicing pollutants but may provide benefits in intercepting granular pavement deicers and sand, as well as particulates unrelated to deicing runoff. Both processes can be designed into a drainage system by increasing the time or the flow path that deicing runoff takes to travel through the system and by providing contact with soil and vegetated surfaces.

Documented Performance

There is no documented performance data on this practice, although published research indicates that significant biodegradation of deicers occurs on airfield surfaces at low temperatures (Revitt and Worrall 2003). The common occurrences of bacterial growth along airfield drainage ways is further evidence of biological activity under wintertime conditions. Significant documentation exists on the performance of stormwater practices, which employ the same underlying principles. Although quantitative performance cannot be extrapolated from the stormwater context, there is good reason to conclude that some level of deicing pollutant reduction will occur if favorable conditions are provided in the airfield drainage system.

2. Implementation Considerations

Applicability Assessment

This practice is intended to use buffer space or separation space that is not designed for aircraft operation or safety purposes. Thus, this practice is appropriate for airfields that have considerable buffer and separation space; it may be less applicable at airfields where space is limited.

The biological degradation process is sensitive to temperature. Cold region applications will tend to see lower biological reduction rates. There is also typically less runoff during cold periods, reducing the flow-through times and loading factors. There may be no significant benefit in extremely cold regions.

In arid regions where vegetation is sparse, the filtering benefit of vegetation, which would reduce the containment of pollutants in particle form, is reduced. For areas with pervious soils and high groundwater, the drainage design should consider options to protect the groundwater from surface water impacts.

Regulatory Considerations

Design and construction of airfield drainage systems is subject to considerable regulations. Most significant are environmental regulations that are covered in other sections of this document. FAA AC-150/5320-5C for airfield drainage has recently been updated to cover both the quantity and quality of airfield runoff. There are allowances for stormwater practices that are consistent with drainage design principles for deicing runoff control.

Planning and Design Considerations

The following general airfield drainage practices are effective to varying degrees in controlling deicing runoff in airfield drainage systems and can be applied individually or in combination to improve effectiveness.

- **Drain paved areas on the surface to vegetation.** This is the conventional method for runways and taxiways. In many situations, it can also be applied to paved apron space.
- **Slope safety areas for positive sheet flow drainage.** Safety areas must be capable of supporting aircraft and safety vehicles. A stable vegetated surface and positive drainage should be provided for these areas.

- **Slope buffer areas for sheet flow drainage over time.** Rapid and effective drainage is not as critical in buffer areas because maintenance activities can be scheduled during dry periods.
- **Provide vegetated swales for shallow concentrated flow rather than earthen or paved ditches or storm sewers.** This practice tends to increase the cross-sectional area of the flow path, thereby increasing short-term storage and reducing flow velocity and peak flow rates.
- **For concentrated flow where velocities are higher and flow durations longer, provide gravel and cobble armor in ditches rather than using paved ditches or storm sewers.** This approach adds roughness to the conveyance system, thereby reducing velocities and providing filtration, greater surface area for biological reduction, and opportunity for infiltration.
- **Allow sheet flow over vegetation upstream of field inlets.** Drains and storm sewers are needed in internally drained infield areas. A vegetated buffer area filters out sediment and attached pollutants before the stormwater enters the storm sewer for discharge to surface waters.
- **Consider temporary stormwater retention in areas not related to airfield operations.** This can provide flood control, contaminant filtration, sedimentation, and biological degradation. Avoid long-term standing water areas that may provide habitat for birds and ground animals.
- **Divert unimpacted surface drainage away from deicing areas.** This practice tends to reduce the volume of deicing runoff that requires treatment.
- **Consider potential impacts on shallow groundwater.** This practice will help avoid unintended transport pathways and water quality impacts.

Certain airfield situations may preclude the use of some of these practices, and practices should never compromise the function of safety areas.

Integration with Other Practices

This practice is compatible with all other deicing practices. Drainage design practices are especially important downstream of deicing areas, where fugitive deicing materials are present in stormwater. They are also beneficial where pavement-deicing materials may be present in stormwater.

Operation and Maintenance Considerations

The following considerations pertain to operation and maintenance associated with this practice:

- Airfield drainage systems should be designed to minimize operation and maintenance incursions into the operations area.
- Features that reduce maintenance requirements—such as self-cleaning inlets and remotely or automatically operated pumps, valves, and gates—are recommended.
- Surfaces and surface slopes should be compatible with normal maintenance and mowing equipment.
- Specialized procedures should be developed for nonstandard drainage and deicing fluid control features.

3. Costs

Capital Costs

Airfield drainage design to improve deicing runoff management is typically less costly than traditional drainage practices. The focus is on reducing more costly paved surfaces and underground drainage structures and incorporating less costly vegetated and armored earthen surfaces and detention areas that reduce the size of drainage features. These practices do require more space than conventional designs, but the space is usually in buffer areas that do not serve a critical aviation function and have little or no commercial value.

Operations and Maintenance Costs

Periodic inspection is required to identify vegetated surfaces that have accumulated sediment and conveyance areas where erosion has compromised vegetated or armored surfaces. Annual removal of accumulated sediment and repair of eroded surfaces may be required, especially after initial installation or after subsequent construction activity. These operation and maintenance activities may be somewhat costlier than those for a system incorporating concrete surfaces and that does not control sediment.

Reference

Revitt, D. M., and P. Worrall. 2003. Low temperature biodegradation of airport de-icing fluids. *Water Science and Technology,* 48(9), 103–111.

Source Reduction
CONTAINMENT/COLLECTION
System Components
Treatment/Recycling

FACT SHEET 26

Deicer-Laden Snow Management

1. Description

Purpose

This practice provides for reducing discharges of deicers to surface water through management of snow containing aircraft or pavement deicers (sometimes called “pink” snow because of the color imparted by high concentrations of entrained aircraft deicers). Within deicer application areas and along runways and taxiways, deicers may runoff into or become entrained in clean snow. During snow-clearing activities, deicer-laden snow may be mixed or stockpiled with clean snow, resulting in further contamination. If containment actions are not taken, runoff from melting snow stockpiles with significant amounts of entrained deicers has the potential to enter the storm drainage system and discharge to surface water or infiltrate into groundwater.

Airports are typically responsible for the implementation of this practice.

Technology

Snow management has two primary objectives that address the concerns associated with deicer entrainment: minimizing the volumes of deicer-laden snow generated and managing deicer-laden snow and the associated meltwater to meet environmental requirements. Snow management includes a variety of practices and techniques to achieve these objectives.

Techniques for minimizing the amount of snow that is subject to being mixed with aircraft deicers may be accomplished in several ways. A common approach is clearing accumulations of clean snow from designated aircraft deicing areas prior to deicing operations. This requires good coordination between snow removal crews and aircraft deicing crews. Another approach is reducing the size of designated deicing areas, which may have additional benefits to deicing runoff collection and treatment or recycling.

Management of deicer-laden snow may be accomplished by plowing operations that distinguish between impacted and clean snow and the use of separate disposal areas for impacted snow that provide for containment of high-concentration meltwater.

Documented Performance

Performance data on this practice were not identified during the development of this guidance document. However, published U.S. Geological Survey research on the glycol content of airfield snow piles at one airport reported that 0.2 to 11% of applied aircraft deicers was contained in snow banks.

The following factors affect performance of a snow management program in intercepting and containing deicers entrained in plowed snow:

- Comprehensiveness of efforts to minimize and segregate deicer-laden snow piles.
- Deicer content in the managed snow piles.
- Degradation of deicers in the snow piles prior to meltwater collection.
- Effectiveness in separating deicer-laden meltwater from relatively "clean" meltwater.
- Timeliness of snow melting and collection activities after snowfall event to avoid losses to soil or surface drainage.

2. Implementation Considerations

Applicability Assessment

Deicer-related snow management is not a widespread practice across the airport industry. This practice is typically implemented in response to evidence that (1) primary deicing runoff controls are not meeting requirements, (2) a significant amount of uncollected deicing runoff is bound up in deicer-laden snow, and (3) the deicers in the meltwater from that snow represent an unacceptable discharge to the environment.

This practice is typically not applicable where snow rarely accumulates, where apron collection or other widespread runoff collection efforts include snow disposal areas, where other deicing practices adequately control deicing runoff discharges, or where there is no practical alternative for disposing of the meltwater.

Requirements for successful management of deicer-laden snow include adequate manpower and equipment for separate plowing and handling of snow from designated deicing areas, suitable land for separate storage/disposal, and a suitable destination for the treatment or discharge of deicer-laden meltwater.

Regulatory Considerations

Management of deicer-laden snow must be consistent with all pertinent FAA regulations, including heights of snow piles allowed in different areas of the airfield. Lining of impacted-snow disposal areas may be required to avoid regulatory requirements associated with discharges to groundwater. Where snow melters are being considered, their impact on air emissions may have regulatory implications.

Planning and Design Considerations

The following factors should be considered in planning a successful snow management program to contain entrained deicers:

- There should be a well-defined justification for snow management to meet environmental requirements.
- Adequate and suitable space must be available for deicer-laden snow storage; it must be readily accessible for equipment transporting deicer-laden snow.

- Controls on meltwater from the storage area(s) should consider both surface runoff (via grading and curbing) and infiltration of the deicer-laden snowmelt into the ground (via a suitable impermeable lining).
- A suitable method for disposing of deicer-laden meltwater is required, with adequate capacity to handle the expected concentrations and volumes; strategies for diverting deicer-laden water to treatment and clean meltwater to the stormwater system should be considered.
- Standard operating procedures (SOPs) should be developed to provide unambiguous guidance for plow operators and truck drivers in identifying, collecting, transporting, and disposing of deicer-laden snow. It is important that the operators understand that depositing deicer-laden snow into areas outside of contained storage areas could result in discharge permit violations. Development of the SOPs should begin early in the planning process and with the explicit commitment and collaboration of staff who conduct snow-clearing operations.
- Snow melters can be used to significantly reduce the land requirements for managing deicer-laden snow.
- If snow melters are considered, details on their placement, operating costs, air emissions, and method of disposal of meltwaters should be evaluated early in the planning process. The economic justification for snow melters is often based on comparing their cost to that of constructing and operating additional confined snow storage areas.
- Modifications may be necessary to the airport's Snow and Ice Control Plan. Guidance to assist airport operators develop a snow and ice control plan is provided in AC 150/5200-30D, Airport Winter Safety and Operations.

Integration with Other Practices

This practice is readily integrated as an element of a comprehensive deicing runoff management program. Disposal of deicer-laden meltwater will require adequate and suitable treatment capacity for the relatively dilute streams involved.

Management of deicer-laden snow generally enhances overall system collection performance. In addition to controlling a fraction of deicing runoff that would otherwise not be collected, snow removal from designated deicing areas prior to deicing operations benefits collection by reducing sources of dilution.

Operation and Maintenance Considerations

Operation and maintenance requirements will be facility-specific. The following general guidelines are provided:

- Some incremental increase in time and effort will be required to implement this practice; in many cases, deicer-laden snow management may be implemented with existing staff and equipment.
- Development of unambiguous guidance for plow operators and truck drivers is essential for success.
- Regular attention will be required during periods of warm weather to monitor the quality of the meltwater and manage its disposition.

- Maintenance at the end of the deicing season will consist of cleaning up accumulated debris and sediment from the storage areas, and inspecting, and repairing as needed, runoff controls and liners to ensure their integrity.

3. Costs

Costs for implementation of deicer-laden snow management will be very site-specific. The following information provides guidance on possible cost elements.

Capital Costs

Capital cost elements may include additional snow plows and trucks, site preparation for a contained snow disposal area, and drainage controls and conveyance for managing meltwater. Snow melters, if purchased, can add significantly to capital costs, with prices that can range into the several hundreds of thousands of dollars, depending on capacity.

Operations and Maintenance Costs

Possible operational cost elements may include labor and fuel for additional equipment operations and coordination, monitoring of snow disposal areas, lease and fuel costs for snow melters, and treatment for meltwater above concentrations that can be discharged to stormwater.

Maintenance cost elements include incremental increases in maintenance of snow plows and trucks, snow disposal area monitoring and control equipment, and snow melters, if owned by the airport. Annual maintenance of the snow disposal area(s) will also be required.

FACT SHEET 27

Portable Tanks (Frac Tanks)

1. Description

Purpose

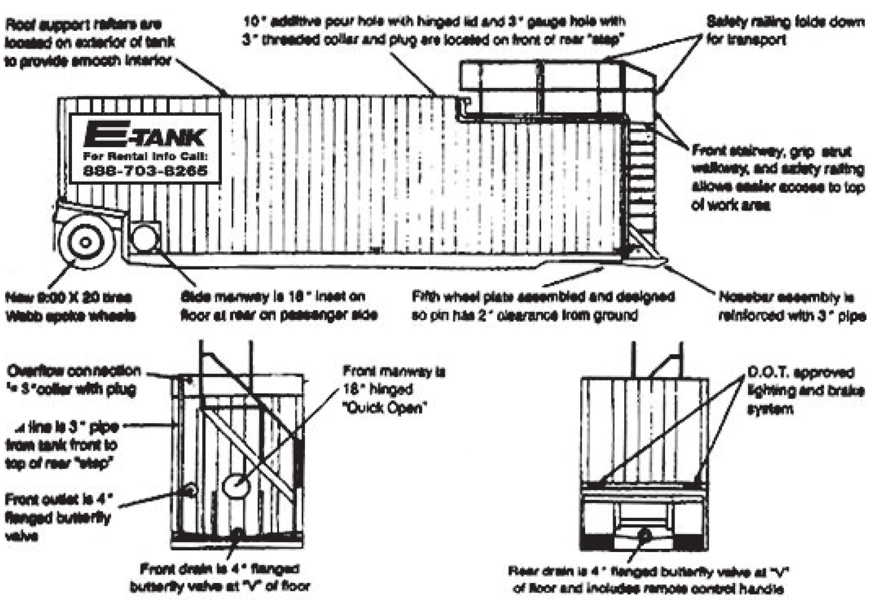
This practice provides a means of temporary storage for deicer-laden stormwater runoff prior to transporting for treatment or disposal. These tanks are commonly known in the industry as frac tanks.

Technology

Frac tanks are portable tanks, generally 21,000 gallons in size, that are delivered when and where needed by conventional semi-tractor trucks. These tanks are easily placed and removed and may be rented for any time period desired.

Documented Performance

Frac tanks have been used successfully for a wide variety of storage applications for many years. The use of frac tanks for reliable and flexible deicing runoff storage applications dates back to at least the early 1990s at some of the first deicing pads established in the country.



A conventional Frac tank schematic (provided by E-Tank).

2. Implementation Considerations

Applicability Assessment

Temporary storage using portable tanks is employed where the runoff volumes to be contained are relatively small and deicer concentrations are relatively high. Multiple tanks can be placed at a single location to meet storage capacity needs, and tanks can be distributed around the airport to serve multiple deicing locations. Additional tanks can be brought in on relatively short notice if additional capacity is required.

Regulatory Considerations

Frac tanks themselves are not regulated since they are not designed for fluid transport. However, because frac tanks may be used to store a variety of materials, including hazardous materials, the cleaning of the tanks is regulated according to the product that has been contained within the tank. Some frac tank rental companies will require an SDS for the material stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that were stored within.

In some instances, secondary containment may be required to prevent spills from entering stormwater systems.

Placement of frac tanks on the airfield must be in compliance with all applicable FAA regulations.

Planning and Design Considerations

The following factors should be considered when planning for the use of frac tanks for storage of deicer-laden stormwater runoff:

- Location of the tanks near the deicing area to simplify transfer into the tanks and minimize transport costs.
- Ease of transfer from the tanks to tankers for treatment or disposal.
- Assurance that the location of the frac tanks does not violate FAR Part 77 imaginary surfaces. (A landside location may be preferable to an airside location for easier tank delivery/removal and tanker transfer.)
- Close coordination with the airport operations department to ensure that the location of the tanks does not affect other airfield operations.
- Provision of a level surface to take advantage of the full 21,000-gallon storage capacity. (Gravel or other material may be required to stabilize the surface.)
- Advance coordination with the frac tank company well before the tanks are needed onsite to ensure availability. (Better rates are often available for long-term rentals, i.e., those longer than 4 months.)

Integration with Other Practices

Portable frac tanks offer great flexibility in placement, being small enough to locate around apron areas for short-term storage of runoff collected by glycol collection vehicles or block-and-pump systems. Frac tanks may also be used as a temporary storage option while permanent tanks are being constructed or undergoing maintenance activities or until the runoff can be transported for disposal.

Operation and Maintenance Considerations

Maintenance requirements are primarily associated with tank cleanout prior to movement at the end of a lease term. Some manufacturers or providers offer cleaning as a service included with the rental agreement. In this case, maintenance on a rented frac tank is negligible.

Frac tanks are not meant for transporting liquids and should be moved only when empty.

3. Costs

Although they can be purchased, frac tanks are generally procured as rented facilities.

Capital Costs

Frac tanks are not typically purchased, and therefore are not normally classified as a capital cost. Permanent, aboveground storage tanks (not frac tanks) are recommended for long-term storage, so frac tank purchase costs are not provided here.

Frac tanks are typically rented because they are used for temporary storage. As such, they can be leased for whatever time period they're needed. However, the best rates are obtained when tanks are rented for at least 4 months. Typical rental fees are provided in Table 1.

Operations and Maintenance Costs

Frac tanks require little in terms of operations and maintenance. However, one potential cost is cleaning the tanks upon completion of their use. Frac tank manufacturers require that the tanks be returned clean and will charge a nominal fee for cleaning the tanks themselves or will require analytical results indicating that the tanks have been cleaned of the materials that were stored within them. Typical frac tank rental and cleaning fees are shown in Table 1 although fees will vary per location and may differ from what is shown.

Table 1. Typical frac tank rental fees.

Fee	Typical Range
Daily	\$30/day
Monthly	\$900/mo
Long-term	Up to 10% discount after approximately 6 months
Hauling	\$400 for delivery and pickup though will vary by location
Cleaning	\$1,500 – \$2,000

Note: Costs reflect prices as of 2017.

FACT SHEET 28

Modular Tanks

1. Description

Purpose

This practice provides a temporary or semi-permanent means of storing deicer-laden stormwater runoff prior to its processing or transport.

Technology

Modular tanks are typically constructed of metal frames with membrane liners and floating covers. They can be purchased or leased and configured in a variety of shapes and sizes to suit the needs of the specific application. Modular tanks are a relatively economical, semi-permanent solution to storing deicer-laden runoff that can be procured and installed in a relatively short period of time. Tanks vary in size from hundreds of gallons up to 2 million gallons and are available in square, rectangular, or circular configurations. Square and rectangular tanks are offered in sizes up to 2 million gallons with wall heights of 4 feet, 9 inches or 6 feet, whereas circular tanks are generally limited to a wall height of 30 feet and 1 million gallons.

Typical modular tank. (Courtesy of Modutank, Inc.)

Documented Performance

Modular tanks have been used successfully for a wide variety of storage applications for many years. As with frac tanks (see Fact Sheet 27), their use dates back to the earliest deicing pads established in the early 1990s. Compared to permanent tanks, they can be procured and assembled in a relatively short time period.

2. Implementation Considerations

Applicability Assessment

Storage using modular tanks is employed where deicing storage is needed, and permanent tanks may not be an available option for budget or height restriction reasons. Modular tanks are often viewed as an interim step before permanent tanks can be programmed in a capital plan and implemented.

Regulatory Considerations

Modular tanks are typically constructed with double membrane liners and may be equipped with leak detection. The cleaning of the modular tanks is regulated according to the product that has been contained within the tank. Annual cleaning may be required, based on the disposition of the deicer-laden runoff, and may require a safety data sheet (SDS) for the material that was stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that were stored within.

In lieu of double liners in a single modular tank, two single-liner tanks may be nested one within the other and still comply with primary and secondary containment requirements.

Placement of modular tanks on the airfield must be in compliance with all applicable FAA regulations.

Planning and Design Considerations

The following factors should be examined when considering the use of modular tanks to store deicer-laden runoff:

- Need for the modular tanks to be located near the deicing area(s) to minimize transport costs.
- Ease of transfer from the tanks to the onsite processing facility or tankers for offsite treatment or disposal.
- Assurance that the location for the modular tank(s) does not violate FAR Part 77 imaginary surfaces. (A landside location may be preferable to an airside location for easier tank delivery/removal and tanker transfer.)
- Need for a level surface to place the modular tank on so that full storage capacity can be taken advantage of.
- Need for a sand or felt layer under the secondary liner to protect the liners from puncture.
- Fact that water may accumulate on the floating covers of these tanks, thus possibility attracting waterfowl.
- Prevailing wind direction and proximity to occupied buildings because odors from stored deicer-laden runoff may be an issue.
- Stainless steel bolts, nuts, and washers should be specified to aid in annual maintenance and inspection.
- Weight adequate to hold down the liners prior to the tank being filled with fluid. (Strong winds may float the liners out of place and potentially damage them.)

Typical modular tank construction.

Integration with Other Practices

Modular tanks offer great flexibility in placement, being flexible enough to configure around apron areas for short-term storage of runoff collected by glycol collection vehicles (see Fact Sheet 23) or block-and-pump systems (Fact Sheet 24). Modular tanks may also be used as storage while other, permanent tanks are being constructed or undergoing maintenance.

Operation and Maintenance Considerations

Maintenance should be performed at least annually for the modular tank components and more frequently for the floating cover and liners. The steel components should be inspected annually for corrosion or sharp edges that may abrade or puncture the liner. The liners and floating cover should be inspected annually for leaks, punctures, or tears. Water accumulating on the surface of the tanks may be pumped off and disposed of as stormwater assuming an analytical test is conducted that confirms that the water is free of deicer-laden runoff.

3. Costs

Modular tanks may be purchased for long-term use or leased for shorter-term use. The costs vary with the size of the tank, and also with the options chosen for the tank.

Capital Costs

Modular tanks are available with different liner materials and different hardware types (galvanized vs. stainless steel), etc. Typical purchase prices, excluding assembly and site preparation, are shown in Table 1.

Table 1. Typical modular tank purchase fees.

Size (gal.)	Typical Cost* ($)
50,000	$30,000
100,000	$40,000
220,000	$88,000
320,000	$90,000
500,000	$108,000
1,000,000	$127,000
2,000,000	$208,000

*Excluding shipping, site preparation, and installation, which could be significant (more than 10% of tank cost) depending on the facility location and site conditions.
Costs reflect prices as of 2017.

Operations and Maintenance Costs

Modular tank components should be inspected annually for repair or replacement. The liners are the most important component of the modular tanks, and they may need to be replaced every 3 to 5 years on average, possibly more frequently. There are costs associated with the annual inspection and cleaning; however, these would vary greatly with tank size. Once these tanks are erected, the operational costs are relatively low, primarily involving monitoring of any tank valves and fluid levels during periods of active filling or discharge.

