APPENDIX C

Airport Deicer Treatment System Summaries

The following Airport Deicer Treatment System Summaries report the deicer treatment experiences at 19 airports that have used the 11 deicer treatment technologies referenced in the Deicer Treatment Technology Fact Sheets (Appendix B).

These summaries update and add to those previously published in Appendix D in *ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Deicers*.

- Airport Deicer Treatment System Summary 1, Bradley International Airport (Reverse Osmosis, Mechanical Vapor Recompression, POTW Discharge) (Updated)
- Airport Deicer Treatment System Summary 2, Nashville International Airport (Activated Sludge, POTW Discharge) (Updated)
- Airport Deicer Treatment System Summary 3, Buffalo Niagara International Airport (Aerated Gravel Bed) (Updated)
- Airport Deicer Treatment System Summary 4, Akron-Canton Airport (Anaerobic Fluidized Bed Reactor) (Updated)
- Airport Deicer Treatment System Summary 5, Confidential U.S. Airport (Aerated Gravel Bed) (Replaced).
- Airport Deicer Treatment System Summary 6, Cincinnati/Northern Kentucky International Airport (Activated Sludge) (Updated)
- Airport Deicer Treatment System Summary 7, Denver International Airport (Mechanical Vapor Recompression, Distillation, POTW) (Updated)
- Airport Deicer Treatment System Summary 8, Detroit Metropolitan Wayne County Airport (Off-Site Glycol Recycling, POTW Discharge) (Updated)
- Airport Deicer Treatment System Summary 9, Wilmington Air Park (Reciprocating Aerated Gravel Bed) (Updated)
- Airport Deicer Treatment System Summary 10, London Heathrow Airport – Mayfield Farm (Aerated Lagoons, Aerated Gravel Beds, Natural Treatment Systems) (Updated)
- Airport Deicer Treatment System Summary 11, Oslo Gardermoen Airport (Off-Site Moving Bed Biofilm Reactor, Off-Site Recycling) (Updated)
- Airport Deicer Treatment System Summary 12, Portland International Airport (Anaerobic Fluidized Bed Reactor, POTW Discharge) (Updated)

Appendix C is supplemental to *ACRP Research Report 257: Guide for Treatment of Airport Stormwater Containing Deicers: Update* (ACRP Project 02-96, “Update ACRP Report 99: Guidance for Treatment of Airport Stormwater Containing Dicers”). The full report can be found by searching for *ACRP Research Report 257* on the National Academies Press website (nap.nationalacademies.org)

- Airport Deicer Treatment System Summary 13, Edmonton International Airport (Aerated Gravel Beds, Off-Site Recycling) (Updated)
- Airport Deicer Treatment System Summary 14, Halifax Stanfield International Airport (Mechanical Vapor Recompression, Distillation, Aircraft Deicing Fluid Blending) (Updated)
- Airport Deicer Treatment System Summary 15, Zurich Airport (Natural Treatment System, Distillation) (Updated)
- Airport Deicer Treatment System Summary 16, Gerald R. Ford International Airport – Grand Rapids (Off-Site Recycling System, Natural Treatment System) (New)
- Airport Deicer Treatment System Summary 17, London Heathrow – Eastern Catchment (Moving Bed Biofilm Reactor) (New)
- Airport Deicer Treatment System Summary 18, Minneapolis-Saint Paul International Airport (Mechanical Vapor Recompression, Off-Site Recycling, POTW Discharge) (New)
- Airport Deicer Treatment System Summary 19, Portland International Jetport (Mechanical Vapor Recompression, Distillation, Aircraft Deicing Fluid Blending) (New)

Airport Deicer Treatment System Summary 1

Airport:	Bradley International Airport—Windsor Locks, CT (BDL)
Treatment Technology:	Reverse Osmosis and Mechanical Vapor Recompression POTW Discharge
Years Operated:	2006–2023 (Currently Operational)

Deicer Management System Description

The Bradley International Airport (BDL) deicer management system uses a spent deicer collection system, collection basins, piping, pump stations, a recycling facility, and a POTW for discharging wastewater. Deicing operations are conducted at the terminal gates, cargo/remote parking areas, and the Remote Deicing Facility (RDF). The active collection involves the use of Glycol Recovery Vehicles (GRVs) in designated gate areas. Passive collection involves the use of dedicated collection drainage systems for both the terminal gate areas and the RDF.