FACT SHEET 29

Basins

1. Description

Purpose

This fact sheet describes basins whose primary function is to provide temporary onsite storage of collected deicing stormwater for subsequent release to onsite treatment, glycol recovery, sanitary sewer, or surface water in accordance with permit limitations. While the basins described here may provide small amounts of ancillary treatment, that is not their primary function. In some cases, these facilities also serve as non-deicing stormwater quantity and quality controls or secondary containment for oil spills to facilitate compliance with 40 CFR part 112.

Technology

Basins (alternatively called ponds or lagoons) provide a method for storing deicing runoff prior to treatment, glycol recovery, sanitary sewer discharge, or surface water discharge. Basins are formed by shaping and compacting soils to create embankments that contain stormwater. Often basin floors are slightly sloped for drainage. Basin side walls have slopes typically ranging from 1:1 (steep include) to 4:1(lower incline). The floors and side slopes of basins intended for storage of deicer-impacted stormwater may be vegetated, but, in most cases, are lined with a geomembrane to prevent contamination of groundwater from the collected stormwater and to prevent groundwater from entering the basin and taking up storage volume. When basins are lined, it is often necessary to have a drainage system below the liner to prevent hydrostatic groundwater pressures from applying upward pressure on the liner. Basins may contain covers made of synthetic materials similar to the liners, for the purposes of reducing attraction of hazardous wildlife and odors. Basins can have various types of inlet and outlet structures for incoming and discharged flows.

Although the primary function of basins in deicer management systems is temporary detention of deicing runoff to absorb high volumes of runoff and discharge flow at an attenuated rate, if designed appropriately, basins can also provide the benefits of solids settling and some degree of equalization of deicer concentration. Basins may also provide small amounts of incidental degradation of glycol-containing deicing materials.

Documented Performance

There is no performance metric to reflect storage. Achieving performance targets for storage are largely a function of appropriate sizing the basin volume. Basins that are engineered to treat deicers through bacterial degradation are more properly classified as aerated lagoons (see Fact Sheet 115). Effective treatment in a basin requires aeration, addition of nutrients, and control of influent discharges. While it has been a common practice to add aerators to basins in an attempt to achieve treatment, without control of loadings and addition of nutrients, aeration alone has virtually no effect on degradation because the bacteria do not have the materials they need to grow and reproduce. Aerators can help reduce the likelihood that the basin will turn anaerobic and may be able to inhibit odor production, although the effectiveness of this technique depends upon the relative extent of aeration and deicer loads in the basin. Seeking to obtain treatment without aeration is also not effective because anaerobic treatment is ineffective at the temperatures typically experienced in winter.

Attempting to achieve treatment in a basin without proper control can also create unintentional consequences such as creation of biofilms that can extend to the stream and become "nuisance growths"; accumulation of biological solids in the basin that need removal; and creation of bacteria types that negatively affect controlled biological treatment farther downstream.

2. Implementation Considerations

Applicability Assessment

Basins are often considered by airports because they generally represent the most cost-effective means of storage available. There are, however, potential constraints to be evaluated.

Basins offer the following advantages:

- Generally, represent the least costly alternative for storage of large volumes of stormwater.
- Generally, do not pose the height restriction concerns that may be encountered with aboveground tanks, although this will depend on berm height and basin location relative to the aircraft operating area.
- The storage capacity of a basin can often be increased less expensively than can other types of storage.
- Storage basins can often be constructed more quickly than storage structures made of concrete, steel, or other solid materials.
- May also be used to meet 40 CFR part 112 Spill Prevention Control and Countermeasure or local non-deicing stormwater quality or quantity management requirements.

Potential constraints related to basins include the following:

- If basins are constructed in areas of high water tables, an extensive drainage system below basin liners may be necessary to keep liners from floating or being damaged. Gravity-based drainage systems are preferred, but in some instances pumps may be necessary. Local hydrogeologic conditions should be carefully evaluated before designing the drainage system.
- Liners may be subject to uplift from wind and may therefore require anchoring and ballast. Only ballasts that can be moved should be considered.

- Basins where stormwater is held for extended periods may experience significant odor problems from the anaerobic degradation of deicing compounds. Aeration may help reduce odors, although determining the proper amount of aeration to avoid odors can be challenging.
- Uncovered basins may expose collected deicing stormwater to local surface runoff, sediment, and debris, which could interfere with treatment operations.
- Drainage layers (e.g., geocomposites), sometimes installed in conjunction with leak detection systems, below the liner may be required to capture any leakage from the basin.
- Uncovered basins may present a wildlife attraction hazard, especially when constructed close to the airfield. Floating covers or other mitigation measures may be required to satisfy FAA requirements. Covers that have the appearance of open water, such as black floating covers, may still attract wildlife and may require camouflaging. For more information about siting and basin design to minimize bird attractiveness, see *ACRP Report 125: Balancing Airport Stormwater and Bird Hazard Management*.

Other issues with basins that should be considered:

- Basins typically require a significantly larger footprint than other storage options, which may restrict potential locations.
- It is often more difficult to efficiently mix the contents of a basin than the contents of a storage tank.
- Synthetic liners can be subject to damage from equipment and animals, necessitating repairs.
- Over time, the integrity of liners and their seams may degrade with exposure to the sun and with ongoing expansion and contraction associated with temperature fluctuation.
- Locating a basin in an area with a high groundwater table or numerous high-yield sand seams can make construction and operation difficult due to dewatering requirements.

Regulatory Considerations

FAA Advisory Circular 150/5200-33, *Hazardous Wildlife Attractants on or Near Airports*, provides guidance on placement and design of stormwater detention basins near airfields. Basins may require a permit-to-install or a construction permit in some states. In many states, a dam permit is required if the basin berms are certain heights above the lowest local discharge route. Compliance with groundwater regulations (including separation distance from groundwater) should be carefully evaluated before design and construction activities occur.

Planning and Design Considerations

Basin design needs to be site-specific, with special consideration given to the proximity to aircraft operating areas, wildlife deterrence, odor generation and control, solids removal, lining, geotechnical soil characteristics, and groundwater dewatering.

The following factors should be considered in basin design:

- Determining the appropriate volume of storage is the most critical design consideration. A variety of techniques can be used to determine storage, but all involve understanding influent flow rate ranges and discharge rates. Using storm "design events" based intensity-duration-frequency curves is typically not effective for sizing deicer storage basins because those methods do not consider the variation of deicing conditions. In systems with onsite treatment, cost savings may be achieved by finding a balance between storage volume and treatment capacity.
- Site geotechnical and hydrogeological characteristics must be determined through soil borings, soil testing, well installation, and potentially groundwater pump tests. This information is needed to appropriately design embankments and the groundwater drainage system.
- Specialized outfall structures may be required to control the rate of discharge more precisely and consistently than would be required for an ordinary stormwater basin.
- Mixing of the basin contents can help equalize deicer concentrations, prevent stratification of water in the basin, and help reduce odors. Mixing of basins is most effectively done through floating units. Because of their shape, however, it is typically more difficult to achieve uniform mixing in a basin than in a storage tank.
- The basin floor should be appropriately sloped to facilitate drainage and solids removal during maintenance.
- A means of access for staff and (potentially) vehicles should be provided for maintenance.

Integration with Other Practices

Storage is often a central component in an airport's overall deicing runoff management strategy, bridging the gap between collection and disposal by detaining collected deicing stormwater until it can be discharged to a glycol recovery system, onsite or offsite treatment, or surface water. Basins can also play a role in an airport's overall stormwater management system, providing flow attenuation and water quality benefits to stormwater during non-deicing periods.

Operation and Maintenance Considerations

Operational and maintenance requirements will vary from minimal to significant, depending on the site, basin design, and integration with treatment operations. Operational requirements may include the operation of gates, pumps, mixers, valves, aerators, and monitoring equipment, depending on the specifics of the facility.

Most basins will require periodic sediment and debris removal and maintenance of basin vegetation. Basins with a geosynthetic liner may require occasional repairs. Associated mechanical equipment will also require routine and preventative maintenance. Removal and replacement of basin covers for inspection and maintenance can be a labor-intensive operation.

3. Costs

Overall costs associated with basins will vary by individual airport site, depending on the design features selected. In general, basins have lower capital and annual costs relative to other storage options (e.g., underground detention and aboveground storage tanks).

Capital Costs

Capital costs for basins include earthwork, liners, drainage fabric, drainage piping and pumping, inlet structures, outlet structures, covers, and potentially monitoring equipment. Basin costs may significantly increase if designs incorporate control systems with associated mechanical equipment, including pumps, aerators, mixers, and monitoring equipment.

Cost for a 6 million gallon basin in 2017 would be about $0.26/gal, including influent and effluent piping, but excluding any pump stations that may be required. Addition of a subdrainage layer and a cover would increase cost to about $0.47/gal. Cost per gallon may be more for a smaller basin and less for a larger basin. These costs exclude land, which may be significant.

Operations and Maintenance Costs

Operational costs associated with basins are relatively minor as they typically do not require day-to-day attention. Maintenance costs can include sediment removal, liner repairs, and maintenance of mechanical equipment. If the basins are aerated, additional costs will be associated with power consumption by aerators.

FACT SHEET 30

Permanent Tanks

1. Description

Purpose

This practice provides a means of storing deicer-laden stormwater runoff in permanent aboveground or underground storage tanks.

Technology

The design of permanent tanks follows conventional tank design principles, and sizes vary from thousands of gallons to multi-million-gallon tanks. They typically offer long-term solutions for higher-strength deicer-laden runoff destined for onsite or offsite treatment or recycling. Permanent tanks can be constructed of concrete, steel, or fiberglass in square, rectangular, or circular configurations with varying wall heights.

Documented Performance

Storage in permanent tanks offers a number of advantages. They offer a smaller footprint and longer life span compared to basin storage. Provisions for mixing can be incorporated to provide concentration uniformity and minimize solid deposits. Odor problems are significantly less of an issue with permanent tanks than with open basins or ponds. Finally, permanent tanks do not present a wildlife attractant problem.

2. Implementation Considerations

Applicability Assessment

Storage tanks are typically required for flow balancing and uniformity of deicing agent concentrations. Permanent tanks are used where there are higher-strength deicing agents that go on to be treated or recycled. Considerations of budget and height restrictions are key in assessing whether to implement permanent tanks or modular or frac tanks, or even a pond or basin. Permanent concrete tanks can be aboveground or underground.

Regulatory Considerations

Leak detection and cleaning are the primary concerns related to permanent storage tank regulations. Generally speaking, state regulations are more stringent when it comes to aboveground and underground storage tanks requirements, regardless of the agent. Title 40 of the Code of Federal Regulations governs and establishes minimum environmental protection standards. Permanent steel tanks are typically fabricated with double walls and are equipped with leak detection systems. The cleaning of the tanks is regulated according to the product that has been stored within the tank. Annual cleaning may be required, based on the disposition of the deicer-laden runoff, and may require a material safety data sheet for the material that was stored as well as analytical results to certify that the tank is fully cleaned and free of the materials that had been stored.

Planning and Design Considerations

The following issues should be examined when considering the use of permanent tanks to store deicer-laden runoff:

- Land availability and suitability.
- Compliance with height restrictions under FAR Part 77 imaginary surfaces (aboveground tanks).
- Geotechnical suitability, especially for larger tanks and in areas with greater risk of seismic activity.
- Accurate sizing.
- Accessibility for future cleaning and removal of solids.
- Costs.

Integration with Other Practices

Permanent tanks are implemented as part of a glycol collection system, which typically incorporates a number of other practices from source reduction to containment and collection and to treatment and disposal.

Operation and Maintenance Considerations

Permanent storage tanks generally have lower maintenance requirements than ponds or basins. Cleaning and maintenance should be performed at least annually for the tank and its components. For concrete tanks, appropriate coatings should be applied and maintained to guard against degradation by pH levels that can result from long-term storage of deicing runoff, especially in the summer. Steel components as well as leak detection system components should be inspected annually.

3. Costs

Permanent tanks are the most costly form of nonportable storage. The costs vary with the size of the tank, and also with the materials (concrete, steel, or fiberglass) and options chosen for the tank.

Capital Costs

Permanent tank prices vary widely based on the size and materials. Steel tanks generally have a lower construction cost compared to tanks constructed of other materials. Tables 1 and 2 provide some basic guidance on unit costs for different permanent tank configurations.

Table 1. Aboveground storage tank capital costs.

Size (gal.)	Typical Cost ($/gal.)
250,000	1.80–2.50
500,000	1.50–2.20
1,000,000	1.20–1.85
2,000,000	1.00–1.25
4,000,000	0.80–1.00

Note: Costs in 2018 dollars are for the tank and a shallow foundation; exclude pumps, piping, design costs, etc.

Table 2. Underground storage tank capital costs.

Size (gal.)	Typical Cost ($/gal.)
3,000–10,000	3.00–5.00
10,000–50,000	2.40–3.00
50,000–100,000	1.80–2.60
100,000–1,000,000	1.10–2.10
1,000,000–4,000,000	0.73–1.40
4,000,000–8,000,000	0.60–1.10
>8,000,000	0.50–0.90

Note: Costs in 2018 dollars and exclude pumps, piping, design costs, etc.

Operations and Maintenance Costs

Operations and maintenance costs associated with permanent tanks include annual inspection, cleaning, and solids removal. These costs vary greatly based on the size of the tank. Although steel tanks typically have a lower construction cost, they have higher operating costs associated with inspection and maintenance of the coating system (paint).

FACT SHEET 31

Manual and Automated Diversion Valves

1. Description

Purpose

This practice provides controlled routing of deicing stormwater flows for the purpose of facilitating more effective and efficient collection, storage, treatment, and discharges. Diversion valves may be automatic or manual.

Technology

Diversion valves provide flexibility in managing stormwater with varying deicer concentrations. Diversion valves may be used to direct stormwater to one of several destinations, including treatment, storage, or discharge. Installations vary in complexity from manually operated valves to automated diversion systems that operate based on real-time monitoring.

Manual diversion valves are typically operated based on deicing conditions or weather observations (e.g., diversion to storage during deicing events and to surface water between events). Automated valves may allow flows to be managed more precisely during deicing events. These valves may be actuated by a supervisory control and data acquisition (SCADA) system, which may make diversion decisions based on online monitoring or management system information.

Several valve types are suitable for use in deicing runoff containment systems. In general, resilient gate valves or plug valves are preferred. Slide gates are often used to manage diversion in open channels or larger pipes. Ultimately, any valve used for deicing runoff must have zero leakage and be chemically compatible.

Documented Performance

Although data on the performance of diversion valves alone have not been collected, a number of airports have implemented successful apron collection systems with manual and automated diversion valves. These airports include, but are not limited to, Portland International Airport, Detroit Metropolitan Wayne County Airport, Baltimore Washington International Thurgood Marshall Airport, Ted Stevens Anchorage International Airport, Seattle Tacoma International Airport, Dallas/Ft. Worth International Airport, T.F. Green Airport, John Glenn Columbus International Airport, and Nashville International Airport.

2. Implementation Considerations

Applicability Assessment

Although most airports will have some form of diversion valve for deicing stormwater management purposes, the appropriate type of valve may vary depending on the application. The variability of concentrations in the flows, as well as storage, treatment, and operational requirements, are major considerations in deciding upon the level of complexity for diversion systems.

Advantages of automated valves include the following:

- Reduced manpower requirements for valve operation;
- Ability to be integrated into a SCADA system in conjunction with online monitoring for automatic, real-time diversion decisions and centralized operation of diversions throughout the system; and
- Improved National Pollutant Discharge Elimination System (NPDES) permit compliance by reducing the chance for human error and improving the precision of diversion decisions.

Advantages of manual valves include the following:

- Lower costs for valves and overall diversion systems;
- Retrofitting into existing storm sewer systems may be easier; and
- Simpler operation and maintenance.

Simple, manual diversion systems are appropriate for airports with relatively simple deicer management systems that are operated infrequently or do not require changes often, and airports that collect and discharge all deicing runoff to a single destination.

More sophisticated and costly automated approaches may be justified at airports with management systems where operation can be optimized using concentration-based flow segregation. Automatic valves are often used in applications requiring frequent diversion.

Regulatory Considerations

If diversion valves are central to environmental compliance, operating conditions for collection or surface water discharge should be approved by regulators and incorporated into an airport's NPDES (or equivalent) surface water discharge permit. Permit conditions may stipulate valve locations, threshold concentrations for collection or discharge, operation schedule, valve operation protocols, and emergency upset conditions for valve operation.

Planning and Design Considerations

The following factors should be considered in planning and implementation of manual or automated diversion valves:

- Diversion locations should be carefully selected with regard to collection efficiency, potential dilution, and integration with other system components such as online monitoring.

- The selection of appropriate threshold concentrations for concentration-based diversion is essential to success.
- The complexity of the diversion valve system should be matched to the airport's application, and the design of the diversion system should be coordinated with the overall deicing management system to optimize benefits.
- When selecting a valve type, airports should consider operation and maintenance, as well as cost. Key considerations for valve selection should include suitability for the application, reliability, and resistance to clogging and corrosion.
- Vaults containing diversion valves should be protected from water intrusion, which may require sump pumps.

Integration with Other Practices

Diversion valve operation is typically integrated with a variety of practices. Valves can be used to divert flows to storage units, treatment systems, glycol recovery systems, or discharges to surface water or a sanitary sewer. If automated, valves may be tied into an overall deicer management control system. Control systems or airport personnel may use information from online monitoring or sampling, as well as storage and treatment system data, to make diversion decisions that comply with effluent limits.

Operation and Maintenance Considerations

Manual diversion valve systems are relatively straightforward to operate; however, they may require significant manpower, especially if the valves are operated frequently. They are also less precise in controlling flows than automated systems and may result in larger volumes of water being stored and treated than would be the case with automated systems. Manual valves should be installed such that they can be operated easily by one person during the deicing season, without interfering with airport operations. Manual valve operating procedures may require only that valves at deicing areas be diverted toward onsite storage or treatment prior to the start of a deicing event. More complex manual systems may divert flows to different destinations, depending on deicing and monitoring observations.

Automated diversion valve systems generally require less manpower to operate than manual systems. Personnel are still required to occasionally remotely monitor and verify automated monitoring results and diversion decisions. Automated diversion systems can provide a factor of safety by ensuring the proper operation of the diversion system when it is not normally staffed by an operator. Operating costs can be reduced if this automation enhances the ability of personnel to multitask and attend to other components of the deicer management system.

Effective performance of this practice requires that the valves and valve structures be maintained regularly. In general, regular inspections are required to verify functionality and to remove debris or address other potential hazards. Maintenance of automated systems may be more complex if it also involves the maintenance of integrated practices.

3. Costs

Overall costs associated with manual diversion valve systems are low compared to those of automated diversion valve systems. Diversion valve costs include the valves themselves, additional practices and infrastructure, and costs to operate the valves manually or automatically.

Capital Costs

Capital costs include the valves themselves, in addition to associated equipment and infrastructure, including diversion structures, piping, online monitoring equipment, and PLCs. Capital costs may vary significantly depending on the type of valve, valve actuation, and valve size. Available data suggest that cost may fall within the range of $5,000–$100,000 per valve.

Operations and Maintenance Costs

Annual costs include wages for personnel to operate and inspect the diversion valves, as well as maintenance costs for cleaning and repairing the valves and diversion structures.

Source Reduction
Containment/Collection
→ **SYSTEM COMPONENTS**
Treatment/Recycling

FACT SHEET 32

Online Monitoring Technology

1. Description

Purpose

This practice provides the opportunity to more precisely manage aircraft and airfield deicers in runoff through online monitoring of key water quality constituents that reflect deicer content. This capability may be employed to selectively route stormwater to different destinations based on concentration ranges, track loads, and concentrations in stormwater discharges to publicly owned treatment works (POTWs) and surface waters to meet concentration or load limits and manage operation of onsite treatment or glycol recovery.

Technology

Online monitors are permanently mounted devices designed to both sample flow streams and analyze the samples on a regular basis without direct involvement of facility staff (see *ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials*). Online monitoring provides a distinct advantage over more traditional manual sample collection and laboratory analysis in that it enables the airport to make decisions based on real-time data instead of waiting hours or even a week for a 5-day Biochemical Oxygen Demand test. Online monitoring also negates the need for an operator to be present for conduct monitoring.

Online monitoring provides near instantaneous measurement of water quality, reduces the error associated with characterizing and managing continuous discharges based on a series of discrete measurements, and reduces the risk of missing high-concentration, low-duration spikes of deicer concentrations that may occur in the runoff. Online monitoring can facilitate automatic diversion of stormwater runoff, changes to treatment or glycol recovery plant operation, or adjustments to flow rates of discharge if used in conjunction with automated valves or pumps. Table 1 lists the types of analytical methods available on online monitors. Note that there are no online monitoring methods that directly measure primary deicer constituents (glycol, formate, or acetate). Each of these analytical methods measures a surrogate parameter that is analogous to a laboratory-measured parameter.

For more information on selecting the appropriate monitoring type and online monitoring technologies see *ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials.*

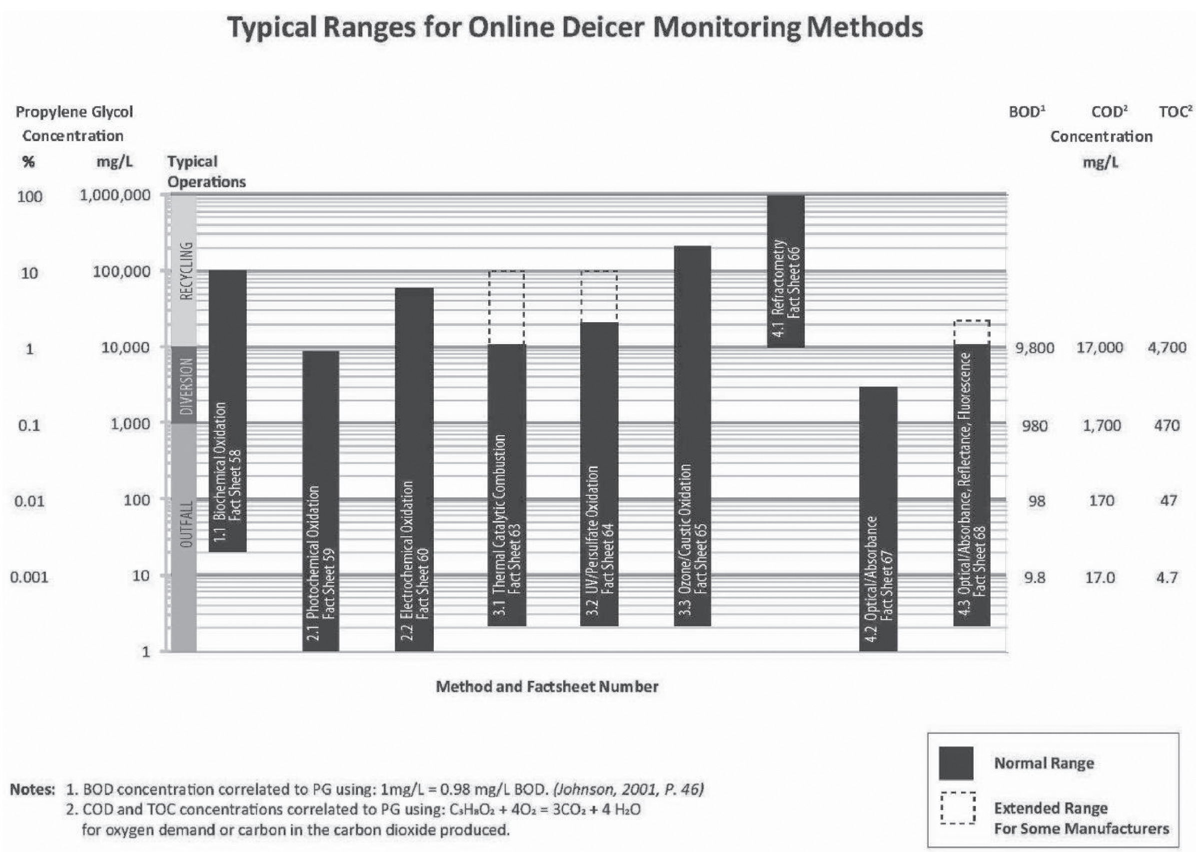
Documented Performance

The most appropriate performance metrics for this technology are detection limit and range. Figure 1 provides typical ranges on the most common online monitoring technologies used for measuring aircraft deicer.

Table 1. Commonly used analytical methods available on online monitors.*

Parameter	Analytical Method	ACRP Report 72 Fact Sheet #	Example Airports That Have Used Technology (Current or Past)
Biochemical Oxygen Demand (BOD)	Biochemical oxidation	58	PDX, CLE, YYZ, MCI
Chemical Oxygen Demand (COD)	Photochemical oxidation	59	
	Electrochemical oxidation	60	
Total Organic Carbon (TOC)	Thermal catalytic combustion	63	YYZ, PHL, LEX, BUF, PVD
	UV/persulfate oxidation	64	CMH, YYZ
	UV/ozone oxidation	65	DFW, AMS, SEA, PDX, BNA, CVG, DUB
BOD/COD/TOC by correlation	Refractometry	66	BGR, MSP
	Optical/absorbance	67	PHL, AMS
	Optical/absorbance, reflectance, and fluorescence	68	
Ammonia as Nitrogen (NH_3-N)	Colorimetric	71	
	Ultraviolet/absorbance	72	
	Ammonia selective electrode	73	BUF

**ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials*



Source: *ACRP Research Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials*, second edition.

Figure 1. Typical ranges for online deicer monitoring methods.

2. Implementation Considerations

Applicability Assessment

Several aspects of the application should be evaluated and understood when online monitoring technologies are being considered. First, is real-time monitoring the appropriate monitoring method. The need for real-time monitoring is typically driven by highly variable deicer concentrations over relatively short timeframes (minutes to hours) and the need to selectively manage flows at a similarly fine scale. This ability to divert flow continuously can significantly reduce stormwater storage volume as well as treatment costs and enhance glycol recovery programs.

Second, once it has been determined that online monitoring is needed, consideration should be given to the specifics of the intended application, including the intended target parameter(s) (COD, TOC, etc.), the expected operational range of runoff concentration(s), the location(s) where monitoring is to be conducted, and the availability of staff to maintain the instrumentation.

Third, the physical constraints of the site should be considered to ensure the technology is a realistic option. In most cases, infrastructure will be required, including a shelter structure and utilities (electricity, water, communications). The specifics will depend on the nature of the implementation.

Fourth, it is important to note that rigorous quality control, like analysis of spiked samples to check for interferences and calibration checks, which are generally performed for laboratory analysis, are not typically performed with online monitoring. Online monitors are generally more complex to operate and troubleshoot than handheld monitors or test kits. Trained personnel are required to calibrate and maintain the sensors to achieve accurate, reliable results.

For more information on selecting the appropriate monitoring type and method, see *ACRP Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials.*

Regulatory Considerations

It should be noted that use of this technology for compliance monitoring requires obtaining formal acceptance by the regulatory agency. Many regulatory personnel may be unfamiliar with this technology and obtaining their explicit acceptance can be a very expensive and time-consuming process. For more information on regulatory considerations related to monitoring see *ACRP Report 166: Interpreting Airport Water Monitoring Results.*

Planning and Design Considerations

The following factors should be considered in planning for online monitoring:

- While online monitoring typically requires less labor than manual sample collection or onsite monitoring, the costs of online monitoring can be significant. It is important to consider the purpose and need for online monitoring prior to making the investment.
- The capabilities of the technology should be matched to the data needs in terms of parameter, concentration range, precision, and accuracy.

- Installations require protective housing and utilities; including power, potable water, and communications, in a location that is readily accessible for routine maintenance.
- Use for compliance monitoring requires regulator acceptance.
- When utilizing for biological treatment system effluent, the effects of the treatment process on stormwater should be considered. Organic compounds remaining in stormwater after biological treatment are often not as biodegradable as those in the influent to a biological treatment process. This may result in a different correlation between BOD/COD/TOC and glycol for the effluent measurements.

For more guidance on online monitoring see *ACRP Research Report 72: Guidebook for Selecting Methods to Monitor Airport and Aircraft Deicing Materials,* second edition.

Integration with Other Practices

Online monitoring technology is always implemented as part of an integrated deicing runoff practice system. Most commonly, it is used in combination with an automated control system and motorized diversion valves or pumps to allow continuous stormwater segregation by concentration, operation of a treatment system, or automated discharge to a publicly owned treatment plant or surface water in the absence of an operator.

Operation and Maintenance Considerations

Proper operation and maintenance is essential for this technology to be effective and reliable. Requirements include the following:

- The instrumentation is sophisticated and requires a trained operator to provide routine maintenance and care to ensure consistent and accurate readings.
- Operation of the equipment is within clearly defined conditions and ranges.

3. Costs

Capital Costs

Online monitors can measure a wide range of concentrations but are relatively expensive, with installed costs in 2017 ranging between $50,000 and $200,000 per unit, which includes enclosures, utilities, and other supporting equipment. A single monitor can sample multiple sample streams, which may decrease the effective capital cost.

Operations and Maintenance Costs

These technologies are relatively sophisticated and require regular maintenance, calibration, and troubleshooting by operators to ensure accuracy and reliability. The costs for training and maintenance will depend on the type of sensor and the level of training required for the individual maintaining the system.

FACT SHEET 33

Catch Basin Inserts/Valves

1. Description

Purpose

This practice provides a means of intercepting deicing stormwater before it can enter the storm sewer system and facilitating collection by glycol collection vehicles.

Technology

Catch basin inserts provide a physical barrier for containing deicing stormwater on the surface of the apron to allow time for collection or for testing prior to its release. Inserts are typically installed in catch basins that receive surface drainage from aircraft deicing areas and are capable of being readily closed prior to the start of the deicing event and opened subsequently to allow clean runoff to enter the storm sewer system.

Different types of physical barriers are available. The simplest method consists of a molded plastic drop-in panel with a depression in the bottom that serves as a sump. These have limited practicality because they require that the storm grate be lifted to install or remove the barrier. A more sophisticated and practical approach employs a metal sump installed under a catch basin grate and fitted with a butterfly valve that can be operated with a T-handle from the surface (Figure 1).

Inserts typically remain closed during the deicing event, although many operators keep them closed longer to prevent dry weather discharges of deicer. Depending on test results, the stormwater may then be released to the storm sewer or collected by a glycol recovery vehicle or vacuum truck.

Documented Performance

The performance of catch basin inserts for preventing the discharge of deicing stormwater depends largely on the effective operation of the stoppers or valves and the integrity of the water-tight seal. The integrity of the catch basin structure beyond the insert needs to be assessed prior to implementation. Some airports have reported that catch basins leak if not properly sealed or maintained, and that maintaining seals that are exposed to sand and other debris can be problematic. In addition, any system that promotes ponding on the apron surface requires that pavement joints be sealed to prevent infiltration under the increased head (Switzenbaum et al. 1999). Performance is also affected by how quickly fluids can be collected from the surface.

Figure 1. Butterfly valve with T-handle.

2. Implementation Considerations

Applicability Assessment

Catch basin inserts are beneficial for use with a glycol recovery program employing glycol collection vehicles. They allow the collection of deicing stormwater near the source, before it enters the storm sewer. This approach has the potential to minimize the overall volume of deicing stormwater that must be managed. They are also effective in preventing the unauthorized discharge of deicers under dry weather conditions (frost, for example).

The following factors should be considered when deciding whether catch basin inserts are appropriate and applicable for an airport deicing stormwater management system:

- Operation and inspection of catch basin inserts, as well as glycol recovery activities, may require dedicated operators.
- Catch basin inserts must be custom-fabricated for individual catch basins, and cost varies with catch basin size.
- Catch basins need to be accessible by collection vehicles without interfering with airport operations.
- Catch basin inserts and glycol recovery activities may result in the following situations, which could significantly interfere with airport safety and/or operations:
  - Potentially dangerous ponding during heavy precipitation if catch basin insert drains or valves are left closed.
  - Added vehicular traffic in congested gate areas.
- The effectiveness of catch basin inserts and glycol recovery activities may be limited by the following airport characteristics:
  - Irregular ground surfaces, which may prevent effective collection.
  - Cracks or joints in pavement and catch basins, which could allow leaks to the stormwater drainage system.
  - Aircraft deicing areas with drainage areas that are large or not well-defined.
  - Exposure of catch basins to debris, including sand and gravel.

Note: It is important to perform regular inspections to verify that catch basin inserts are operating properly.

Regulatory Considerations

Installation and operation of catch basin inserts must be performed in compliance with FAA regulations. Ponding has the potential to interfere with airport and aircraft operations, and FAA Advisory Circular 150/5320-5C, *Surface Drainage,* recommends that ponding above apron catch basin inlets be limited to a depth of 4 inches. Standard operating procedures should include upset conditions for opening valves when hazardous flooding occurs.

Planning and Design Considerations

The following factors should be considered by airports in planning the implementation of catch basin inserts:

- Appropriate locations for inserts or valves, including the likelihood or impact of ponding at those locations;
- Appropriate level of complexity for catch basin inserts;
- Inserts or valves must be sized to allow peak flows to pass without unacceptable flooding;
- Standard procedures and protocols for preparation, inspection/monitoring, operation, and maintenance of the catch basin inserts, including threshold concentrations and upset conditions associated with hazardous flooding;
- Time and staffing required to operate inserts/valves and to collect ponded deicing stormwater at each installation;
- Accessibility of catch basin insert locations by glycol recovery vehicles or vacuum trucks; and
- Plan to address potential leak points, including cracks in pavement or within drainage infrastructure.

Integration with Other Practices

Most commonly, catch basin inserts are installed in designated deicing areas and operated in conjunction with collection vehicles, which collect the deicing stormwater that ponds above the inserts during deicing events. Catch basin inserts may also be used for controlling deicer-laden snowmelt runoff or for applications where the management of runoff is facilitated by keeping it out of the storm sewer system.

Operation and Maintenance Considerations

Operational requirements associated with catch basin valve inserts include manual operation of the valves, periodic testing of the ponded stormwater, and tracking of the status of inserts during the deicing season. Maintenance tasks associated with catch basin inserts include regular inspections of the catch basin structures and inserts or valves to ensure functionality, removal of debris, and repairs to maintain watertight seals. In some applications, removal of inserts or valves is required at the end of the deicing season if non-deicing runoff rates exceed the flow capacity of the insert.

3. Costs

Overall costs associated with catch basin valve insert systems depend upon the number and sizes of catch basins that will require inserts as well as the initial condition of the catch basins.

Capital Costs

Capital costs for catch basin valve inserts consist primarily of the insert itself, which must be custom fabricated to fit a catch basin. Vendors have indicated that the cost of a single catch basin insert will vary with the size of the catch basin. Rough unit costs are reflected in one vendor's quoted costs that range from $4,000 for a smaller catch basin to $6,000 for a larger catch basin (2017 prices). Installation of the inserts is often provided by the vendors as a separate cost item. Other initial costs may include repairs to existing catch basins and surrounding pavement to ensure an adequate water-tight seal.

Operations and Maintenance Costs

Operational costs for catch basin inserts are those associated with monitoring and manual operation. Maintenance costs may include the following:

- Regular inspection of catch basin structures and inserts;
- Repairs to maintain proper operation and integrity of seal within catch basin; and
- Repairs to pavement surrounding catch basins to prevent infiltration of ponded deicing stormwater.

Reference

Switzenbaum, M. S., Veltman, S., Schoenberg, T., Durand, C., Mericas, D., and Wagoner, B. 1999. *Best Management Practices for Airport Deicing Stormwater*. USA: University of Massachusetts/Amherst Water Resources Research Center.

FACT SHEET 34

Publicly Owned Treatment Works Discharge

1. Description

Purpose

This practice provides a means of disposing of deicer-laden stormwater offsite at a treatment facility not owned or operated by the airport authority.

Technology

Publicly owned treatment works (POTWs) use biological processes to break down biodegradable organic compounds in domestic, commercial, and industrial wastewaters. Glycols and other organic constituents of deicing runoff are generally amenable to biological treatment, and access to a POTW can represent a convenient and cost-effective offsite option for disposing of deicing runoff that cannot be discharged untreated to the environment.

Discharge to a POTW can be accomplished in various ways. Most airports have a direct connection to a suitable sanitary sewer, while others have found over-the-road tanker transport to an offsite discharge location to be cost effective if quantities to be disposed of are small. An industrial user permit must be obtained to discharge to a POTW. Conditions and restrictions may apply to the volume, concentration, load, and flow rate of discharge. Monitoring requirements may also be applied.

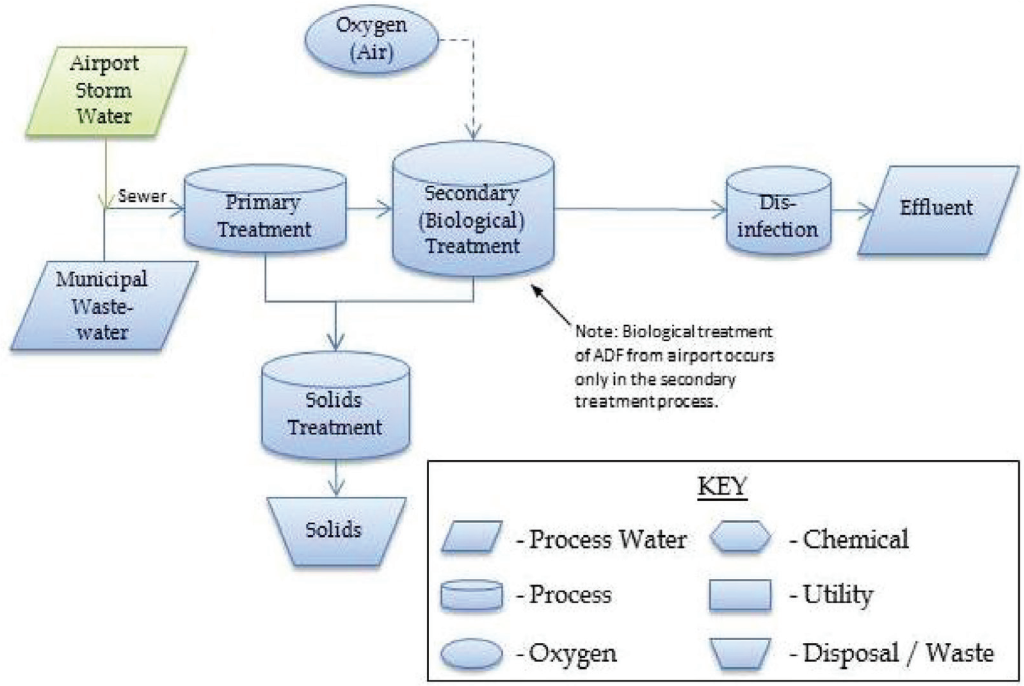
Documented Performance

Biochemical oxygen demand (BOD) loadings in deicing discharges to sanitary sewers are typically in the range of several thousands to tens of thousands of pounds per day. Allowable BOD discharge rates are always site-specific and depend on POTW capacity and the relative volumes and loadings of the deicing discharges. The success of the practice at an individual airport can be evaluated by assessing the airport's ability to fully utilize hydraulic and BOD loading allowances, the number of exceedances of those allowances, the number of instances in which the POTW restricts discharges to below those allowances, the need to seek out alternative disposal practices on a short-term or long-term basis, and the current discharge fees and potential future increases in discharge fees imposed by the POTW.

2. Implementation Considerations

Applicability Assessment

POTWs are generally willing to accept discharges of airport deicer-impacted stormwater under rate structures that apply to industrial discharges. The POTW



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Flowchart of POTW process.

operator typically must consider the following technical and regulatory factors in determining the conditions under which these discharges are accepted:

- Hydraulic capacity of the sanitary sewers, including the timing of other batch discharges to the affected sewer lines;
- Hydraulic and BOD load capacity of the treatment plant;
- The variable and seasonal nature of the discharges as it affects plant performance and revenue streams;
- Limitations on POTW capacity during wet weather events;
- The potential effect of deicer additives on plant performance and the ability of the plant to meet its own NPDES permit limitations; and
- Established policies, such as maximum fraction of POTW capacity that can be allocated to a single discharger, and prohibition on stormwater discharges to the plant.

Application for a POTW discharge permit will require characterization of the volumes and constituents in the proposed discharges. Bench-scale or pilot-scale treatability studies may be required to demonstrate that the discharge will not negatively impact the POTW's operations or compliance with its own NPDES permit.

POTWs can revoke discharge permits or significantly increase fees. This may occur if the POTW is under pressure to comply with a consent order from the U.S. EPA or state environmental regulatory authority to eliminate combined sewer overflows. POTWs may also not allow or seek to discontinue the seasonal airport discharges if capacity is needed for an entity that provides a year-round source (resulting in year-round revenues for the POTW). This possibility increases the level of risk for the airport if POTW discharge is the primary disposal practice. Numerous airports have experienced situations in the last two decades where the ability to use POTWs has changed or where more restrictive limitations have been applied. When planning a POTW discharge, it may be prudent to identify short- and long-term disposal contingencies that can be implemented if access to the POTW is terminated, restricted, or significantly costlier.

An airport's decision to discharge to a POTW is typically based on the adequacy of treatment capacity offered by the POTW operator to meet the airport's needs, capital costs for implementation, user fees, and reliability/sustainability of service.

Regulatory Considerations

An industrial discharge user permit is typically required for discharging deicing stormwater to a sanitary sewer. These permits are issued by either the POTW operator or a state agency that regulates POTWs. The permit defines the conditions and limits under which wastewater is accepted by the POTW. Limits are typically based upon the treatment and hydraulic capacity of the POTW, the ability of the POTW to process the airport stormwater without causing a plant upset, and possibly on the hydraulic capacity of the sanitary sewer being used. Limits may also include restrictions on slug loading and may require a ramp-up time for discharges of significant BOD loads. A construction or tap-in permit may also be required from local or state regulators to access the existing sanitary sewer with a new sanitary sewer pipe.

Planning and Design Considerations

The following factors should be considered in planning a successful POTW discharge system:

- The airport's flow rates and BOD loads requiring disposal under a variety of weather conditions;
- The available POTW hydraulic (flow) and BOD loading capacity;
- Flow or loading restrictions that the POTW may consider during special circumstances (e.g., high flow conditions, plant upsets);
- User fee calculations for industrial discharges, including both volume and "high-strength" charges;
- Projections for changes in user fees in the next 10 years;
- Permit requirements;
- Potential sewer access points near the airport and the capacity of the sewers at those locations;
- Storage requirements to contain large storm events under the constraints of flow and loading to the sanitary sewer;
- pH adjustment in collected deicing runoff discharges to the sanitary sewer may be required if the runoff is held for an extended period; and
- Alternative disposal options if the allowable discharges are decreased or the actual loadings are larger than expected.

Integration with Other Practices

Hydraulic restrictions in the sanitary sewers or at the POTW, the difference between airport discharge BOD concentrations (typically 500–50,000 mg/L) and POTW design influent concentrations (typically about 200 mg/L), or restrictions on wet weather discharges almost always require onsite storage and controlled release of deicing runoff discharges as part of an integrated system. These site-specific constraints and interrelationships will define how POTW discharge is used to meet the airport's program needs. The following system components are frequently required to implement the POTW discharge practice:

- Online monitoring/diversion systems to segregate low- and high-BOD concentration stormwater;
- Onsite storage to equalize discharge flows and loads; and
- Monitoring and metering procedures to control the flow or BOD loading rates of discharges to the sanitary sewer.

Operation and Maintenance Considerations

Operational requirements associated with POTW discharges are associated primarily with monitoring (e.g., pollutant concentrations, flow rates, storage volumes) at key locations in the system, and metering (flow rates and BOD loads discharged to the sanitary sewer). Monitoring and metering can be achieved either manually or automatically, depending on the system requirements and budget.

Adjusting pH may be required where deicing runoff is stored for extended periods and anaerobic degradation lowers pH below that allowed in discharges to the POTW.

Maintenance requirements are primarily associated with sediment cleanout in the storage facilities, as well as preventive and emergency maintenance on mixing, monitoring, pumping, and metering equipment.

3. Costs

In general, POTW discharge offers lower capital costs and higher operating costs relative to other disposal options.

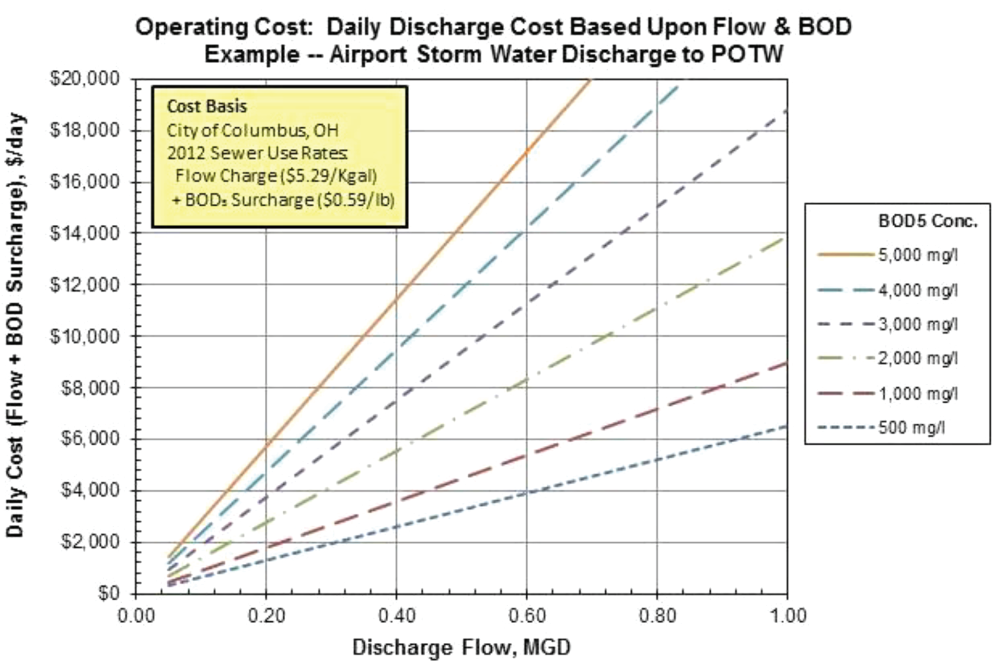
Capital Costs

Capital costs for discharge to a POTW may include storage tanks or ponds, BOD (or equivalent) monitoring equipment, metering pumps or control valves to regulate sanitary sewer discharges, and new conveyance to the local sewer system. The costs depend on site-specific factors, including the airport's deicer use, weather conditions, storm sewer infrastructure, available space, as well as the proximity and accessibility of the local sanitary sewers.