Captured spent ADF is sent to two, 1-million gallon storage tanks located at the on-site recycling facility. The tanks provide storage and feed for the glycol processing facilities. Spent ADF is segregated by propylene glycol (PG) concentration, with one storage tank for “high” concentrate (>4%) and one for “low” concentrate (<4%). The recycling facility uses Reverse Osmosis (RO) and Mechanical Vapor Recompression (MVR) treatment technologies. Spent ADF treatment equipment is housed in two buildings (one for MVR; one for chemical pre-treatment, Ultrafiltration (UF), and RO).

The Connecticut Airport Authority (CAA) is required to collect and treat glycol-contaminated stormwater runoff to prevent stormwater pollution at BDL. The CAA previously held a joint wastewater discharge permit which allows for the discharge of pre-treated wastewater from the glycol recycling and wastewater pre-treatment operation via the sanitary sewer to the Metropolitan District Commission’s (MDC) Windsor/Poquonock Water Pollution Control Facility in Windsor. Due to recent regulation changes, the CAA is currently operating under a Significant Industrial User General Permit (SIU GP) to authorize this discharge while a formal registration is being prepared.

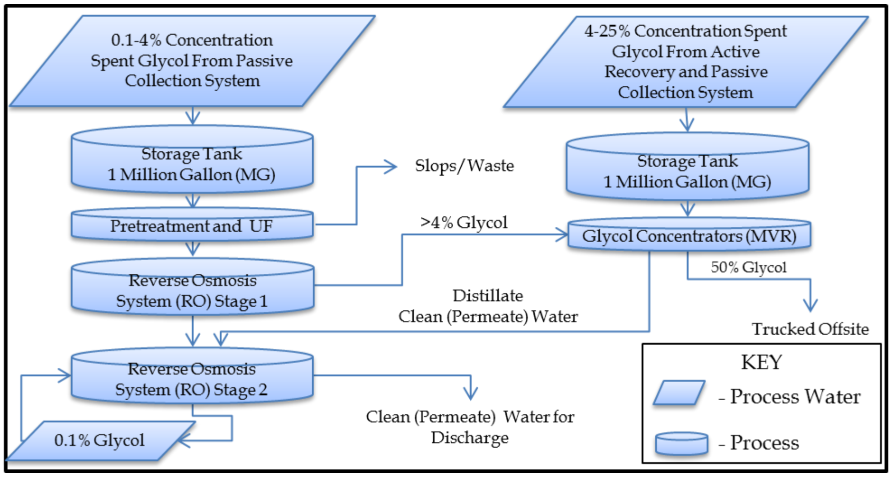

Figure 1. BDL spent ADF management system process flow diagram.

Deicer Treatment Technology Selection Considerations

The BDL on-site recycling system was implemented to meet the following requirements:

1. Compliance with federal and state environmental regulations and wastewater discharge/pre-treatment permits at the airport, including wastewater discharged to the sanitary sewer meeting the following limits:
    - Maximum flow: 288,000 gallons per day.
    - Concentration limits: 125 mg/l PG.
    - 600 mg/l BOD_5.
    - 1,200 mg/l COD.
    - pH 6.0–10.0.
    - 125 mg/l TSS.
2. Glycol processing rate of 600,000 gallons per month when spent ADF volumes are present.
3. Minimum volume of 100,000 gallons in each storage tank before systems must start, with an objective to empty the tanks before Sept. 1 each year.

The RO and MVR treatment technologies were specifically selected because:

1. Collecting and recycling runoff with PG concentrations greater than 0.1%.
2. The combined technologies are able to handle fluctuating PG concentrations in spent ADF that occur with each weather-related deicing event.
3. The systems could be separated into two independent processing trains capable of recycling:
    - 0.1%–4% PG concentration fluid from the one tank.
    - Greater than 4% PG concentration through the second tank.