Operations and Maintenance Costs

Commonly, POTW use fees are based on the flow volume discharged, plus a surcharge fee for BOD concentrations in excess of some maximum (e.g., 275–300 mg/L). Often, the elevated BOD concentrations in deicer-laden stormwater discharges result in significant annual surcharge fees. Figure 2 presents an example of a sewer use rate schedule from the city of Columbus, Ohio. The charges shown in the chart would apply to any industrial user—they include a commodity (flow) charge and an extra-strength BOD5 surcharge.

POTW fees have risen significantly in recent years and are expected to continue to increase in the future as municipalities seek funding to replace aging infrastructure and to manage combined sewer overflow discharges. Because of the volatility of sewer fee rates, airports should obtain details on expected rate changes prior to completing the financial analysis on potential discharges to a POTW. It is important to identify short- and long-term contingencies in case the discharge authorization is revoked by the POTW.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 2. Example POTW discharge fees.

Source Reduction
Containment/Collection
System Components
→ TREATMENT/RECYCLING

FACT SHEET 35

Anaerobic Fluidized Bed Reactor

1. Description

Purpose

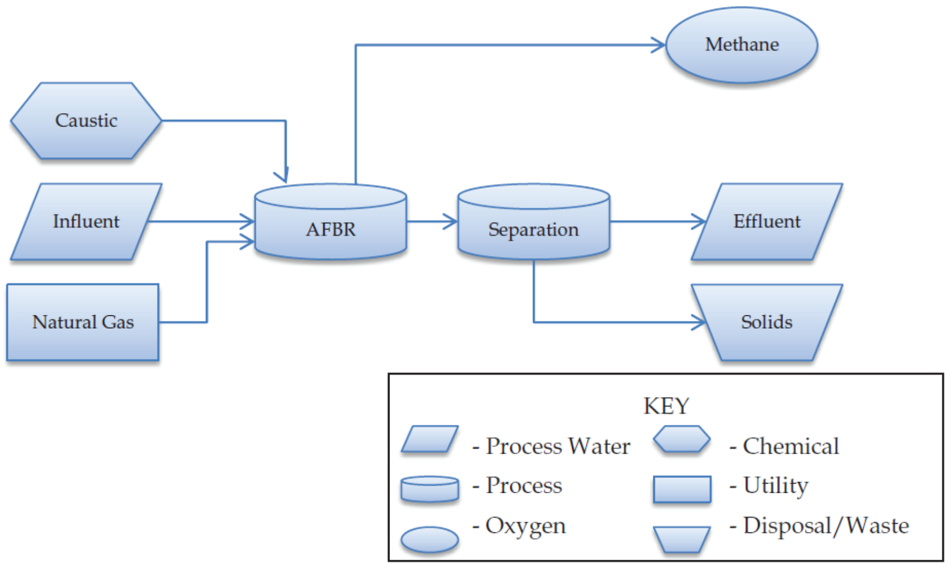
The anaerobic fluidized bed reactor (AFBR) technology is a small-footprint biological process for treating deicer-impacted stormwater with higher COD mass loads and concentrations. The AFBR technology features the sustainable use of treatment byproduct methane to heat the stormwater and isolate treatment from weather conditions.

Technology

The core elements of the AFBR treatment process are shown in Figure 1. Treatment occurs using anaerobic bacteria housed in specially designed 30–35-feet tall reactors to breakdown organic deicing compounds into water, methane, carbon dioxide, and biological solids. The reactors contain granular activated carbon that is fluidized to provide an optimal surface for bacterial growth. Nutrients, including nitrogen, phosphorous, and trace amounts of inorganics must be added for optimized bacterial growth. Byproducts include biological solids and methane gas. Captured methane is used to heat influent water through use of a boiler and heat exchange system. Relatively small quantities of biological solids must be dewatered and are typically disposed of in a landfill. Water entering the AFBR must be heated to 85°F to 90°F to achieve appropriate anaerobic bacterial growth and pH must be controlled. For more information on the AFBR technology, please see the *ACRP Report 99,* Fact Sheet 104.

Documented Performance

The AFBR technology has been successfully used at four airport locations in the United States: Albany International Airport (5,400-lb COD/day, 1998); Akron-Canton Airport (3,500-lb COD/day, 2007); Portland International Airport (7,700-lb COD/day, 2012); and T.F. Green Airport (7,700-lb COD/day, 2015). AFBR systems are capable of treating water with virtually any COD concentration; however, at concentrations less than 2,700 mg/L COD, some natural gas must be used to supplement captured methane to achieve target temperatures. Flow rates influent to the AFBR (in the range of five to 200 gallons per minute, typically) are adjusted in response to influent COD concentrations to achieve a constant mass load. Initial season development of the bacterial population (from a seed) takes 2 to 3 months. In subsequent



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Flow chart of AFBR process.

seasons, no seeding is required, and full capacity can be achieved in 2 to 4 weeks. The AFBR reactors can sit idle for more than 9 months while still maintaining viable anaerobic bacteria. Treatment performance of AFBR systems is very consistent, with propylene glycol removals of 99% and COD removals of more than 95%.

2. Implementation Considerations

Applicability Assessment

The following AFBR characteristics may affect applicability to given airport:

- Optimal influent concentration in the range of 2,700 mg/L to 80,000 mg/L of COD.
- Can treat multiple deicer chemicals (propylene glycol, ethylene glycol, glycerine, formates, acetates) and reduce concentrations to near zero.
- Effluent COD concentrations of 75 to 100 mg/L
- Treatment building footprint of 0.5 to 1 acre and a height of 30 to 40 feet.
- Self-generation of methane for fuel isolates treatment performance from weather.

Regulatory Considerations

Potential permits for AFBR installation and operation may vary by location, but may include wastewater permit-to-install; air permit-to-install/operate; approval from local fire marshal for methane handling system; and modification of NPDES for monitoring.

Planning and Design Considerations

The following factors should be considered in the planning and design of an AFBR system:

- Performance data from other AFBR systems can provide rates of treatment, but individual systems must be sized and designed for each airport's site conditions.
- Although sludge generation for bacterial die-off is low compared to aerobic systems, a system for sludge dewatering and offsite disposal (e.g., landfill disposal) is needed.
- The system requires utility connections for water, electricity, and natural gas.
- The AFBR treatment process requires a building to house the system.
- The AFBR facility height is 30–35 feet tall and FAA requirements for safe, efficient use and preservation of the navigable airspace should be consulted when considering this technology.
- A minimum 2-year window should be allocated for design, bidding, construction, and startup of an AFBR system.
- Greenhouse gas emissions.

Integration with Other Practices

The concentration and flow ranges suitable for the AFBR are compatible with the ranges of runoff concentrations associated with apron collection systems where higher and lower concentration streams are segregated (see Fact Sheet 22), centralized deicing facilities (Fact Sheet 21), glycol collection vehicles (Fact Sheet 23), block-and-pump systems (Fact Sheet 24), and snow melt systems (Fact Sheet 26). Diversion valves can be used with real-time concentration monitoring to optimize the influent loading to the system, which can enhance system performance and reduce costs. Storage capacity upstream of the system is essential for effective system operation. Designers can consider different combinations of storage and treatment capacities to achieve the most cost-effective balance.

Operation and Maintenance Considerations

Two to three full-time operators are typically required for an AFBR system. Because of the seasonal nature of operations, airports with an AFBR system have utilized airport staff trained for the specific operation. The AFBR technology uses extensive monitor and computer control, which reduces day-to-day operator decision-making. Daily collection and review of operating data by operators is needed to support decision-making. AFBR systems do not have to be staffed full-time, although computer calls to operators are necessary to respond to alarms and short-term performance issues. The first startup of the AFBR systems can take 2 to 3 months to establish the full anaerobic population, with 2 to 3 weeks required in subsequent years. The AFBR is a relatively low-maintenance system compared to other deicer treatment technologies. A 4,000-lb COD/day system can be expected to generate approximately 10 cubic yards of solids per year of dry solids that will require offsite disposal.

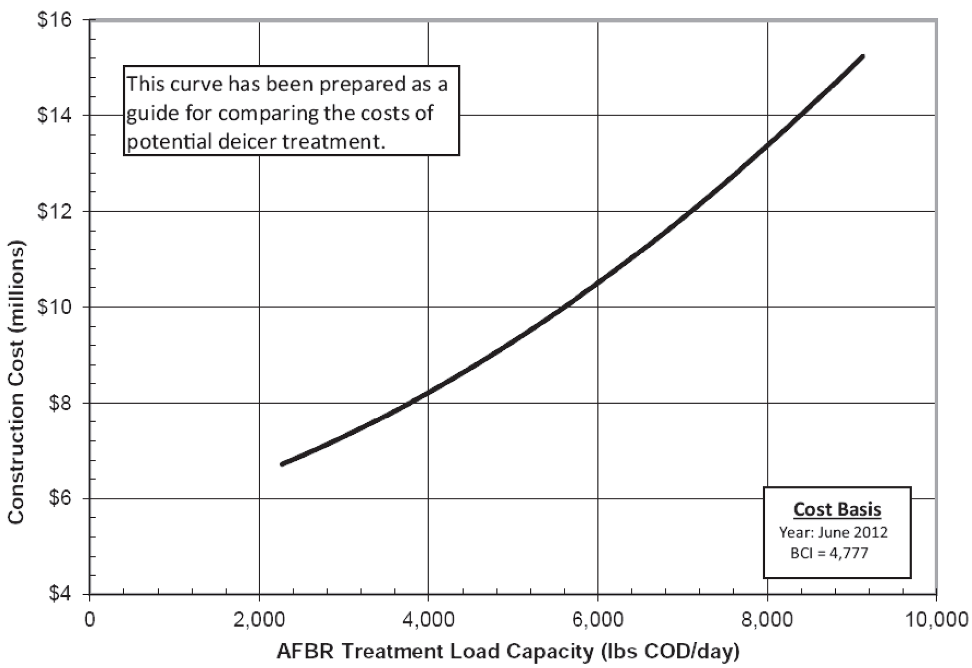
3. Costs

Capital Costs

Figure 2 provides guidance on AFBR capital costs per pound of COD treated daily. Costs include a treatment building, interior mechanical equipment, electrical, and controls. The costs exclude non-treatment components such as collection, storage, and conveyance.

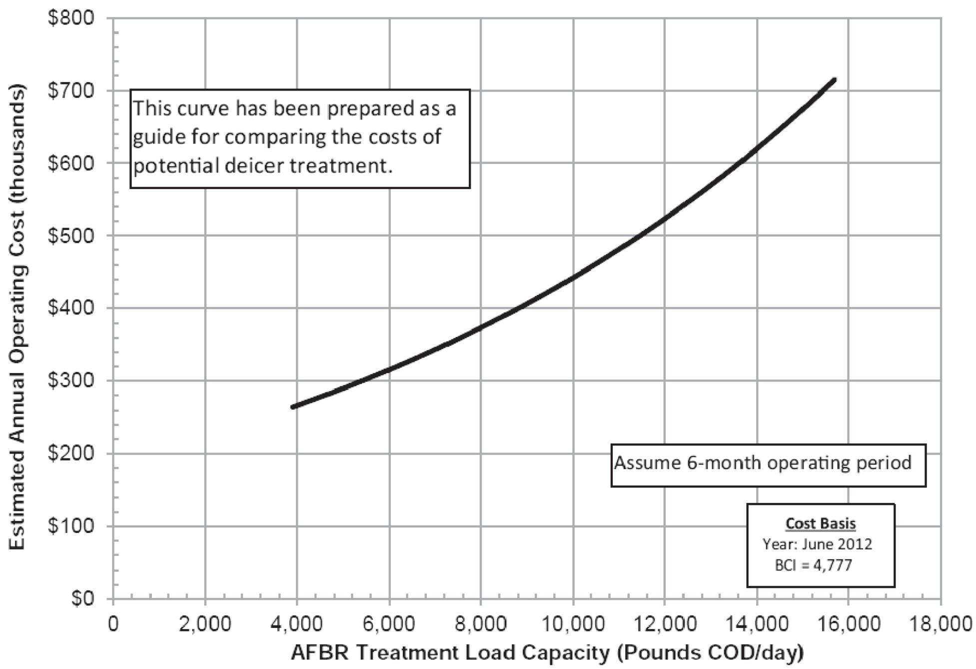
Operations and Maintenance Costs

Figure 3 provides guidance on AFBR O&M costs per pound of COD mass load treated. Costs include labor, sludge disposal, utilities, and chemicals.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 2. AFBR capital cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 3. AFBR O&M cost curve.

FACT SHEET 36

Aerated Gravel Bed Treatment

1. Description

Purpose

The aerated gravel bed (AGB) technology is an aerobic biological process capable of treating higher flow rate, lower COD concentration flows. The technology is well suited to situations requiring a low profile and more passive operational characteristics.

Technology

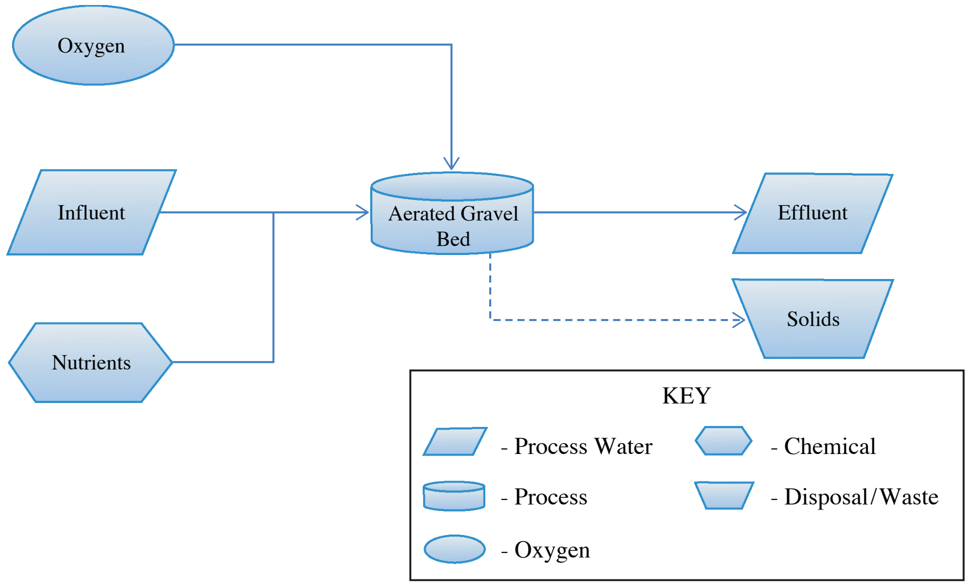
The main elements of the AGB treatment process are illustrated in Figure 1. Treatment occurs utilizing aerobic bacteria in a submerged gravel bed system to break down organic deicing compounds into water, carbon dioxide, and biological solids. The gravel in AGB technology serves as a medium for attached bacterial growth. Typically, the system consists of lined, below grade gravel beds arranged in series to maximize removal of COD. Often parallel series of beds are configured to maximum flow rate processed. The footprint of an AGB facility is dependent on the required COD loading per day (lb COD/ft^2/day) to be treated.

Influent flow is distributed over the footprint of the treatment cells via buried, perforated headers and migrates downward through the gravel bed. Aerobic conditions are maintained in the bed through one of two methods. Blowers can be used to provide air (oxygen) in the bed, or a passive aeration system can be used where the bed goes through cycles of flooding and draw down, with air pulled into the bed through stand pipes during the draw down. Nutrients may need to be added for optimal bacterial growth. COD loading into the AGB must be controlled at a relatively constant level to achieve optimal performance.

Biological solids, a natural byproduct of a biological treatment system, are typically digested in place within the treatment cells. External collection, dewatering, and disposal of biological solids is not typically required, although operators must carefully monitor solids discharges at the end and beginning of each season. For more information on the AGB technology, please see *ACRP Report 99,* Fact Sheet 102.

Documented Performance

The AGB technology has been successfully used at the following airport locations: Buffalo-Niagara International Airport (17,000-lb COD/day, 2009); Edmonton International Airport (3,540-lb COD/day, 2001/2016); London Heathrow International Airport (13,000-lb COD/day, 2001); Long Island MacArthur Airport



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Flow chart of AGB process.*

(1,000-lb COD/day, 2012); Calgary International Airport (7,400-lb COD/day, 2017); and Gerald R. Ford International Airport (4,600-lb COD/day, 2015). AGB systems are capable of treating water with COD concentrations up to 10,000 mg/L COD and are ideal for dilute, higher flow rate influent streams. Treated effluent COD concentrations depend upon the degree of mass loading relative to system capacity, configuration of the treatment cells, appropriate nutrient loads, and appropriate oxygen supply, but effluent concentrations of less than 50 mg/L COD are achievable. While the AGB can be considered a more passive system operationally than many other biological treatment technologies, balancing of COD and nutrient loadings into the system must be controlled. Between seasons there is usually a 1 week startup period to reach treatment capacity. The system typically does not need to be reseeded with bacteria seasonally. Seasonal startup is a critical period for monitoring and control of solids and nutrient content in the effluent due to bacterial die-off during the non-deicing season.

2. Implementation Considerations

Applicability Assessment

The following AGB characteristics may affect applicability to a given airport:

- Optimal influent COD concentrations are less than 10,000 mg/L.
- Sizing is based on COD mass loading (lb/day COD), not concentration.
- Effluent COD concentrations of 50–100 mg/L are typical, but less than 50 mg/L is achievable with the appropriate sizing and cell configuration.
- Treatment footprint is typically greater than 1 acre, with building and equipment height less than 20 feet.

Regulatory Considerations

Potential permits for AGB installation and operation may vary by location, but may include site land disturbance, wastewater permit-to-install and modification of NPDES for monitoring.

Planning and Design Considerations

The following factors should be considered in the planning and design of an AGB system:

- Performance data from other AGB systems can be used to extract rates of treatment, but individual systems must be sized and designed for each airport's site conditions.
- Most AGB installations require utility connections for water (maintenance only) and power.
- Site topography may allow use of gravity flow between treatment cells, reducing or eliminating the need for pumps and associated utilities. The Gerald R. Ford International Airport AGB facility was designed to take advantage of a sloped site and operates entirely on gravity.
- A 2-year window is optimal for design, bidding, construction, and startup.

It should be noted that aerated gravel beds do not have open water surfaces or wetland vegetation. To avoid attraction of birds and other wildlife, aerated gravel beds are designed with piping and other water conveyance below the gravel surface and controls that prevent water levels from rising above the surface. AGB treatment occurs via bacteria growing on the gravel and not from plant uptake. The gravel bed in AGBs is covered with a soil layer that helps retain heat generated from the biological activity. This soil cover is planted with common low maintenance grasses. Installed AGBs look like grassy areas and are no more a wildlife attractant than any other grass areas at the airport

Integration with Other Practices

The concentration and flow ranges suitable for the AGB technology are generally compatible with all collection technologies. Diversion valves can be used with real-time concentration monitoring to segregate flows with optimal characteristics for AGB treatment. Storage capacity upstream of the system is essential for effective system operation. Online monitoring for COD or TOC between storage and treatment is recommended. Designers can consider different combinations of storage and treatment capacities to achieve the most cost-effective balance.

Operation and Maintenance Considerations

One to two full-time operators are typically required for an AGB system. Because of the seasonal operations, airports with AGB system have utilized trained airport staff. The AGB technology is best applied with monitoring and computer control, which reduces day-to-day operator decision-making. Daily collection and review of operating data by operators is needed to support decision-making. AGB systems do not have to be staffed full time, although computer call outs to operators are helpful to respond to alarms. The first startup of the AGB systems can take up to 2 months to establish the full aerobic population, with 1 week required in subsequent years. The AGB system requires off season cleaning to prevent blockages. Solids buildup can be managed if operational ranges are met, or else significant effort may be needed to clean or replace the media.

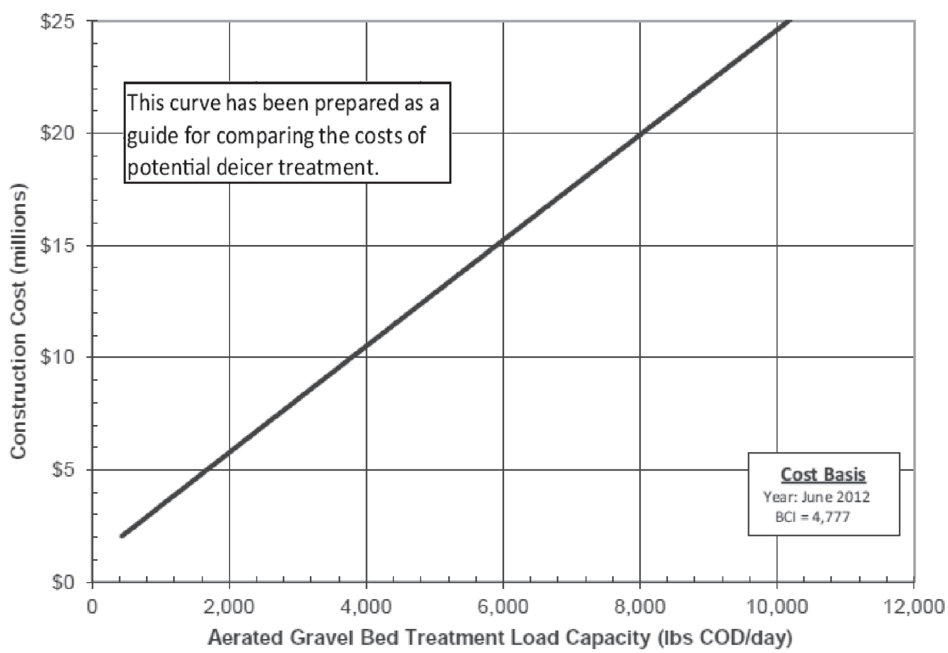
3. Costs

Capital Costs

Figure 2 provides guidance on AGB capital costs per pound of COD treated daily. The costs exclude non-treatment components such as collection, storage, and conveyance. Lower costs will be incurred with passively aerated systems because blowers and associated infrastructure are not required.

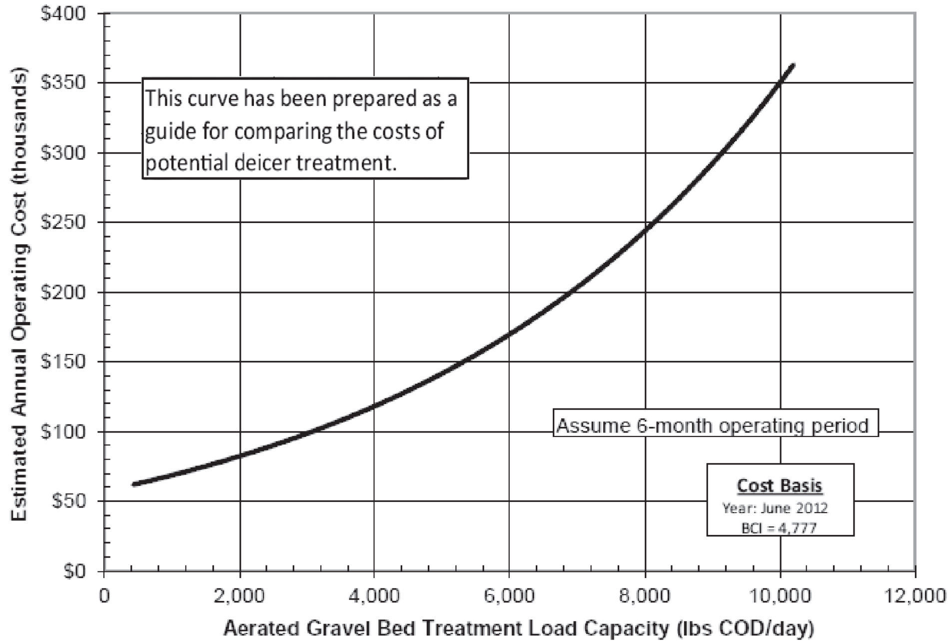
Operations and Maintenance Costs

Figure 3 provides guidance on AGB O&M costs per pound of COD treated daily. Costs include labor, utilities, and chemicals. Passive aeration systems have significantly lower O&M costs because utility costs are much less.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 2. AGB capital cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 3. AGB O&M cost curve.

Source Reduction
Containment/Collection
System Components
→ **TREATMENT/RECYCLING**

FACT SHEET 37

Moving Bed Biofilm Reactor

1. Description

Purpose

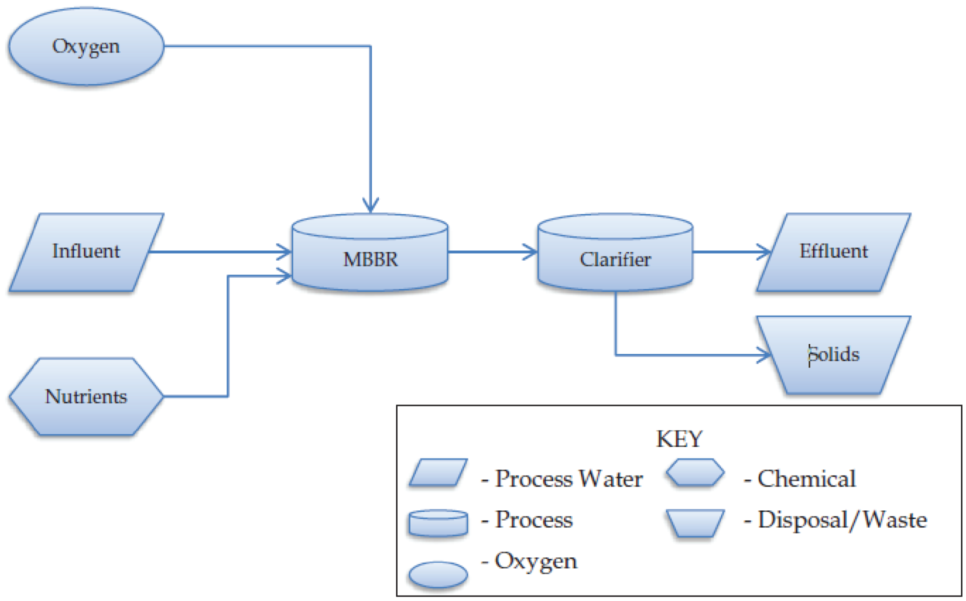
The moving bed biofilm reactor (MBBR) technology is a small-footprint biological process for treating deicer-impacted stormwater with lower concentrations and higher flow rates. The MBBR technology may be used to treat deicer-impacted stormwater for discharge to surface waters.

Technology

The core elements of the MBBR treatment process are shown in Figure 1. This treatment technology operates similar to an activated sludge process. Unlike activated sludge, it involves use of media upon which aerobic bacteria attach to improve the efficiency of the break down organic deicing compounds into water, carbon dioxide, and biological solids. Nutrients must be added to facilitate optimal bacterial growth in deicing-impacted stormwater. Influent is pumped into large open tanks with oxygen fed into the MBBR basin. Effluent is screened to prevent media from exiting the aeration tank. A clarifier is needed after the aeration tank to separate biological solids in the effluent. Dewatering of the biological solids is required before the solids are disposed of, typically in a landfill. This technology is better suited for low concentration, high flow situations. For more information on MBBR technologies, please see the *ACRP Report 99*, Fact Sheet 107.

Documented Performance

The MBBR process has been implemented at one European airport: Oslo Airport (12,000-lb COD/day, 1998). It has also been tested on a bench scale for the Pittsburgh International Airport. MBBR systems are ideal for treating deicer-laden water with low COD concentrations and high volumes. Treated effluent COD concentrations depend upon the degree of mass loading relative to system capacity, appropriate nutrient loads, and appropriate oxygen supply, but effluent concentrations similar to activated sludge and less than 20 mg/L COD are achievable. COD and nutrient loadings into the system must be controlled. Control is best achieved through online monitoring and SCADA control of pumps with operator review and fine tuning. Between seasons a startup period is needed to reach treatment capacity and the system may need to be reseeded with bacteria seasonally. Seasonal startup is a critical period for monitoring and control of solids and nutrient content in the effluent due to bacterial die off during the non-deicing season.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Flow chart of MBBR process.

2. Implementation Considerations

Applicability Assessment

The following MBBR characteristics may affect applicability to a given airport:

- Influent concentrations of COD need to be relatively low.
- Aeration system sizing dictates treatment rate (lb/day COD).
- Effluent COD concentrations of 10–20 mg/L COD can be achieved.
- Treatment footprint is typically less than 1 acre, with building and equipment height less than 20 feet.

Regulatory Considerations

Potential permits for MBBR installation and operation may vary by location, but may include wastewater permit-to-install and modification of NPDES for monitoring.

Planning and Design Considerations

The following factors should be considered in the planning and design of an MBBR system:

- Performance data from other MBBR systems can be used as some guidance for determining rates of treatment, but individual systems must be sized and designed for each airport's site conditions.
- Because of the scarcity of MBBR systems in use for treating deicer-impacted stormwater, a site-specific pilot test should be considered.

- The system requires utility connections for power.
- The treatment process will produce sludge that requires dewatering and disposal.
- Land for siting the system should be relatively flat.
- A 2-year window is optimal for design, bidding, construction, and startup.

Integration with Other Practices

The concentration and flow ranges suitable for the MBBR technology are compatible with the range of deicing runoff concentrations associated with apron collection systems (Fact Sheet 22) and airfield drainage systems (Fact Sheet 25). The technology is also compatible with systems where diversion valves separate high- and low-concentration streams, and performance can be optimized by blending these streams to maintain a constant load to treatment. Storage capacity upstream of the treatment system in the form of basins (Fact Sheet 29) or permanent tanks (Fact Sheet 30) is essential for effective and efficient operation. The required storage capacity can be accurately determined if the temperature-loading rate relationship is integrated into the system operation and the variation in stormwater flow rates and COD concentrations in the collected stormwater are understood.

Operation and Maintenance Considerations

One to two full-time operators are typically required for an MBBR system. Because of the seasonal operations, airports with a MBBR system have utilized trained airport staff. The MBBR technology is best applied with monitoring and computer control, which reduces day-to-day operator decision-making. Daily collection and review of operating data by operators is needed to support decision-making. MBBR systems do not have to be staffed full time, although computer call outs to operators are helpful to respond to alarms. Reseeding of the system may be required between seasons. Up to 5% of the media may need replacement from season to season. Startup of the MBBR technology could take up to 2 months.

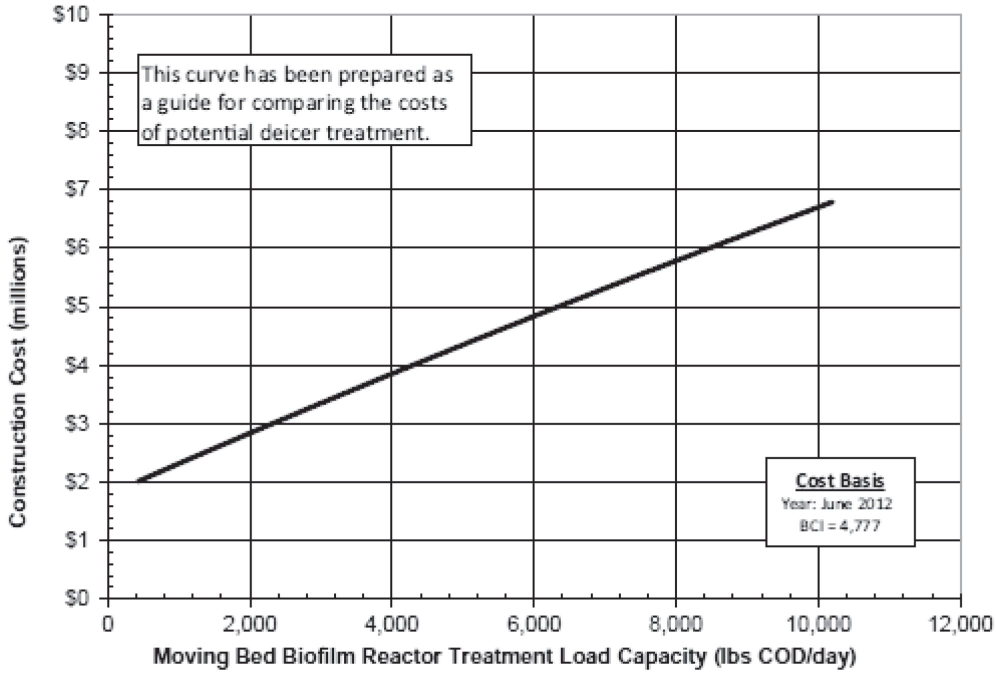
3. Costs

Capital Costs

Figure 2 provides guidance on MBBR capital costs per pound of COD treated daily. The costs exclude non-treatment components such as collection, storage, and conveyance.

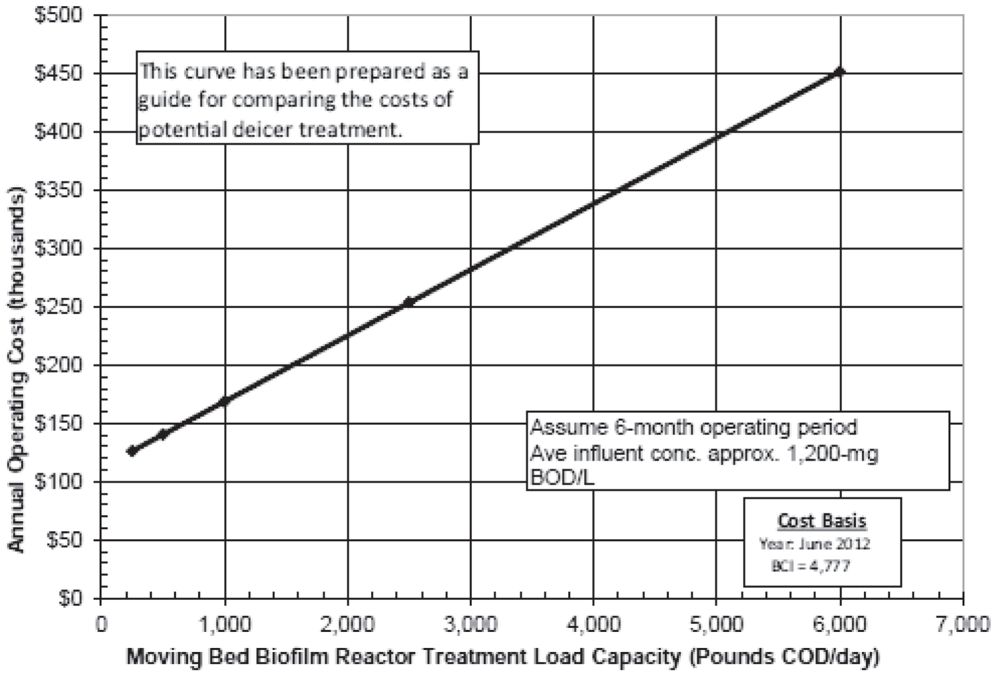
Operations and Maintenance Costs

Figure 3 provides guidance on MBBR O&M costs per pound of COD treated daily. Costs include labor, utilities, and chemicals.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 2. MBBR capital cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 3. MBBR O&M cost curve.

FACT SHEET 38

Activated Sludge

1. Description

Purpose

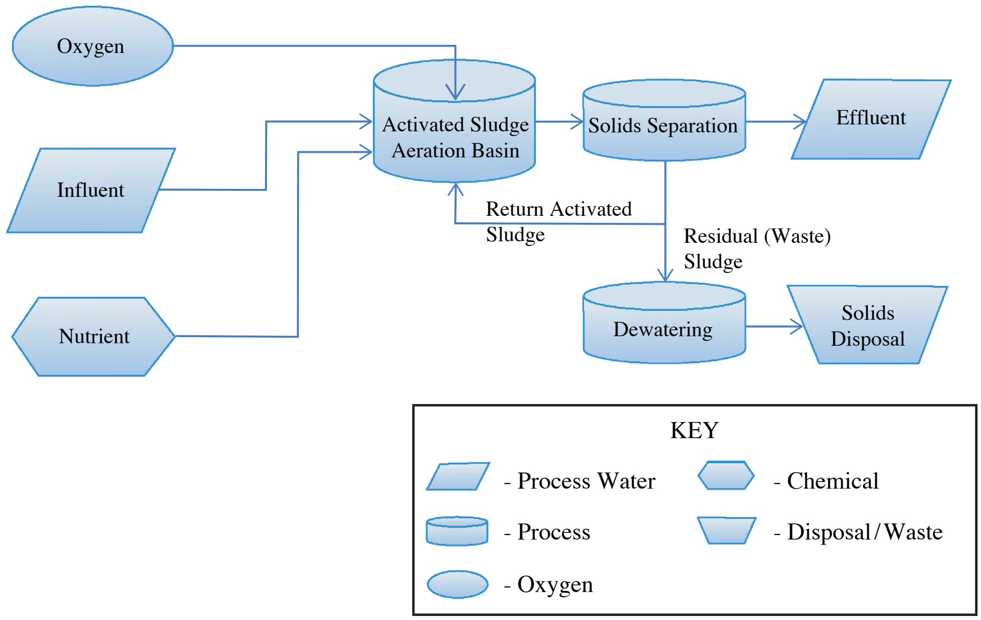
This technology is a small-footprint aerobic biological process for treating deicer-impacted stormwater with lower COD concentrations and high flow rates.

Technology

The core elements of the activated sludge treatment process are shown in Figure 1. Treatment occurs utilizing aerobic bacteria suspended in wastewater in an aerated basin or tank that break down organic deicing compounds into water, carbon dioxide, and biological solids. Activated sludge technology is differentiated from aerated lagoons by recirculation of settled bacterial solids (sludge) back into the aerated basin. The aeration basins are often rectangular concrete structures, but can be lined earthen structures. The recirculation of sludge provides greater control, increased treatment efficiency, and the ability to treat higher COD loads. Influent is pumped into large open tanks and is aerated through mechanical surface aerators or compressors. Nutrients must be added to optimize bacterial growth in deicing-impacted stormwater. A clarifier is used to separate biological solids from the water exiting the aeration basin, with clarified water discharged and settled solids returned to the aeration basin. For deicing systems, no other treatment processes typically follow the clarification process. Some portion of the settled biological solids are removed from the system and are generally dewatered prior to disposal to reduce transportation costs as well as meet criteria for transport and disposal in a landfill. For more information on activated sludge technologies, please see the *ACRP Report 99*, Fact Sheet 101.

Documented Performance

The activated sludge technology has been used at the following airport locations: Chicago's O'Hare International Airport (12,000-lb COD/day, 1997); Cincinnati/Northern Kentucky Airport (52,500-lb COD/day, 2004); and Nashville International Airport (9,000-lb COD/day, 2015). The primary benefits of activated sludge technology are the ability to achieve low effluent COD concentrations and the ability to achieve high COD load removal rates in a relatively small footprint. Effluent concentrations as low as 10 mg/L COD are achievable, although the concentrations depend upon the degree of mass loading relative to system capacity, appropriate nutrient loads, temperature, and appropriate oxygen supply. Because of the variability of flow rates and COD concentrations associated with deicing, activated sludge technologies applied to airports operate most effectively if COD and nutrient mass loadings into the system are controlled at relatively steady rates. Control can be achieved through online monitoring and SCADA control of



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Activated sludge process flow chart.

pumps with operator review and fine tuning. Between seasons, a startup period is needed to reach treatment capacity and the system may need to be reseeded with bacteria seasonally. Seasonal startup is a critical period for monitoring and control of solids and nutrient content in the effluent due to bacterial die off during the non-deicing season. Biogrowth is rapid and treatment capacity is reached in a matter of weeks after startup.

2. Implementation Considerations

Applicability Assessment

The following characteristics may affect applicability of activated sludge to a given airport:

- Effluent concentrations as low as 10 mg/L COD can be achieved.
- Influent concentrations greater than 10,000 mg/L COD can result in localized areas of low oxygen in the aeration basin, potentially creating treatment dead zones.
- Aeration system sizing dictates treatment rate (lb/day COD).
- Treatment footprint is typically less than 1 acre, with building and equipment height less than 20 feet.
- System may require more operator attention than other treatment technologies.
- The technology may be more susceptible to performance swings if periods of low deicing load are encountered. Therefore, it is not particularly applicable to locations with infrequent deicing. Seasonal reseeding of biomass can be a challenge.

- The technology requires a significant sludge handling and disposal operation.
- The technology can operate at water temperatures as low as 41°F, although performance is better at higher temperatures.

Regulatory Considerations

Potential permits for activated sludge system installation and operation may vary by location, but may include wastewater permit-to-install and modification of NPDES for discharge of treated effluent.

Planning and Design Considerations

The following factors should be considered in the planning and design of an activated sludge system:

- Performance data from other activated sludge systems that treat deicer-impacted stormwater can be used to extract rates of treatment, but individual systems must be sized and designed for each airport's site conditions.
- The system requires utility connections for blowers or aerators.
- The treatment process will require an extensive system for settling, dewatering, and disposal of sludge.
- Nutrient addition is essential and a means for balancing nutrient loading with COD load is needed.
- A 2-year window is optimal for design, bidding, construction, and startup.
- The activated sludge technology should be sized based on COD mass loading rate (lb/day COD), with capability for monitoring concentrations and flows to help control influent loads.

Integration with Other Practices

The concentration and flow ranges suitable for the activated sludge technology are compatible with the range of deicing runoff concentrations associated with apron collection systems (Fact Sheet 22) or airfield drainage systems (Fact Sheet 25). Pairing activated sludge systems only with deicing pads could result in COD concentrations that create dead zones in the aeration basin. The technology is also compatible with systems where high- and low-concentration streams are separated. Storage capacity upstream of the treatment system in the form of basins (Fact Sheet 29) or permanent tanks (Fact Sheet 30) is essential for effective and efficient operation. Activated sludge may be used to pretreat stormwater prior to its discharge to a POTW. It also may be paired with treatment or recycling technologies that are capable of handling higher-concentration influent streams.

Operation and Maintenance Considerations

Two to three full-time operators are typically required for an activated sludge system. Operators require training and need to understand the dynamics of biological treatment because frequent system adjustments may be necessary. Because of the seasonal operations, airports with activated sludge systems have utilized trained airport staff. The activated sludge technology is best applied with monitoring and computer control, which reduces day-to-day operator decision-making. Daily collection and review of operating data by operators is needed to support decision-making. Activated sludge systems do not have to be staffed full time, although computer call outs to operators are helpful to respond to alarms. Either the reseeding of the system between seasons or an extended season is required. Startup of the activated sludge technology could take several weeks. Additional maintenance may be required to address any sludge buildup that occurs within the system.

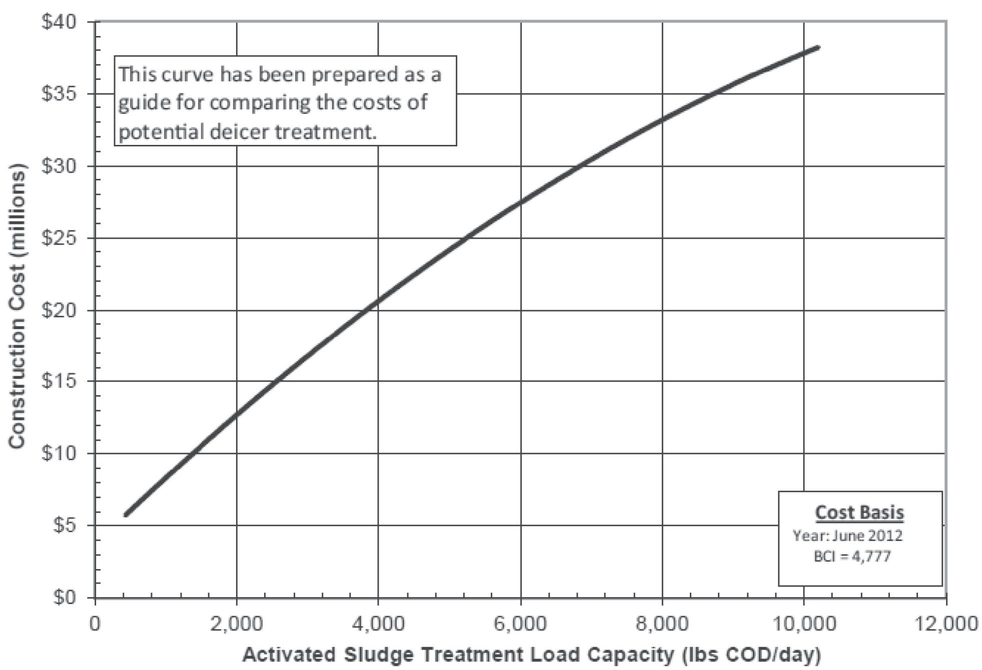
3. Costs

Capital Costs

Figure 2 provides guidance on activated sludge capital costs per pound of COD load treated. The costs exclude non-treatment components such as collection, storage, and conveyance.