The glycol that is reclaimed from the system is sold and the revenues generated are used to offset program costs to provide glycol management services.

Deicer Treatment Technology Description

The BDL treatment system employs both the RO and MVR treatment processes. The deicing treatment system was designed to operate both systems simultaneously. Descriptions of the MVR and RO treatment technologies can be found in the Treatment Technology Fact Sheets in Appendix B.

Figure 2. New Processing Building 2021.

Description of Support Systems

The support systems at BDL for the RO and MVR treatment technology include:

- *Collection system diversion, storage, and pumping*. The passive system for ADF collection at BDL includes a diversion structure and pump station to move fluid from terminal areas and RDF to the recycling facility. The terminal collection area is limited by the placement of the drainage inlets, which reduces runoff that needs to be collected and increases the PG concentration of the collected runoff. Incorporated in this conveyance system is underground piping to allow testing of fluid so that spent ADF is directed to appropriate recycling storage tanks based on PG concentration. The main storage reservoirs for glycol recycling activities are two (2) one million-gallon tanks.
- *Chemical pre-treatment*. Pre-treatment is located upstream of the UF and RO membrane systems to treat all dilute spent ADF fluid. Constituents in the feed are analyzed to determine which chemical additives will perform best. In the pre-treatment tank, chemical pre-treatment is carried out to remove undesirable constituents from the waste fluid. The tank consists of a water softening system and a mixed reaction tank with pH control and chemical addition. After the influent is treated with the chemicals, it is transferred to a series of settlement tanks, where the chemically precipitated constituents of the waste stream will be allowed to precipitate and settle. This material is removed from the system prior to passing from the pre-treatment tank to the UF system. The UF system is used to remove constituents that may foul the RO membrane.
- *Storage for recycled glycol*. All recycled glycol at 50% PG concentration is temporarily stored in two (2) double-walled 20,000-gallon storage tanks. The 50% PG fluid is shipped to an off-site centralized distillation system at PWM Airport where it is recycled to a 99+% concentration before it is sold. All solid waste and membrane wash fluid is temporarily stored on-site and then shipped to an approved waste disposal facility.

Treatment System Capacity and Performance Parameters

Component Capacities

Table 1. Overall treatment system component capacities.

Component/Parameter	Size/Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity	1 MG 1 MG	2	2.0 MG
Treatment Unit Volume			
• RO	1,060 ft³	1	1,060 ft³
• MVR	980 ft³	4	3,920 ft³
Treatment Unit Dimensions			Total Area: 612 ft^2
• RO	22-ft L x 6-ft W	1	
• MVR	20-ft L x 6-ft W	4	
Treatment Facility Footprint	0.15-acre building	1	0.15 acres

Table 2. Component capacities for RO (low concentration treatment facility).

Component/Parameter	Size/Description of Treatment Units	Number of Treatment Units	Total Value
Stormwater Storage Capacity (Low Concentration PG tank)	1 MG	1	1 MG
Annual Chemical Pretreatment Rate	7.956 MG per unit	1	7.956 MG
Annual UF Treatment Rate		2	>10.5 M per year
Annual RO Treatment Rate	>10.5 MG per unit	1	>10.5 MG
Support System Dimensions			10,800 ft^3
• Chemical Pretreatment	9’8 L x 6’ W x 6’ H	1	
• UF 1	11’L x 6’ W x 7’ H	1	
• UF 2	9’ L x 7’ H x 5’ W	1	
• Process Tank	20’ L x 9’ H x 10’ W	6	
Support System Capacities			
• UF Poly Tank Capacity	4,000 gal	1	4,000 gallons
• RO Poly Tank Capacity	2,000 gal	1	2,000 gallons
Treatment Building Footprint	100' W x 80’ L x 24’ H	1	5,000 ft^2
Wastewater Discharge Tanks	20’ L x 9’ H x 10’ W (13,000 gal)	2	3,600 ft^3 (26,000) gallons

Table 3. Component capacities for MVR (high concentration treatment facility).

Component/Parameter	Size/Description of Treatment Units	No. Treatment Units or Capacity	Total Value
Stormwater Storage Capacity (High Concentration PG tank)	1 MG	1	1 MG
Annual MVR Treatment Rate	1.2 MG/YR	4	4.8 MG/YR
Support System Capacities:			
• MVR Feed tanks (Spent ADF Storage)	13,000 gal	2	26,000 gal
• Product Storage Tanks • (Recycled Glycol)	20,000 gal	2	40,000 gal
MVR Treatment Unit Dimensions	L = 20’, W = 6’, H= 8’2 with scrubber 22’H	4	
Treatment Facility Footprint	L= 60’, W= 32’, H = 22’	1	1,920 sq-ft

Treatment System Performance

Although the RO and MVR systems operate simultaneously, they have unique design requirements. The tables below reflect the design parameters for RO and MVR separately.

The RO and supporting membrane systems were specifically configured to accomplish two tasks:

1. Treat influent streams with PG concentrations from 0.1%–4%.
2. Treat all water produced from both MVR and membrane operations to ensure the process distillate water quality meets the sanitary discharge permit requirements.

Table 4. Summary of RO system performance.

Parameter	Value*	Unit
Flow Rate Range	40 - 50	gpm
Treatment Mass Load Capacity	30,000	lbs PG/day
Influent Concentration Range	0 - 50,000 (design) 3,700 – 20,100 (actual to-date)	mg PG/L
Effluent Concentration Range	50 – 450 (design) 5 to 1200 (actual to-date) 0 - 1,000 (design) 1 to 125 (actual to-date)	mg COD/L mg COD/L mg PG/L mg PG/L
Design Treatment Efficiency	95.4 to 99.9	% Influent PG load treated

*Actual data derived from monthly average data collected between 2009 and 2012.

Performance data provided in Table 5 represents a single MVR treatment unit. A sufficient number of MVR units is used to provide the processing needs of the airport’s system.

Table 5. Summary of MVR system performance.

Parameter	Value*	Unit
Flow Rate Range	8 - 12	Gallons per minute
Treatment Load Capacity	1,800 – 7,650 (actual to-date) 9,700† (design capacity)	lbs PG/day
Influent Concentration Range	27,000 – 105,000 (actual-to-date) 10,000 ~ 270,000 (design capacity)	mg PG/L
Effluent Concentration Range to RO System	<50 to 1000 <50 to 1,000	mg COD/L mg PG/L
Treatment Efficiency	94.1 to 99.7	% Influent PG load treated

*Actual data derived from monthly average data collected between 2009 and 2020.

† Data reflects absolute maximum. Typical maximum loads are 12,000 lbs COD/d.

Data provided in Tables 6 and 7 represents RO and MVR performance from a typical season.

Table 6. Actual BDL RO data for 2020–2021.

Stage One	Nov	Dec	Jan	Feb	Mar	Total or Average for Season
Influent Volume Processed (gal)	19,083	449,958	911,040	617,140	339,242	**2,336,463**
Average Influent PG Concentration (% PG)	1.10%	1.00%	1.00%	1.10%	1.10%	**1.06%**
Effluent Volume of Permeate Produced (gal)	683	307,537	254,400	361,985	206,142	**1,130,747**
Average Effluent Permeate (% PG)	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%	**< 0.5%**
Effluent Volume of Reject Produced (gal)	12,240	142,421	329,187	255,155	133,100	**872,103**
Average Effluent Reject (% PG)	4.90%	5.50%	5.30%	6.00%	6.00%	**5.54%**
Stage Two						
Influent Volume Processed (gal)	12,240	307,537	581,853	361,985	206,142	**1,469,757**
Total System Average Influent PG Concentration (% PG)	< 0.5%	< 0.5%	< 0.5%	< 0.5%	< 0.5%	**< 0.5%**
Effluent Volume of Permeate Produced (gal) "Sanitary"	10,046	234,019	464,824	294,954	171,702	**1,175,545**
Average Effluent Permeate (PG ppm)		11	7.2	9	26	**13.3**
Average Effluent Permeate (BOD_5 mg/L)		129	331	196	280	**234**
Average Effluent Reject (% PG)	0.5%– 1.0 %	0.5%– 1.0 %	0.5%– 1.0 %	0.5%– 1.0 %	0.5%– 1.0 %	**0.5%– 1.0 %**
Effluent Volume of Reject Produced (gal)	2,194	73,720	329,187	67,277	378,596	**850,974**
Average Amount of Waste Produced Month (gal)	0	0	0	5000	15,000	**45,000**

Table 7. Actual BDL MVR data for the 2020–2021 deicing season.