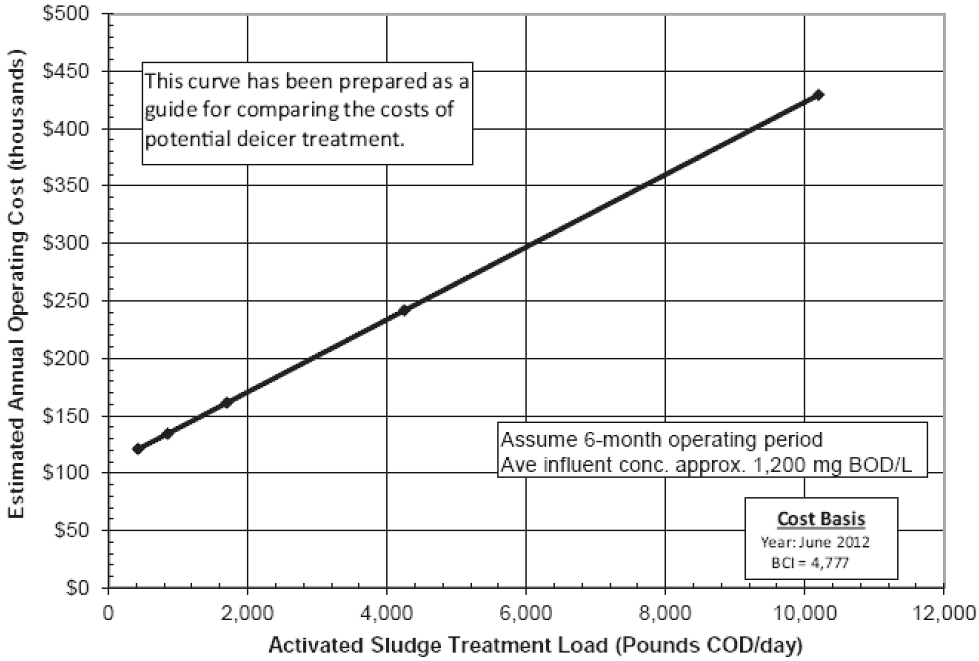
Operations and Maintenance Costs

Figure 3 provides guidance on activated sludge O&M costs per pound of COD mass load treated. Costs include labor, utilities, and chemicals.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 2. Activated sludge capital cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 3. Activated sludge O&M cost curve.

FACT SHEET 39

Passive Facultative Treatment Systems

1. Description

Purpose

Passive facultative treatment (PFT) systems are used to treat runoff impacted by aircraft and airfield deicers onsite. This category includes lagoons, wetlands, sand and gravel filters, in situ soil treatment, and similar approaches that provide passive removal of deicing compounds from stormwater. Although PFT systems are sometimes referred to as “natural treatment systems,” use of that terminology does not sufficiently differentiate these technologies from other biological treatment technologies, which also rely on naturally occurring biology (*ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*).

Technology

PFT systems are among the lowest maintenance deicer treatment systems because the treatment function usually occurs in relatively simple environments rather than engineered and controlled reactors. However, high performing PFT systems require management and control of the flows to the soils to ensure flow rates and concentrations do not exceed levels that result in bacterial inhibition and poor performance. Control features can include metering pump stations, hydraulic control structures, and monitoring. Nutrients are necessary for bacteria in PFT systems to function, but soils may provide the necessary nutrients if flows and BOD loadings are controlled. If not, nutrient feed systems may be necessary for optimal operation. Biological degradation occurs over a range of oxygen levels, treating generally at the rate that it would occur naturally in the environment.

PFT systems include a number of technologies. Surface flow wetlands rely on diffusion of oxygen between air and water and require a large surface area for treatment of the deicer. Because oxygen is obtained from the atmosphere and not supplied, wetlands are not efficient and require much larger surface areas than systems like aerated gravel beds in which oxygen is supplied to the bacteria by mechanical means.

Non-aerated lagoons, also known as facultative ponds or polishing ponds in conventional wastewater treatment, treat deicer in three zones. Aerobic degradation occurs at the surface of the pond, anaerobic degradation occurs at the bottom of the pond, and a facultative zone exists in the intermediate depth where either aerobic or anaerobic treatment can occur.

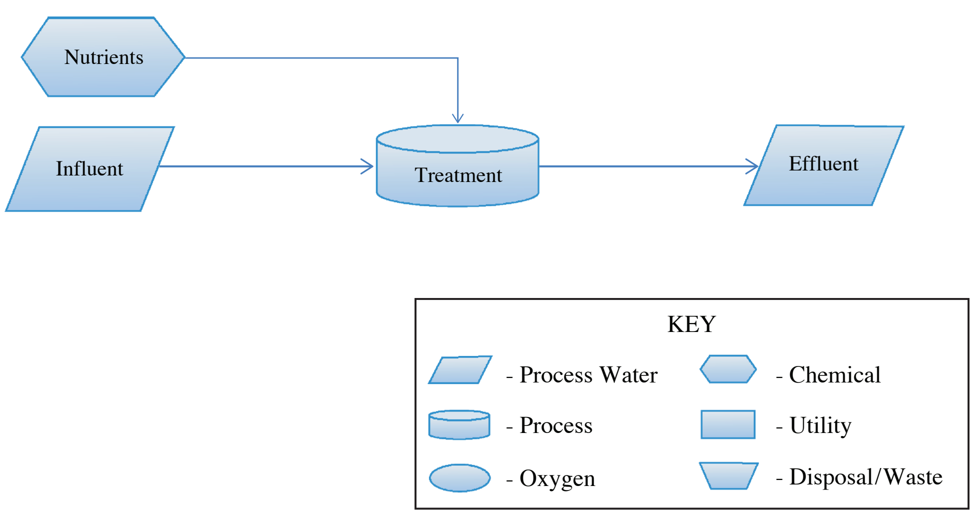
In situ soil treatment relies on bacteria in soil to degrade the organic compounds in deicers. Since the treatment is limited based on the oxygen transfer below ground, the area required is typically large.

The most common passive facultative treatment system implementations at airports are constructed subsurface-flow wetlands and land application systems. These technologies are often utilized for treatment of lower concentration of deicers and combined with other technologies for treating high concentrations of deicers. Figure 1 illustrates the process flow diagram for PFT systems.

Documented Performance

Available performance data are limited to the sites shown in Table 1 and summarized in the following paragraphs:

- Lester B. Pearson International Airport (YYZ) utilities a three-cell wetland system consisting of a sedimentation basin, 1-acre subsurface vertical flow reed-bed wetland system, and 3.4-acre surface horizontal flow reed-bed wetland for storing and treating runoff designed to achieve a 73% reduction in BOD. (YYZ also utilizes recycling and the local POTW for high concentrate stormwater.)
- Heathrow International Airport (LHR) utilizes a floating reed bed, and then a 2-hectare horizontal subsurface aerated gravel bed filled with reeds. Forced bed aeration and nutrients are used to promote bacterial growth and the degradation of hydrocarbons found in the ADF. Treated effluent is discharged to surface waters or a wastewater treatment plant, depending on glycol concentration. The design flow of the system is 6,900 m3/day, and the treatment capacity of the system is 3,500 kg BOD/day.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Process flow diagram for PFT systems.

Table 1. Examples of passive facultative treatment system size and type.

Airport	Construction	
	Size	Type
Toronto, Canada	1.0 ac 3.4 ac	vertical subsurface flow horizontal surface flow
Heathrow, United Kingdom	5.1 ac 2.5 ac	subsurface flow floating mat
Washington Dulles, Virginia, United States	5 cells, 0.25–1 ac	cells
Zurich, Switzerland	52 acres	spray irrigation system

- Washington Dulles Airport (IAD) utilizes in situ soil treatment through five vertical flow treatment systems for treatment of fugitive deicing stormwater from a runway and taxiways. Each system is between .25 and 1.00 acre. (IAD also utilizes recycling and the local POTW for high concentrate stormwater collected from deicing pads.)
- Zurich International Airport (ZRH) utilizes in situ treatment through infiltration basins for low concentrate stormwater (less than 50 mg/L dissolved organic carbon, and in situ soil treatment through a spray irrigation system over a 52-acre area for mid-concentrate stormwater (50 to 10,000 mg/L dissolved organic carbon). The spray irrigation system is regulated with specific conditions limiting its use and requires intense monitoring and control. (ZRH also utilizes distillation for high concentrate stormwater.)

2. Implementation Considerations

Applicability Assessment

Land requirements are the major consideration in assessing the potential applicability of PFT systems. Land requirements depend on the type of technology, influent runoff quality, required effluent quality, drainage area treated, and local climate.

It is also important to consider the existing drainage infrastructure to determine if a PFT system will fit within the confines of the airport, and if the flow must be pumped or conveyed by gravity.

Available information indicates that passive facultative systems can treat runoff concentrations of up to 10,000 mg/L TOC (ZRH) for highly controlled large installations. Typical PFT installations are designed for incidental airfield, fugitive, or low concentration stormwater (<1,000 mg/L COD).

Regulatory Considerations

Bird airstrike hazards are a critical safety consideration at airports. Because most passive facultative systems involve applying stormwater to a grass or soil surface, the potential for creating wet areas and increasing wildlife attractiveness should be carefully considered.

Planning and Design Considerations

No standardized model exists for the design of PFT systems for aircraft and airfield deicer removal. If an airport is considering a PFT system, pilot testing or phased implementation of a full scale with testing is recommended because performance is highly site-specific. Site variables include local climate, soil characteristics, stormwater runoff characteristics, degree of control of influent flows, and the general lack of standard design guidelines for PFT systems.

The need for reliable performance during cold weather and minimized wildlife hazards poses significant challenges to PFT system applications at airports. However, methods are available to address these concerns. Vegetation species can be chosen that pose minimal or less desirable waterfowl food sources. Surface water drawdown durations within the treatment system can be reduced to minimize habitat value to water fowl. Finally, the vegetation in some PFT systems may be mowed regularly to avoid forming large stands that could represent attractive habitat. *ACRP Report 125: Balancing Airport Stormwater and Bird Hazard Management* provides additional guidance on designing stormwater management structures to minimize bird strike hazards.

Hydraulic surface flow routing is a critical design factor in delivering runoff to the PFT system. PFTs are often sited downgradient of the sources of runoff to be treated to avoid pumping. Existing drainage systems may require modification to accommodate this practice.

Integration with Other Practices

PFT systems can be combined with other practices as part of an integrated system. Frequently, the highest-strength runoff is isolated and collected for recycling or other suitable biological treatment, and lower strength runoff is routed to the PFT system. Conveyance design may also provide opportunities to incorporate benefits such as solids settling.

Operation and Maintenance Considerations

PFT systems typically require less maintenance than other treatment practices. With favorable conditions and proper design, there are very few moving parts in these systems.

A trained operator who understands the operating principles and conditions of the system will be required. Monitoring, nutrient addition, and control of flows through the PFT system may be required to manage treatment rates to meet required effluent concentrations. It is not likely that passive, uncontrolled discharges to PFT systems will meet performance goals.

Table 2. Examples of passive facultative treatment system capital costs.

Airport	Construction	Year
Washington	$1,500,000	2008
Toronto	$2,000,000	2001
Zurich	$31,000,000	2000
Heathrow	$20,000,000	2001

Biological activity is significantly reduced in cold temperatures, and storage in winter and treatment in summer may be required in colder climates. Vegetation management may be required to minimize bird airstrike hazards, or to maintain appropriate hydraulic flow conditions. Mowing or hand cutting during the summer may be required.

3. Costs

Construction costs of full-scale PFT systems to treat deicing fluids vary depending upon size, flow, and operating season. Cost data presented here are for preliminary guidance only.

Capital Costs

Table 2 summarizes available capital cost data. Per-acre costs vary from $543,000 to $2,000,000.

Operations and Maintenance Costs

Average annual reported operating costs for a PFT system facility vary widely depending upon the type of system. There is typically a strong correlation between O&M costs and performance. More highly controlled systems can have O&M costs in excess of $100,000 per year as of 2012. Less controlled systems can have significantly lower costs, but typically do not have the ability to treat higher concentrations flows or produce consistent results. Maintenance activities may be included with other site operation activities with negligible cost effect.

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FACT SHEET 40

Membrane Filtration

This fact sheet has been retired.

FACT SHEET 41

Glycol Recovery

1. Description

Glycol recovery is a disposal practice that includes a variety of technologies aimed at recovering the glycol in deicer-affected stormwater for reuse or sale. This practice is different from technologies described in other fact sheets in that outside entities will typically select, configure, own, and operate glycol recovery systems, often with the facilities located offsite from the airport. For that reason, the information in this fact sheet is organized somewhat differently than the others in the *ACRP Research Report 14*, second edition compilation.

Purpose

Recovered glycol may be used as "feed stock" for products such as coolants, coatings, paints, and plastics. In Europe and at some U.S. airports, recovered glycol is reformulated as aircraft-deicing fluid after certification that it meets all SAE AMS 1424 specifications. Other airport uses for recovered glycol include anti-freeze for maintenance trucks and aircraft lavatory fluid. The market for recycled glycol is linked to the oil markets. When oil prices are low, glycol can be produced from petroleum at lower prices, which makes recycled glycols from deicers less attractive economically.

Technologies

Glycol recovery is typically achieved through implementation of one or more of the following technologies:

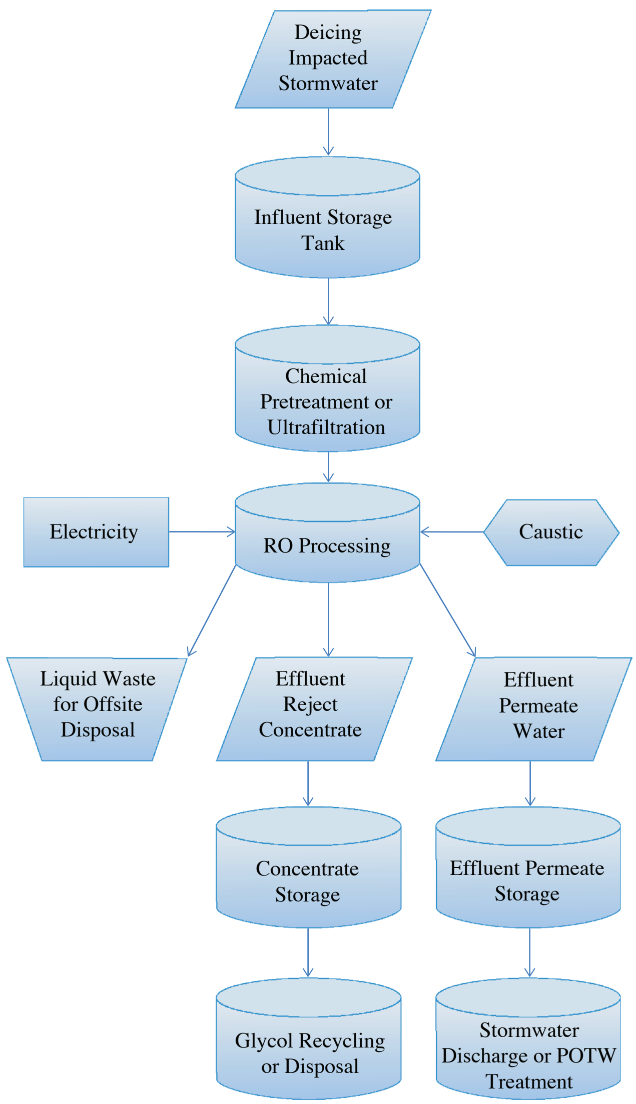
- Reverse osmosis (RO) (typical influent >1% and effluent 8–12% glycol);
- Mechanical vapor recompression (typical influent 8–12% and effluent 40–50% glycol); and
- Distillation (typical influent 40–50% and effluent >99% glycol).

Decisions on which technologies to implement at a given airport are based on the influent characteristics, quantities of glycol that can be reclaimed, availability of regional processing facilities, costs recovered from recycled glycol based on market conditions, and overall processing costs. These technologies may be used separately or in series to recover glycol from stormwater at varying concentrations. For example, if glycol concentrations in collected runoff are less than 8% and the desired target concentration is greater than 99%, reverse osmosis, mechanical vapor recompression, and distillation might be applied in series. If glycol runoff concentrations are above approximately 8% and a 50% glycol target is required, mechanical vapor recompression alone might be sufficient. Other combinations are possible and typically dependent on economics and site constraints.

The concentration and flow ranges suitable for the glycol recovery technology is compatible with glycol recovery vehicle and deicing pad collection systems because those systems provide higher initial concentrations of glycols. The following sections provide overviews of each of the three glycol recovery technologies. Detailed information on applicability, regulatory considerations, planning and design considerations, operation and maintenance considerations, and cost for each of the technologies may be found in *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*.

Reverse Osmosis

RO utilizes a semipermeable membrane along with high pressures to separate glycols from deicer-affected stormwater. The core elements of the RO treatment process are shown in Figure 1. RO employs membrane filtration to physically



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

Figure 1. Flow chart of RO process.

separate dissolved substances based on molecular size. The membranes have pores that allow water molecules to pass through while blocking larger molecules, such as glycols and other deicer constituents. High pressures are used to encourage the passage of water through the membrane. The result is increased concentrations of glycols and other deicers in the concentrate (reject) stream and reduced concentrations in the dilute (permeate) stream. Higher influent glycol concentrations result in higher permeate glycol concentrations, slowing the processing rate per unit.

Components of a RO treatment system include pretreatment to remove suspended solids and hydrocarbons, chemical feed for pH adjustment and scale control, a higher pore size membrane filtration upstream of the RO unit such as ultrafiltration, the RO treatment train, and a system for membrane cleaning. The influent may be heated to optimize the removal efficiency.

RO can serve two different purposes in glycol recovery, depending on the concentration of stormwater collected:

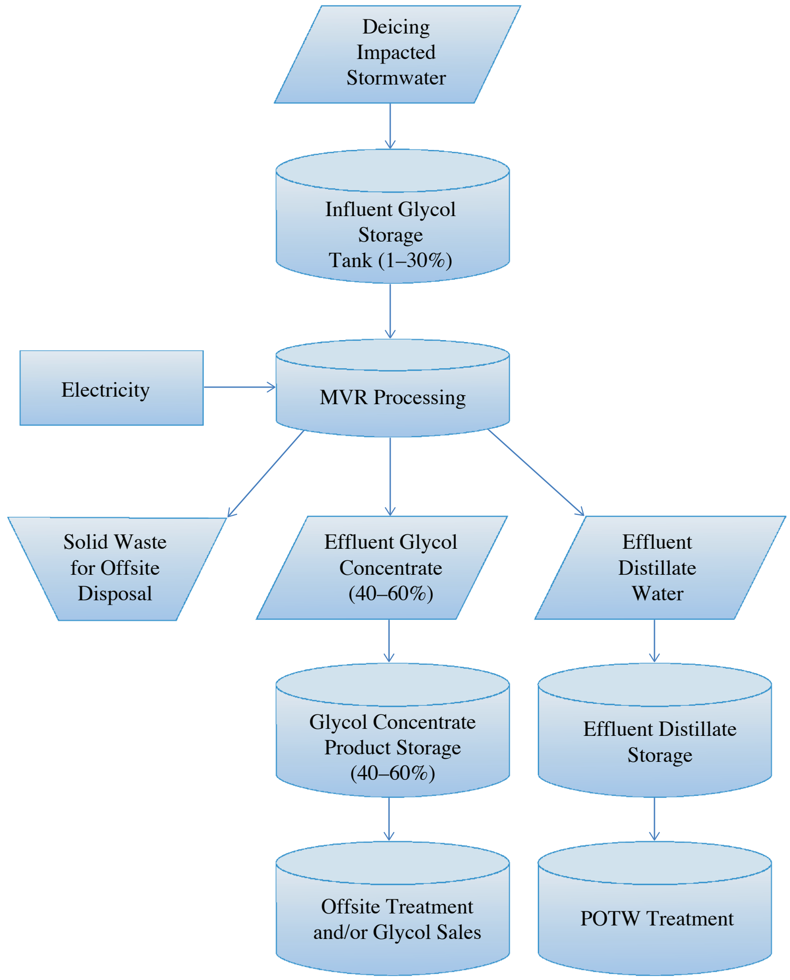
- 0.1%–5% glycol – To remove large volumes of water quickly from storage tanks to separate higher concentrations of glycol to be recycled or disposed of. This produces a concentrate (reject) stream between 2% and 10% glycol, which can then be further recovered utilizing another glycol recovery technology. The dilute (permeate) stream may have a concentration of propylene glycol (PG) in excess of local discharge limits and may require further onsite treatment or discharge to a publicly owned treatment works (POTW). Generally, to make glycol recovery economically viable, influent concentrations should exceed 1% glycol.
- 0.01%–1.5% glycol – To reduce the concentrations in stormwater for discharge of the dilute (permeate) stream to stormwater outfalls or to POTWs with stringent discharge requirements. This results in a lower volume of concentrate (reject) to be managed through another form of onsite treatment or discharge to a POTW.

For more information on RO technology, see *ACRP Report 99*, Fact Sheet 111.

<u>Mechanical Vapor Recompression</u>

Mechanical vapor recompression (MVR) is a physical process where deicer-affected stormwater is heated, and the water is separated from the deicer based on the difference in boiling points. The core elements of the MVR process are shown in Figure 2. MVR systems are typically designed to concentrate influent glycol mixtures of 1% to 30% glycol. The stormwater influent is normally preheated through heat exchangers before entering the evaporation tank. Once evaporated, the glycol/steam mix enters a cyclone where steam separates and higher concentrate glycol is recovered. The effluent product is a concentrated glycol-containing stream typically 40% to 60% glycol, while the effluent distillate contains low levels of COD and is generally discharged to a POTW or treated onsite (*ACRP Report 99*). For more information on distillation technology, see *ACRP Report 99*, Fact Sheet 106.

The primary benefits of an MVR system are the ability to concentrate glycols for possible resale or reuse. The system runs most efficiently when influent



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*

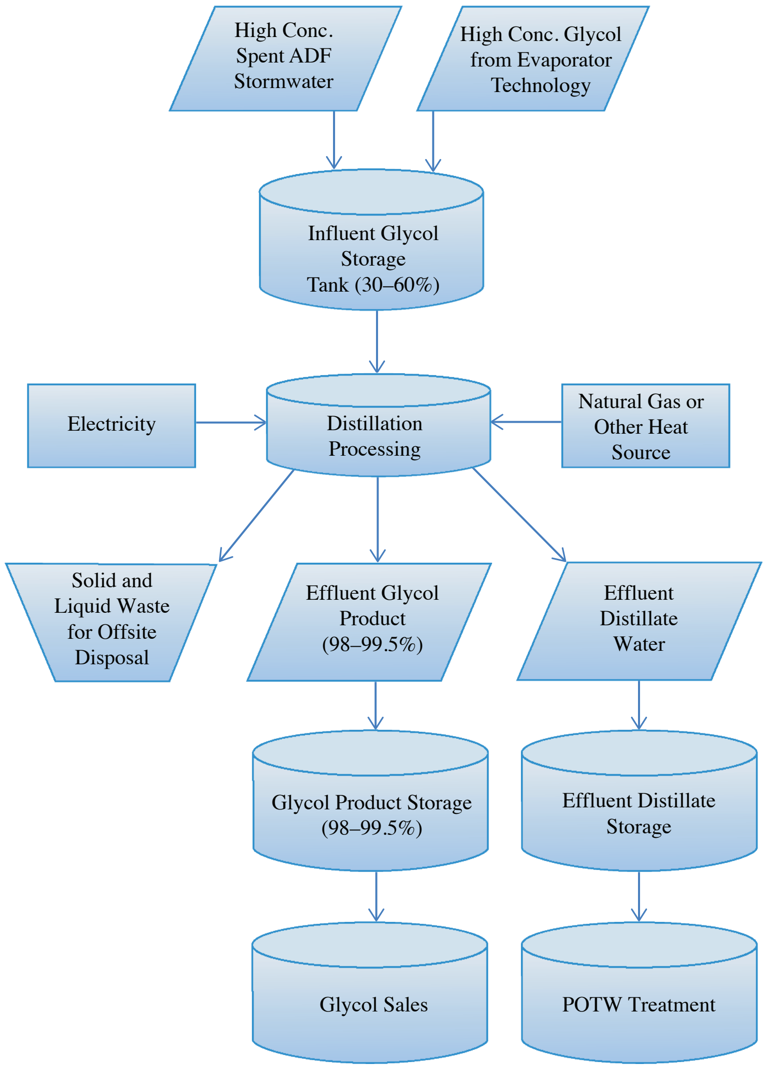
Figure 2. Flow chart of MVR process.

glycol concentrations are between 8% and 15% glycol, which is why MVRs are often paired with RO systems for glycol recovery. Additionally, effluent concentrations of the distillate range from 50–1,000 mg/L COD. Effluent can be treated onsite with a separate biological treatment process or sent to the POTW. MVR systems run 24 hours a day, 7 days a week during deicing season except during maintenance and cleaning. MVR units can be constructed on- or off-site and be delivered.