	Nov	Dec	Jan	Feb	Mar	Season
Stage One (1/4 MVRs)	**1/2 MVRs**	**3/4 MVRs**	**3 MVRs**	**3 /4 MVRs**	**3/4 MVRs**	
Influent Volume Processed (gallons)	33,461	170,420	272,708	255,972	205,856	938,417
Average Influent PG Concentration (% PG)	3.6	4.67	6.1	6.6	5.3	5.3
Volume of 100% PG in Influent (gallons)	1,083	12,486	16,635	16,484	9,737	56,425
Average Influent Flow Rate (gph) *	199	195	179	172	172	183.4
Effluent Volume of Distillate Produced (gallons)	28,046	139,203	211,897	199,585	164,419	743,150
Effluent Volume of "Concentrate" Produced (gallons)	5,415	31,217	60,811	56,387	41,437	195,267
Average Effluent Concentration of Concentrate (% PG)	18.7	19	19	22	23.5	24.51
Volume of 100% PG in Concentrate (gallons)	2,708	15,609	11,554	12,405	20,719	62,994
Stage Two/Single Stage (1/4 MVRs)		**1 MVRs**	**1 MVRs**	**1 MVRs**	**1 MVRs**	
Influent Volume Processed (gallons)		23991	60,162	47,780	49,622	181,555
Average Influent PG Concentration (% PG)		18	19.6	22	20	19.9
Volume of 100% PG in Influent (gallons)		4273	8,856	8,910	8,532	30,571
Average Influent Flow Rate (gph)		196	186	161	173	179
Effluent Volume of Distillate Produced (gallons)		15444	39,052	29,960	32,557	117,013
Effluent Volume of "Concentrate" Produced (gallons)		8547	21,110	17,820	17,065	64,542
Average Effluent concentration of Concentrate (% PG)		50	49.9	49.9	48.8	49.65
Volume of 100% PG in Concentrate (gallons)		4,273	10,533	8,892	8,327	32,025

Cost Assessment for RO and MVR Treatment System

In 2020, the State of Connecticut DOT sponsored the new RO system, processing building, two (2) one-million-gallon storage tanks, associated pumping stations, and the process tanks. This equipment replaced a similar equivalent that was previously accidentally damaged.

The recycling vendor installed the chemical pre-treatment system, the two (2) UF units, the MVR building, four (4) ADF concentrators, and two (2) concentrate product storage tanks and upgraded the RO system (state-owned). The recycling vendor is responsible for the maintenance and operation of all equipment associated with the processing of spent ADF.

Operating cost considerations for the BDL RO and MVR system include:

- Actual treatment capacity/RO volume compared to nominal design capacity.
- Effect of treatment efficiency on caustic demand.
- Chemical use data per pound of COD treated, which may vary with the concentration of influent soluble COD.
- Electrical costs per ft³ of membrane.
- Solids generation rates per pound of COD treated.

Capital and operating costs for the new system are provided in Table 8. Approximately two-thirds of the capital cost was associated with the MVR system.

Table 8: Costs for the treatment system.

Cost Category	Actual
Capital Cost	$2.9 Million in 2020
Annual Operating Cost (Total)	$500,000 to $700,000

BDL MVR and RO System Changes Since Startup

The following represent system changes since the 2006 startup based on interviews with operations staff in 2022.

1. The original RO and MVR equipment was replaced with new equipment of the same technology in 2019 following accidental damage to the original equipment.

Lessons Learned from BDL for Airports Considering Selection of MVR, RO, and POTW Technologies

The following lessons learned are applicable to those considering MVR, RO, and POTW discharge technologies at other airports.

1. Since POTW discharge permit modifications can require a significant length of time, discussions with regulators regarding permit conditions should be started early in the implementation process.
2. The MVR technology is excellent for enabling recycling of the concentrated PG for offsetting costs.
3. The RO and MVR technologies are excellent for treating high PG concentrations.
4. The two-stage RO installed at BDL performs as intended. The RO does not run continuously (i.e., 24 hrs per day) and runs only partial days since it can easily handle the volume fed from both the UF and concentrator systems. Based on the historical operation of the system at BDL, it can be concluded that the system met the airport's needs.
5. The RO/MVR treatment system at BDL has treated concentrations as low as 3,700 mg PG/L and as high as 105,000mg PG/L.
6. By employing both membrane and MVR technologies, BDL is able to handle a large range of influent concentrations. Membrane systems allow the airport to meet stringent limitations for discharge of distillate to the sanitary sewer. Using both MVR and membrane technologies allowed the facility footprint to be minimized while still achieving a sufficient treatment capacity.
7. Cost recovery from the recycled PG is dependent on the market value of PG and the amount of PG available for capture and recycle. High-volume seasons increase costs since more consumables are used and labor is extended into the summer to monitor equipment before shutdown. The costs also typically increase as influent has higher concentrations of TSS since these require more chemical pre-treatment and typically more operational shutdowns for cleaning the system. If the runoff to be treated has PG concentrations less than 1%, the system becomes less cost-effective as the volume of PG recovered per unit volume of runoff processed is low. Average annual operating costs for utilities, chemicals, analyses, and solids management are $500,000 to $700,000 annually. The BDL system uses one (1) full-time supervisor, two (2) full-time operators, and seasonal operators as necessary for the system. Most maintenance activities at BDL are performed by the glycol recycling contractor as part of their duties.

Lessons Learned from BDL for Onsite MVR and RO Operators at Other Airports

The following lessons learned are applicable to those operating MVR and/or RO technologies at other airports.

1. The effluent concentrations can be minimized through optimizing turbidity, pressure, temperature, and pH.

2. The system can start and stop as required with little impact to the influent loading rates or effluent concentrations.
3. The system performs very consistently and predictably once a constant concentration, pressure, temperature, and pH are obtained in the influent.
4. Sufficient ability to control flow rates is important, especially if influent concentrations are high, resulting in higher chemical dosing and maintenance.
5. The airport has experienced recent issues in getting spare parts for the system because of supply chain and component delivery issues.
6. No issues experienced with treating pavement deicers.
7. To prevent fouling of the RO membrane, the RO process requires pre-treatment of the influent deicing impacted stormwater by the UF processes. The processed fluid from the UF systems must be less than 200 NTU before being fed to the RO system. The temperature of the influent is closely monitored to maximize the flow rate through the membranes. Both UF systems are monitored continuously for influent temperature and show symptoms of fouling when flow rates fall below desired parameters. At that point, the units are flushed with a mild cleaning solution to clean the membranes.
8. The influent deicer concentration is a primary factor in the design and operation of RO and MVR treatment systems. While dilute concentrations of PG-impacted stormwater can be treated by an RO/MVR treatment system, the RO/MVR treatment system performs better with higher influent deicer concentrations. Therefore, it is beneficial to operate the collection system in a manner that provides high-influent deicer concentrations into the RO/MVR treatment process. The influent deicer concentrations of less than 40,000 mg PG/L are concentrated using the RO processes. Concentrate from the RO process with influent concentrations greater than 40,000 mg PG/L is treated by the MVR.
9. Based on the data the average influent concentration was approximately 10,400 mg PG/L during the 3-year span. The RO reject produced yielded PG concentrations averaging 3%–5%. This indicates that at least 50% of the glycol flowing through RO is removed and sent to the MVR systems for recycling. The remaining glycol that carries over in the Stage 1 permeate of the MVR eventually becomes Stage 2 influent and averages between 0.5%–1% PG. The remaining PG is removed with the fluid quality consistently meeting all discharge requirements. Overall, the RO system 3-year data indicates a 92% average removal rate of PG. The data suggests the unit is capable of removing 99% of the PG that is processed, but according to the recycling vendor the unit is set to continually meet the permit requirements while maximizing flow rates and in turn maximize removal rates as to maintain as much spent ADF storage capacity at any given time. For this reason, the main focus when adjusting parameters on the RO system is not to reclaim all glycol but to maximize production flow rates while maintaining permit compliance.
10. It was anticipated that flow rates would average 40 to 50 gpm through the RO treatment system and average 8 to 12 gpm for the MVR treatment process. In practice, the flow rates have averaged 9.2 gpm for RO and 9.0 gpm for MVR. The lower-than-anticipated flow rates are a reflection of the system not operating continuously (i.e., 24 hrs per day). Instead, the RO system operates only on partial days since it can easily handle the volume being fed from both the UF and concentrator systems. The UF effluent output capacity, the MVR distillate output, and the overall availability of low-concentration spent ADF are the RO system's limiting factors to the flow rate.
11. The effluent PG concentration of the RO system effluent is a key performance indicator for the removal efficiencies. The BDL RO and MVR were designed to concentrate the PG for recycle and reuse. By concentrating the PG into one stream, PG is removed from the distillate stream. The distillate stream discharges are sent through the RO treatment system again. The RO system is operated so that the distillate stream contains concentrations below the permitted concentration. The average PG concentration in the