Distillation

Distillation is a physical treatment process where deicer-affected stormwater with very high glycol concentrations is subjected to heat or pressure variations that cause evaporation and separation of water from the glycol. The result is an end product that is nearly pure glycol.

The core elements of the distillation process are shown in Figure 3. Distillation is typically a continuous process ranging from a single-stage to three-stage



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers,* Fact Sheet 105

Figure 3. Flow chart of distillation process.

system with columns or towers. The stormwater influent is normally preheated through heat exchangers before entering the vacuum distillation towers due to the separation method being energy-intensive. A re-boiler is used to provide heat to the bottom of the distillation column(s) to generate vapors from the liquid, which return to the column to drive physical separation. The water vapors exit from the top of the columns, and the heaviest products (glycol and other organics), exit from the bottom of the column. The effluent glycol product is typically >99% glycol concentration, and the low concentrate effluent distillate contains glycol and other organics that must be discharged to a POTW or treated onsite. The bottoms, or the residual waste produced, is normally trucked offsite for disposal (*ACRP Report 99*). For more information on distillation technology, see *ACRP Report 99*, Fact Sheet 105.

Documented Performance of Glycol Recovery Systems

Many airports in North America have implemented glycol recovery programs at various scales. Examples of a few of the larger programs are discussed in the following paragraphs.

Detroit Metropolitan Airport (DTW) collects spent deicing fluid runoff generated in all areas where aircraft deicing is conducted and segregates this runoff from that generated from runway, taxiway, and grassy areas. Runoff containing PG concentrations greater than 2% is hauled to a private facility located approximately 5 miles from the airport where processing is conducted (evaporation and distillation) to generate a 99.5+% industrial grade PG. Runoff containing less than 2% PG is discharged to two POTWs.

Dallas/Fort Worth International Airport employs RO of deicing runoff to meet surface water discharge limits for glycol. The system includes bulk solids removal, ultrafiltration to remove oil, grease and turbidity, and then a three-stage RO to concentrate glycols. The dilute (permeate) stream, with glycol concentrations of less than 30 mg/L, is discharged to an offsite treatment plan and the concentrate (reject) stream, with up to 15% glycol is transported for further processing offsite. The RO facility cost $14.1 million and was completed in 2003, with a capacity of 208 gallons per minute and 26 million gallons a season.

Bradley International Airport utilizes a two-stage RO process along with MVR units and discharge to the local POTW. Stormwater less than 4% glycol undergoes chemical pretreatment and ultrafiltration before being processed in the first RO unit. The concentrate (reject) stream, along with runoff collected that is greater than 4% glycol is treated by the MVR. The dilute (permeate) stream from the first RO unit and the distillate (permeate) stream from MVR is processed in the second RO unit. The dilute (permeate) stream from the second RO unit is discharged to surface waters. Bradley International Airport treats over 10.5 million gallons annually through the RO units; the units process between 40 and 50 gallons per minute.

Salt Lake City International Airport utilizes RO to treat concentrated (>1–2% glycol) stormwater. Stormwater is pretreated using pH adjustment, oil water separation, waster softening, ultrafiltration, and ion exchange. The dilute (permeate) stream from the RO process is discharged to the local POTW and the concentrate (reject) stream is further processed in an MVR and distillation column. Finished glycol product is 99% glycol.

Pittsburgh International Airport utilizes RO to treat concentrated (1–4% glycol) stormwater. The concentrate (reject) stream is sent offsite for further processing.

Denver International Airport collects runoff greater than 1% glycol from its deicing pads for recovery. Runoff is treated in eight MVR units to 40–50% glycol. Each MVR processes between 3,000–5,000 gallons per day. The concentrate stream from the MVR units is further processed in a distillation system to produce 99% propylene glycol concentrate stream. The distillation system processes 14,000–18,000 gallons per day. Distillate from the MVR and distillation units is discharged to the local POTW. The system includes a hot filter system on the influent to the MVR units, and an activated carbon filtration system on the influent to the distillation system to remove solids. The system also includes a glycol polishing system to further remove trace contaminates after distillation.

A recent development in glycol recovery was the establishment of a recovery plant at the Portland International Jetport in Maine that manufactures certified Type I aircraft deicing fluid and aircraft lavatory antifreeze from PG distilled onsite from deicing runoff collected at the airport and brought in from other airports in the northeast United States. This operation is a partnership between the airport and a glycol recovery service provider. The airport owns the recycling/processing facility and associated storage tanks, and the service provider owns the processing and blending equipment inside the facility, and operates the plant. The airport and service provider share in the sales of the deicer and lavatory fluid products and fees from other airports for accepting their deicing effluent.

2. Implementation Considerations

Applicability Assessment

The feasibility of glycol recovery is dependent on collecting sufficient volumes of adequately high concentrations of glycol in runoff to reach an economically sustainable scale.

- Mixed-glycol streams are generally impractical to recycle because the resulting product has a very low market value. This means that only propylene glycol–based aircraft deicing fluid (ADF) and aircraft anti-icing fluid (AAF) may be used in the areas where deicing runoff is to be recycled to ensure the highest value of the recovered material.
- A critical criterion for recycling is collection of runoff with glycol concentrations that are high enough to make recovery economical. Minimum concentrations should be at least 1%, whereas average concentrations should be significantly higher. Implementation of source reduction deicing technologies may result in lower collection concentrations, which can affect the economics of glycol recovery.
- The volume of high-concentration runoff that is collected will determine the feasibility of onsite processing versus offsite transport for processing. Only the largest airports are likely to generate the volume of concentrated runoff necessary to support onsite-processing facilities.
- Smaller airports may be able to implement recycling if they are able to transport collected runoff economically to a recycling facility that serves other airports and/or industries. If the runoff volumes are large enough, limited onsite processing to reduce water content may make transport for further processing at an offsite facility more economically feasible.
- It is technically feasible to recover glycol to concentrations in excess of 99%, although energy requirements and cost increase significantly with concentrations. Therefore, glycol is concentrated only as much as necessary to meet the needs of the reuse application.
- Relatively highly skilled operators are required, and airports often hire a contractor to operate these systems.

- If the concentrate stream from reverse osmosis is not further processed onsite or offsite for resale or reuse, disposal of the concentrate can be a significant factor in assessing applicability and cost.
- Mechanical vapor recompression and distillation are energy intensive processes and are typically not cost effective for average glycol concentrations less than 5%.

Regulatory Considerations

Waste streams from the recycling process, if performed on airport grounds, must be properly permitted and handled. This may require an industrial discharge permit for sanitary sewer discharges, and/or pretreatment and solids disposal.

Air emissions from over-the-road transport to offsite facilities may be of regulatory concern, depending on location.

Planning and Design Considerations

Several airports in North America have active glycol recycling programs. The strategies and scales of these recycling operations vary significantly, determined by site-specific factors such as volume and reliability of ADF usage, glycol concentrations in collected runoff, volume of high-concentration runoff, and proximity to processing facilities.

Practical onsite glycol recycling is generally restricted to airports where large volumes of glycol are used annually and where glycol is collected at high concentrations.

At smaller airports where onsite processing is not economically advantageous, access to an offsite recycling facility is necessary, and costs for transporting collected runoff may be a significant limiting factor.

Typically, a glycol recycling contractor implements this practice under an agreement with either the airport or an air carrier (or group of air carriers). The details of the contractual arrangements vary significantly. In the simplest cases, the contractor serves as a waste hauler, transporting collected runoff to an offsite processing facility. In the largest programs, the contractor may be responsible for all onsite collection, storage, handling, and processing activities.

Laboratory and pilot testing may be required to confirm treatment effectiveness, select membrane type for reverse osmosis, and develop design parameters.

Storage tanks are usually needed to hold processed fluids prior to further processing or transport offsite.

A destination for the processed glycol (concentrate), and means of disposal for the permeate, distillate, and other waste streams need to be identified.

Treatment system footprint for each glycol recovery technology is typically less than 1 acre. Height restrictions may be a siting concern for these technologies. Reverse osmosis facilities have a typical height of 12 to 16 feet, mechanical vapor recompression facilities have a height of 16 to 22 feet, and distillation facilities have heights of 20 to 30 feet. All glycol recovery technologies require electrical and water utility connections, and mechanical vapor recompression requires natural gas.

Proper pretreatment is essential to manage biofouling and avoid impacts on system efficiency and costs.

Integration with Other Practices

Glycol recovery and recycling relies on a collection system that is capable of consistently capturing significant volume of deicing runoff at or above 1% glycol.

The economic feasibility of recycling may be undermined by source control practices that reduce the volumes of ADF used and thereby reduce volumes and concentrations of deicing runoff generated.

Glycol recovery technologies are often implemented in conjunction with discharge to a POTW. The POTW may receive runoff that is above the surface water discharge limits, but not concentrated enough for glycol recovery. Dewatered solids, permeate, and distillate streams from glycol recovery processing may also be discharged to the POTW.

Operation and Maintenance Considerations

For implementations that involve offsite processing, the primary operation and maintenance considerations will involve temporary onsite storage, maintenance of a truck route and truck loading area, and tracking of high-concentration runoff prior to its transport offsite. Depending on the location of the storage site, a gated entrance for transport vehicles may be required.

Onsite glycol processing is typically operated by a contractor, who is responsible for setting up, operating, and maintaining the onsite equipment, facilities, and programs. Additional details on technology operation and maintenance are included in *ACRP Report 99,* Fact Sheets 105, 106, and 111.

3. Costs

Costs for implementing recycling are very site-specific, depending on the scale. Factors that affect cost include volume and glycol concentration of collected material and proximity and access to a processing facility (for offsite implementation).

There are some unique cost considerations when evaluating this practice. The benefits of employing glycol recovery as a practice for managing collected deicing runoff include reduced costs for POTW treatment, reduced dependence on POTW capacity, and the potential for cost recovery in the form of income from the value of the recovered glycol. At DTW, a contractor pays the airport an annual fee for the right to “harvest” glycol from runoff collected at centralized deicing facilities, plus additional fees for harvested glycol above a stipulated minimum volume recovered for the season. However, the potential income from recovered glycol fluctuates based on market forces and the current value of the processed glycol product.

Capital Costs

For onsite implementation, although most airports choose to contract with a vendor to "harvest" glycol and process onsite, some airports choose to construct their own facilities and hire operators. The following information applies if the airport constructs the onsite facility. If the facility is constructed and some equipment is owned by a contractor, the airport is responsible for providing a suitable site.

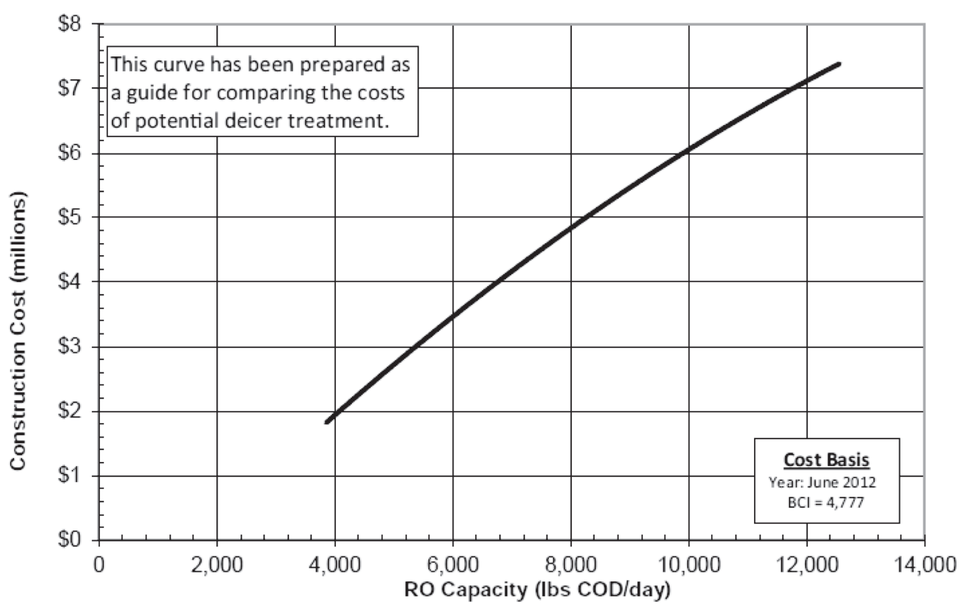
Figure 4 provides guidance on capital costs per the capacity of the RO system, including land acquisition, membrane filtration units, internal pumps and pipes, control systems, and a building.

Figure 5 provides guidance on MVR capital costs per pound of COD mass load treated.

Figure 6 provides guidance on distillation capital costs per pound of COD treated per day. The capital cost curves reflect the unit processes that are most typically needed to execute the core technological functions. Individual airports may incur additional costs, beyond those determined for these curves, for solids handling and disposal, distillate waste treatment, and support system items based on site-specific needs and owner preference.

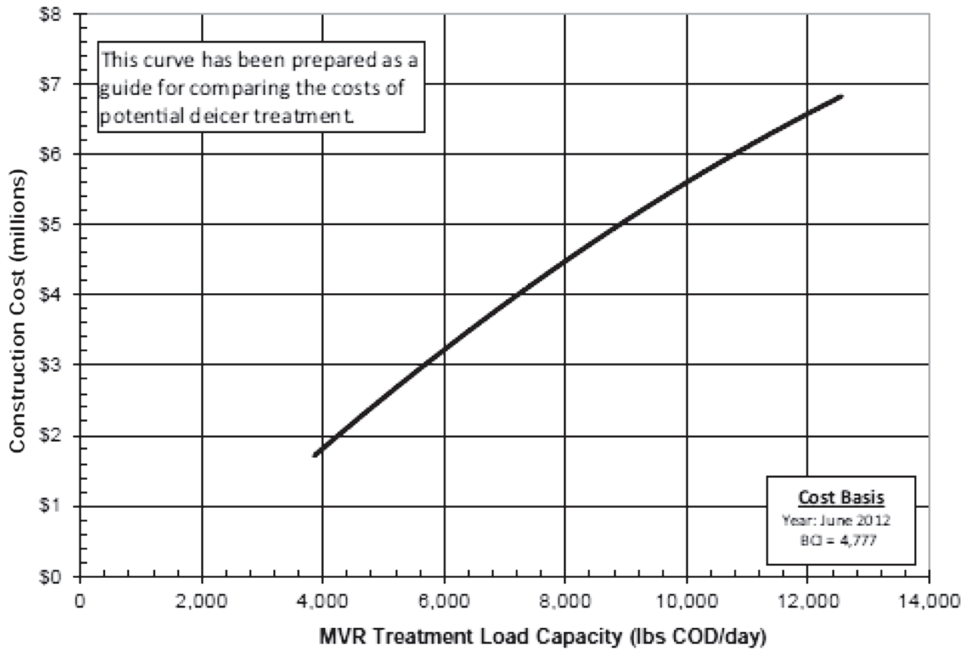
Operations and Maintenance Costs

Glycol recovery is an energy-intensive process, and there are multiple waste streams that need to be managed. An airport should make sure that the contract with the vendor is clear about who is responsible for utility and disposal costs associated with operating the system. The following figures provide information on operations and maintenance costs for each technology.



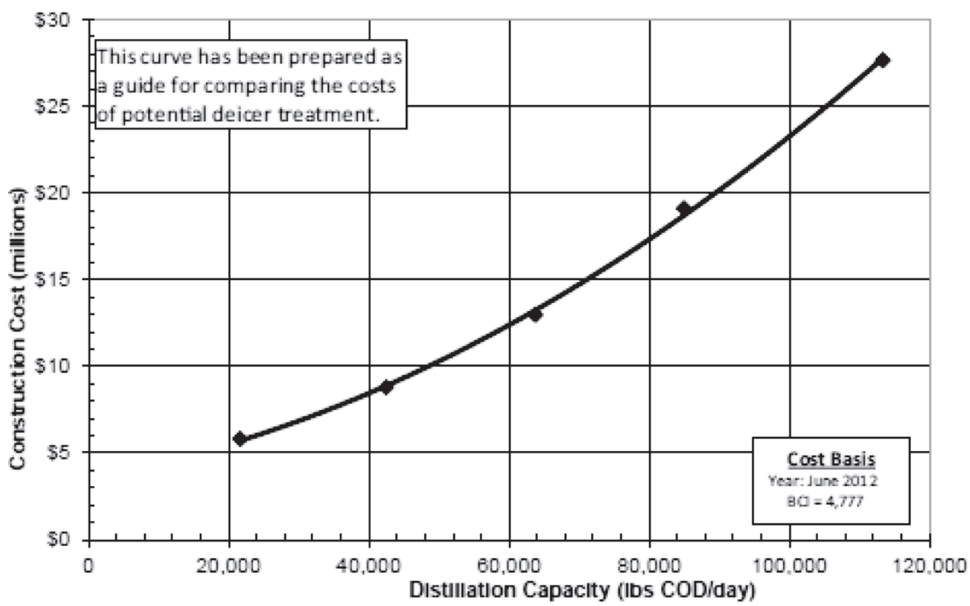
Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 111

Figure 4. RO capital cost curve.



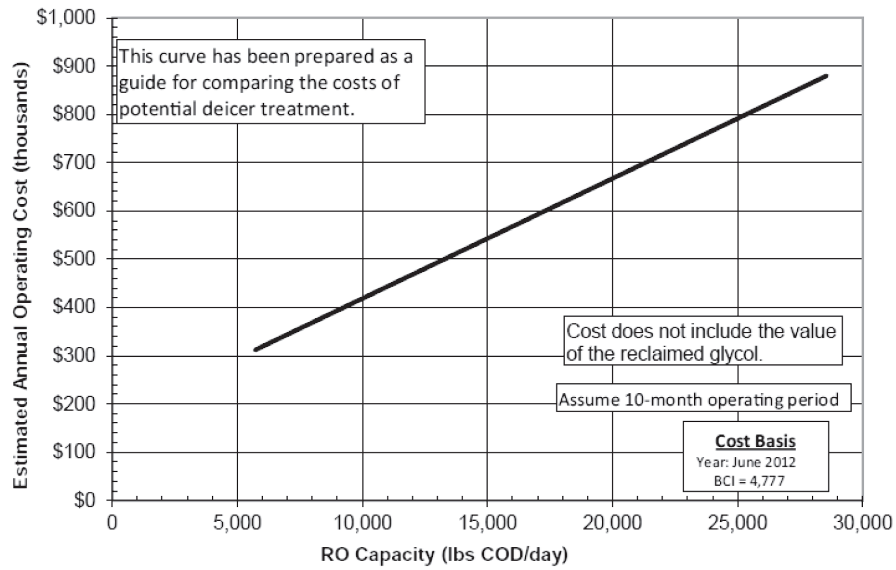
Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 106

Figure 5. MVR capital cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 105

Figure 6. Distillation capital cost curve.

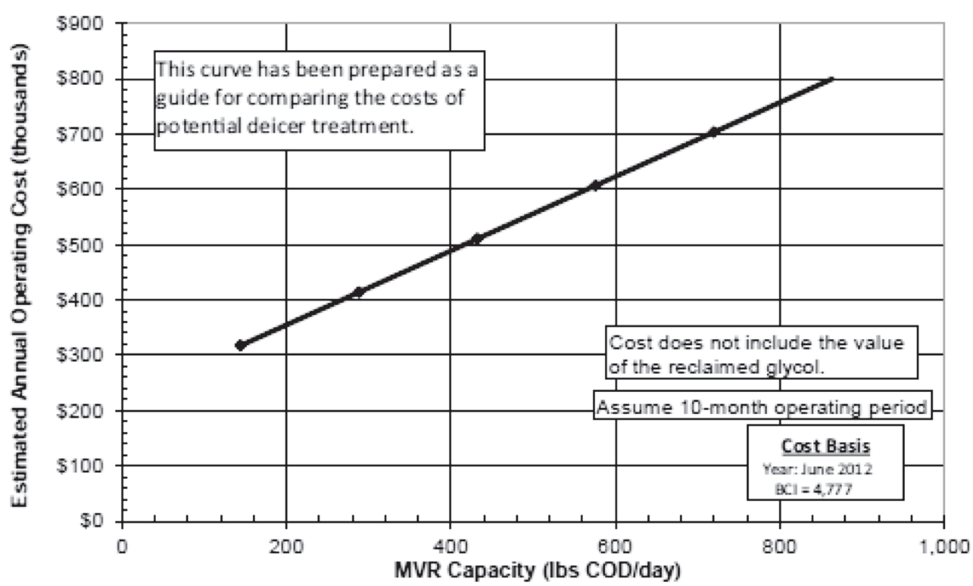


Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 111

Figure 7. RO O&M cost curve.

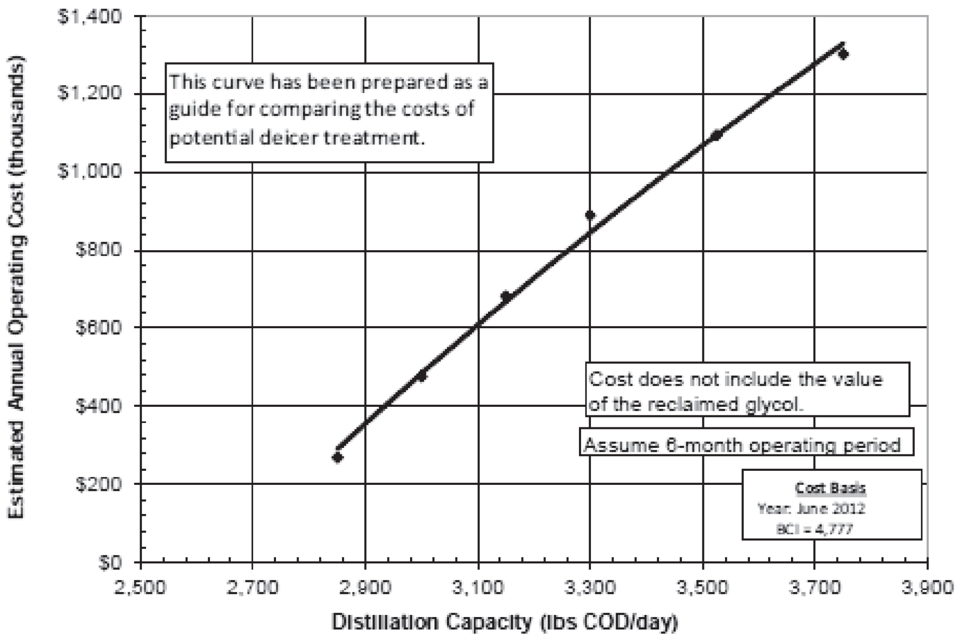
Figure 7 provides guidance on O&M costs per the capacity of the RO system. Operating and maintenance cost items include labor, utilities, solids disposal, and distillate discharge to sanitary sewer.

Figure 8 provides guidance on MVR O&M costs per pound of COD treated per day. Operating costs include labor, solids disposal, utilities, and distillate discharge to the sanitary sewer.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 106

Figure 8. MVR O&M cost curve.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 105

Figure 9. Distillation O&M cost curve.

Figure 9 provides guidance on distillation O&M costs per pound of COD treated per day. Operation and maintenance costs include labor, solids disposal, utilities, and distillate discharge to the sanitary sewer or treatment.

Reference

EPA. 2000. Preliminary Data Summary: Airport De-Icing Operations. *EPA-821-R-00-016.* From http://www.epa.gov/waterscience/guide/airport/.

FACT SHEET 113

Low Flow Nozzles

1. Description

Purpose

This fact sheet describes the use of low flow aircraft deicing fluid (ADF) application nozzle technology that uses a reduced amount of ADF as compared to standard nozzles. Low flow nozzles may be used on most existing deicing trucks as an immediate low-cost method of improving the efficiency of ADF application and reducing ADF usage.

Technology

Although specific models will vary, a typical low flow nozzle has flow rates that can vary between 11 and 40 gallons per minute (gpm), compared to conventional fixed flow nozzles that typically are between 50–60 gpm. Some variants of the low flow nozzles maintain a constant pressure over a range of flow settings. Low flow nozzles that change the pressure to regulate the flow can result in higher pressures that are not applicable for all aspects of deicing.

Documented Performance

Low flow nozzles, particularly constant pressure variable flow nozzles, have been shown to deice aircraft in the same amount of time and as effectively as conventional nozzles. Constant pressure low flow nozzles are able to maintain a useable stream while flow is being adjusted. An additional benefit is that it moderates fluctuations in flow due to truck systems.

Nozzles that decrease flow by increasing pressure (similar to placing your thumb over the end of a garden hose) have been shown to be useful to penetrate more resilient snow and ice, such as refrozen snow.

Some nozzles deliver flows as low as 11 gpm, which is applicable to aircraft defrosting operations. These nozzles have been reported to result in significant reductions in ADF used in defrosting operations compared to conventional nozzles.

Specific glycol savings are difficult to estimate because it varies for each user depending on flow rates used and fleet composition. However, because low flow nozzles are generally capable of deicing an aircraft in the same amount of time as higher flow nozzles, operators should be able to estimate their glycol savings by estimating glycol use as a function of flow and time taken to deice an aircraft.

2. Implementation Considerations

Applicability Assessment

This technology is directly applicable to operators who have the responsibility for selecting and using ADF application technology that meets all requirements for maintaining aircraft safety.

Older generation trucks with original nozzles may have flow rates as high as 50–60 gpm. Some trucks also have the capability of using multiple nozzles and switching between them. Using low flow nozzles as either the sole nozzle or as an option on a multi-nozzle truck allows for a reduction in applied ADF volume. This option is often cited as low hanging fruit when considering options for reducing glycol consumption and is particularly applicable to improving the efficiency of older generation trucks.

Regulatory Considerations

There are no regulatory considerations that directly affect this practice. However, aircraft must be free from contamination before takeoff, and the exclusive use of low flow deicing nozzles may make it difficult to meet these requirements in a timely manner under severe winter conditions.

Planning and Design Considerations

The following factors should be considered in planning for low flow nozzles:

- Existing deicing equipment that can accommodate low flow nozzles.
- Size and configuration of aircraft.
- Time requirements associated with reduced flow nozzles (particularly during severe weather conditions).
- Additional training for personnel.

Integration with Other Fact Sheets

Low flow nozzles may be employed in association with forced air/fluid (Fact Sheet 5) or blending to temperature (Fact Sheet 4) to further reduce ADF use.

Operation and Maintenance Considerations

Low flow nozzles are compatible with the majority of existing trucks and their installation is generally uncomplicated. Compatibility should be confirmed before switching/supplementing low flow nozzles on trucks equipped to monitor real time ADF use to ensure accuracy. Pumping systems for trucks may have to be adjusted to meet flow and pressure ratings for specific nozzles.

Higher pressure low flow nozzles may be impractical for use in anti-icing operations because the higher pressure may result in uneven fluid application or exceedance of allowable sheer stress on the fluid.

Care should be taken when using low flow nozzles in conjunction with blending to temperature or forced air/fluid technologies to ensure that temperature buffers are met. Holdover time is a function of volume of fluid on the aircraft and the temperature of the fluid. Therefore, if the volume of the fluid is reduced (and subsequently the inherent total heat) holdover time will also be reduced. This problem may be amplified when deicing aircraft where the skin of the aircraft is colder than normal, for example, from having flown long distances.

3. Costs

Capital Costs

The primary cost associated with this technology is the initial purchase of the nozzles, which as of 2017 is on the order of $200 each. Although installation is relatively simple, details vary with the make and model of the trucks and selected nozzles. Total initial costs will depend on fleet size. Truck pump modifications may be necessary depending on the specific truck and nozzle pairing. Additional system adjustments may add to the initial cost.

Operations and Maintenance Costs

Beyond initial cost to purchase and install this technology, there are not considered to be any significant additional costs. This procedure provides the potential for savings through reduction in deicing fluid usage.

FACT SHEET 114

Pumping Systems

1. Description

Purpose

This practice provides a means of conveying deicer-laden stormwater runoff to storage or treatment facilities.

Technology

The design of pumping systems for conveying deicer-laden stormwater runoff follows conventional pumping system design principles. Pumping system sizes vary from tens of gallons per minute (gpm) to thousands of gpm. Pumping systems are used when stormwater conveyance by gravity is no longer possible or economically feasible. Typical pumps used for stormwater conveyance can be classified into three types: submersible, vertical shaft, and horizontal. The pumps typically discharge into a pipe called a force main. Because the flow in the force main is under pressure, the pipe can be smaller than a gravity flow pipe sized to handle the same flow and it can slope up as well as down.

Submersible pumps are close-coupled pumps driven by a submersible motor. Submersible pumps are designed to be immersed in water and are therefore self-priming. Pump impellers may be recessed (out of the flow) or in-flow designs. In-flow impellers are more efficient than recessed impellers, but they are also more susceptible to clogging from stringy material in the stormwater. Submersible pumps are available in a wide range of sizes. A disadvantage of submersible pumps is the need to pull them out of the wet well with a hoist to conduct basic maintenance like inspections and oil changes.

Vertical shaft pumps have a pump bowl immersed in the stormwater to be pumped connected by a vertical shaft to the pump motor located above the water level. Vertical shaft pumps can have a single-stage impeller that are used for pumping higher flow rates at relatively low heads. Multiple-stage impellers can be used to increase the head capacity of vertical shaft pumps. A primary advantage of vertical shaft pumps is easy access to pump motor. The primary disadvantages to vertical shaft pumps include need of a crane to lift the pump to access the pump bowl, relatively long drive shaft that can require expensive maintenance, and generally louder operation compared to submersible pumps.

Horizontal pumps have the pump connected to a motor by a horizontal shaft. This connection can be either close–coupled or frame mounted. The pump and motor are located in a separate structure, called a dry well, from the water to be pumped. The pump is connected to the structure where the water is located, called a wet well, by a suction pipe. If the pump is located below the water level in the wet well, it is called a flooded suction and if the pump is located above the water level in the wet well it is called a suction lift. Suction lifts are typically limited to 15–18 feet. Advantages of horizontal pumps include ease of access to pumps and motors, lower capital cost for pumps and motors, and generally longer service life. The primary disadvantage of horizontal pumps is related to the expense of construction and maintenance of a separate dry well to house the pumps.

Documented Performance

Pumping systems offers a number of advantages over gravity sewers in some situations. Flow rate can be more easily controlled with pumping systems compared to gravity flow systems. The flow rate from a pumped system can be controlled by the number of pumps that are turned on and the speed at which they operate if the pumps are provided with variable speed drives. This is particularly important in situations where downstream facilities have limited capacity to receive the stormwater, like treatment facilities or conveyance systems subject to flooding. Routing force mains to convey stormwater is more flexible than gravity sewers. Force mains can change horizontal directions without access structures and can change vertical directions to avoid obstructions and limit the depth of pipe bury. Force mains are also typically a smaller diameter than the equivalent pipe diameter needed to convey flows by gravity, reducing the potential for conflicts with other buried infrastructure during installation.

2. Implementation Considerations

Applicability Assessment

Pumping systems are typically required when gravity sewer flow is not possible, gravity sewer installation cost becomes excessive, or there is a need for a high level of flow rate control. Considerations of operating costs, including power and maintenance are key in assessing whether to implement pumping systems.

Regulatory Considerations

Pumping system sizing, pump redundancy, emergency backup power, force main leakage, and safety are the primary concerns related to pumping systems regulations. Generally speaking, state regulations are more stringent when it comes to pumping system requirements, regardless of the agent.

Planning and Design Considerations

The following issues should be examined when considering the use of pumping systems to transport deicer-laden runoff:

- Hydraulic grade lines of collection system, storage facilities, treatment facilities, and discharge outfalls.
- Constructability of gravity sewers including groundwater conditions, presence of bedrock, and underground obstructions.

- Size of pumping system with sufficient capacity for deicer-laden runoff under design storm conditions. *ACRP Report 81: Winter Design Storm Factors for Airports* provides guidance for selecting proper design storm conditions.
- Size and configuration of wet wells for proper pumping hydraulics and allowance for maintenance.
- Selection of appropriate controls and communication equipment to allow effective operation, maintenance, and management of the pumping system.
- Provisions for emergency generator or back-up pumping system in the case of lost electrical service.
- Main size and material of construction for optimization of project life-cycle costs.
- Accessibility for maintenance.
- Costs.

Integration with Other Practices

Pumping systems are implemented as part of a glycol collection and treatment system, which typically incorporates a number of other practices from source reduction to containment, collection, treatment, and disposal.

Operation and Maintenance Considerations

Pumping systems generally have higher operation and maintenance requirements than gravity flow systems. Maintenance should be performed on the pumps and motors as recommended by the equipment manufacturers. This is likely to be at least annually on the pumps. If the pumps do not operate during the non-deicing season, the pumps should be exercised at least quarterly. The pumps and motors should be inspected for proper operation at least weekly during the deicing season.

3. Costs

Pumping system costs vary with the capacity of the system, complexity of control system, and type of facility for housing the pumping system.

Capital Costs

Pumping system prices vary widely based on the capacity, controls, and type of pumps. Submersible or vertical pumps with a pedestal-mounted control panel would be the least expensive, and horizontal pumps located inside a building would be the most expensive.

Operations and Maintenance Costs

Operations and maintenance costs associated with pumping systems include annual maintenance and power. These costs vary greatly based on the capacity of the system and how frequently it is used.

FACT SHEET 115

Aerated Lagoons

1. Description

Purpose

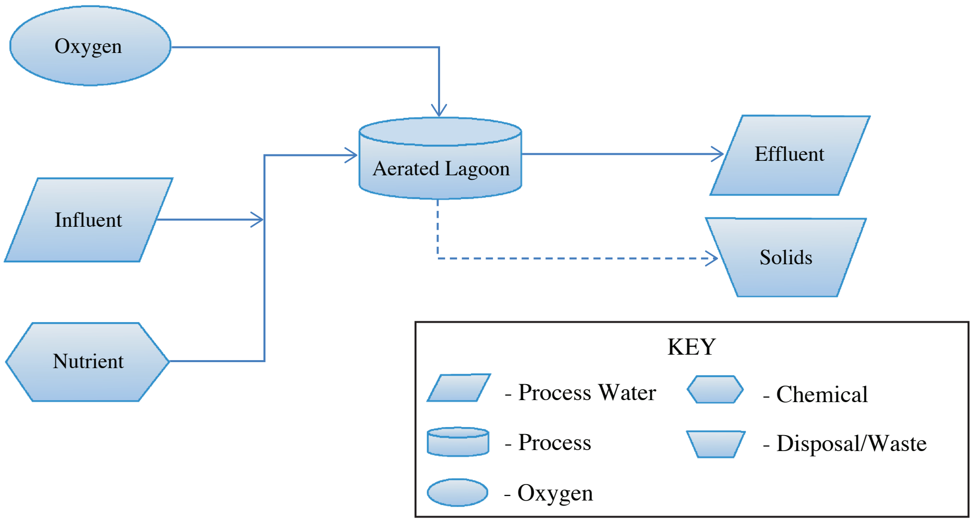
The aerated lagoons technology is a large-footprint biological process for treating deicer-impacted stormwater with low COD concentrations.

Technology

The core elements of the aerated lagoons technology treatment process are shown in Figure 1. Treatment occurs utilizing aerobic bacteria suspended in water within the lagoon that breaks down organic deicing compounds into water, carbon dioxide, and biological solids. Nutrients must be added to promote bacterial growth in deicing-impacted stormwater. Aeration for lagoons can either be mechanical (floating splash or aspirator type units) or diffused (submerged air compressor blown air). Aeration provides both air and mixing to promote biogrowth. Water levels in the lagoon are kept constant by hydraulic control structures at the outlet. Hydraulic residence time is controlled by these structures and is typically 2–3 days. Low-energy partial mix lagoons are large and aerated to meet oxygen demands. Bacterial solids generated are left to settle on the lagoon floor. Complete-mix lagoons provide more mixing and have solids generation uniformly created across the lagoon. Generally, effluent flows to a settling basin for solids separation. For more information on aerated lagoon technologies, please see *ACRP Report 99*, Fact Sheet 103.

Documented Performance

The aerated lagoon technology has been used at the following airport locations: Duluth Airport; London Gatwick; London Heathrow (13,000-lb COD/day, 2010); and Chicago Rockford International Airport. Performance of aerated lagoons treating deicer-laden stormwater has been mixed. Typically, lack of performance is due to insufficient nutrients, insufficient biomass, limited hydraulic residence time, or failure to adapt to cold temperatures. Aerated lagoon systems are best suited for treating water with low COD concentrations (below 2,000 mg/L COD). Treated effluent COD concentrations depend upon the degree of mass loading relative to system capacity, appropriate nutrient loads, temperature, and appropriate oxygen supply. Effluent concentrations from 30–100 mg/L COD can potentially be achieved under the right conditions, but performance is highly variable. COD and nutrient loadings into the system must be controlled. Control is best achieved through online monitoring and control of pumps with operator review and fine tuning.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers,* Fact Sheet 103

Figure 1. Aerated lagoons process flow chart.

2. Implementation Considerations

Applicability Assessment

The following aerated lagoon characteristics may affect applicability to a given airport:

- Influent concentrations below 2,000 mg/L COD are the best fit.
- System treatment slows significantly when temperatures are cold.
- Effluent concentrations in the range of 30–100 mg/L COD can be achieved under the right conditions.
- Aeration system sizing dictates treatment rate (lb/day COD).
- Treatment footprint is greater than 1 acre, with building and equipment height less than 20 feet.
- Measures must be taken to avoid the lagoon becoming a hazardous wildlife attractant.

Regulatory Considerations

Potential permits for aerated lagoon installation and operation may vary by location but may include wastewater permit-to-install and modification of NPDES for monitoring.

Planning and Design Considerations

The following factors should be considered in the planning and design of an aerated lagoon system:

- Performance data from other aerated lagoon systems that treat deicer-impacted stormwater can be used to extract rates of treatment, but performance is site-specific, so pilot testing should be considered.

- The system requires utility connections for power.
- Because the lagoon contains deicer-impacted stormwater, it is typically necessary to line the lagoon with a synthetic geomembrane to avoid the potential for groundwater contamination.
- It is necessary to have a nutrient system where nutrient loadings can be paced to COD loads.
- Under cold temperatures, performance will be significantly diminished, so additional storage may be necessary to hold deicer-impacted stormwater during those periods.
- The treatment process will require cleaning and disposal of the biosolids produced.
- Land for siting the system should be relatively flat.
- A 6- to 12-month window is optimal for design, bidding, construction, and startup.
- Compared to the related activated sludge treatment technology, aerated lagoons for deicer treatment have less ability to treat high load and high flow rate streams of deicer-impacted stormwater.

Integration with Other Practices

The concentration and flow ranges suitable for the aerated lagoon technology is compatible with the range of deicing runoff concentrations associated with apron collection systems (Fact Sheet 22) or airfield drainage systems (Fact Sheet 25). It is not compatible with deicing pads. The technology is also compatible with systems where high- and low-concentration streams are separated. Storage capacity upstream of the treatment system in the form of basins (Fact Sheet 29) or permanent tanks (Fact Sheet 30) may be applicable for effective and efficient operation. Aerated lagoons may be used to pretreat stormwater prior to its discharge to a POTW.

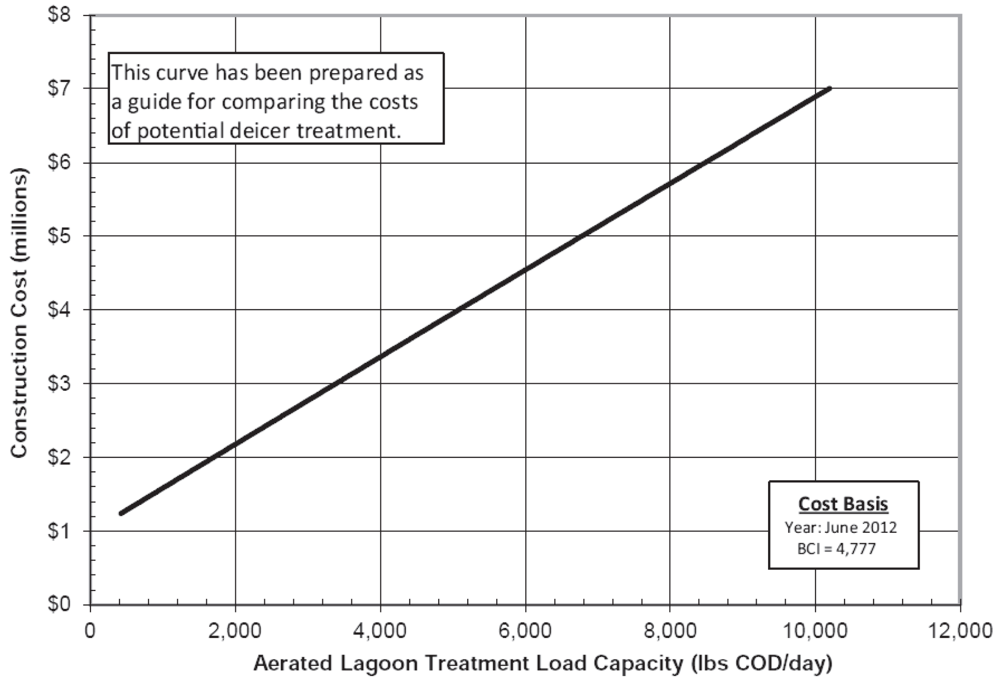
Operation and Maintenance Considerations

Despite relative ease of operation, aerated lagoons do require operator attention. Aerated lagoons can function effectively if designed properly and applied to the appropriate stormwater streams, but the operators must understand their capabilities and limiting conditions. The aerated lagoon technology is best applied with monitoring and computer control, which reduces day-to-day operator decision-making. Daily collection and review of operating data by operators is needed to support decision-making. Aerated lagoon systems do not have to be staffed full time, although computer call outs to operators are helpful to respond to alarms. Additional maintenance may be required to address any sludge buildup that occurs within the system.

3. Costs

Capital Costs

Figure 2 provides guidance on aerated lagoon capital costs per pound of COD mass load treated. The costs exclude non-treatment components such as collection, storage, and conveyance.

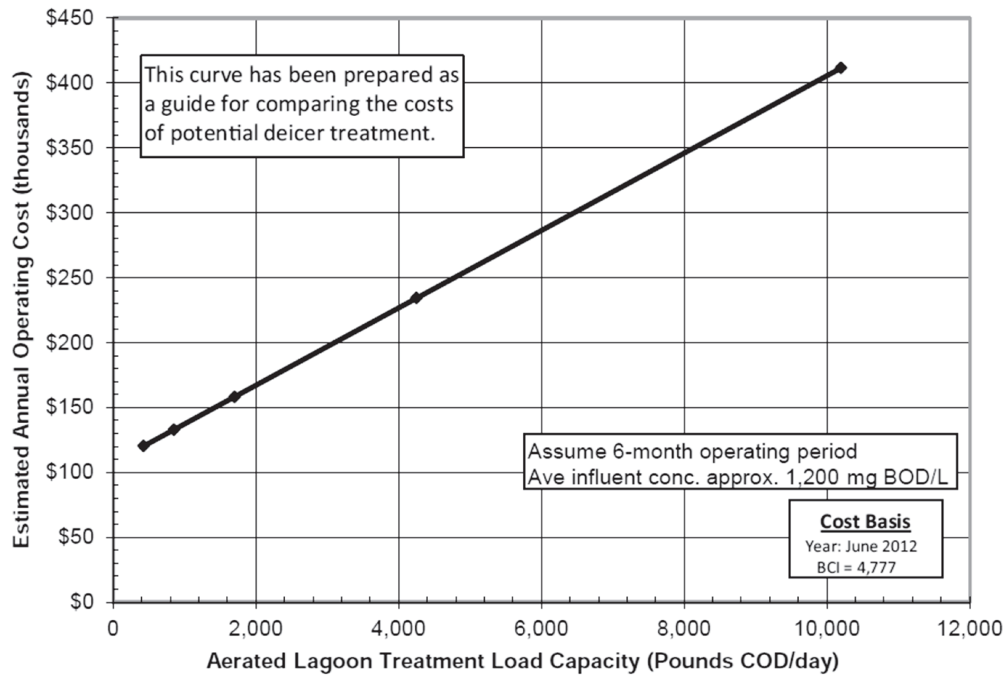


Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 103

Figure 2. Aerated lagoon capital cost curve.

Operations and Maintenance Costs

Figure 3 provides guidance on aerated lagoon O&M costs per pound of COD mass load treated. Costs include labor, utilities, and chemicals.



Source: *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*, Fact Sheet 103

Figure 3. Aerated lagoon O&M cost curve.

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