RO distillate stream has been 27 mg/L. The MVR also has a concentrate and a distillate stream. However, the concentrate from the MVR is trucked off-site at BDL for PG reuse. The MVR distillate stream is sent back to the RO system for further treatment.

12. Each MVR at BDL can be adjusted to produce a desired PG concentration product. The MVR units produce two effluent streams and the desired concentration set points in each effluent stream directly impact the performance of the concentrators. The PG concentration is continually monitored to balance the parameters on the machine to increase the processing rate. The effluent PG concentration is crucial since the recycling contractor has a goal to produce 50% PG. At this level and higher, the contractor trucks the fluid off-site so that it can be distilled to the 99.1% and higher concentration level. The second effluent stream produced from the MVR units is “distillate.” This distilled water is not continuously monitored since this fluid is sent to an interim storage tank, where it is comingled with the other low-concentration spent ADF to be processed through the membrane systems. The quality of distillate is clean enough to be fed directly through the RO system. The RO system will remove any fugitive glycol to meet discharge permit levels. Based on the data, 94.6% of the glycol that was fed through the MVR systems was reclaimed. The remaining glycol was reclaimed through the RO system and the balance discharged through the effluent stream to the POTW.
13. Adequate filtration methods prior to treatment are essential to prevent fouling of membranes and scaling of MVR equipment.
14. Seek to maintain process variables such as temperature, turbidity, flow rate, and pressures at consistent set points.
15. Provide ability to adjust the UF/RO and MVR systems to respond to variability in influent PG concentrations.
16. The ability to meet desired effluent concentrations affects influent processing rate.
17. Integrate daily preventative maintenance into operations in order to optimize equipment performance.
18. Treated the membrane systems with biocide when the processing systems sit idle for extended periods of time to eliminate potential biological growth.

Documents and Information Review in Development of Airport Summary

Bradley International Airport. (2020). Treatment System Operational Records.

Svedruzic, Michael and Arendt, Tim. (2010). *Deicer Treatment Options and Considerations for ELG*, 22 July 2010.

Airport Deicer Treatment System Summary 2

Airport:	Nashville International Airport—Nashville, TN (BNA)
Treatment Technology:	Activated Sludge POTW Discharge
Years Operated:	1997 – 2023 (Currently Operational)

Deicer Management System Description

At BNA, aircraft deicing fluid is applied primarily on dedicated deicing areas (pads). All stormwater runoff from the pads flows by gravity to the North and South Storage Ponds, along with runoff from adjacent non-deicing areas that are interconnected within the drainage network. The inclusion of non-deicing area runoff from adjacent apron areas results in lower BOD_5 concentrations than would otherwise be expected from a deicing pad operation. Each storage pond has a pump station for conveying runoff to a lagoon that has been modified to act as an activated sludge treatment system. With permission from the POTW, the treated effluent can also be discharged to the sanitary sewer under special circumstances.

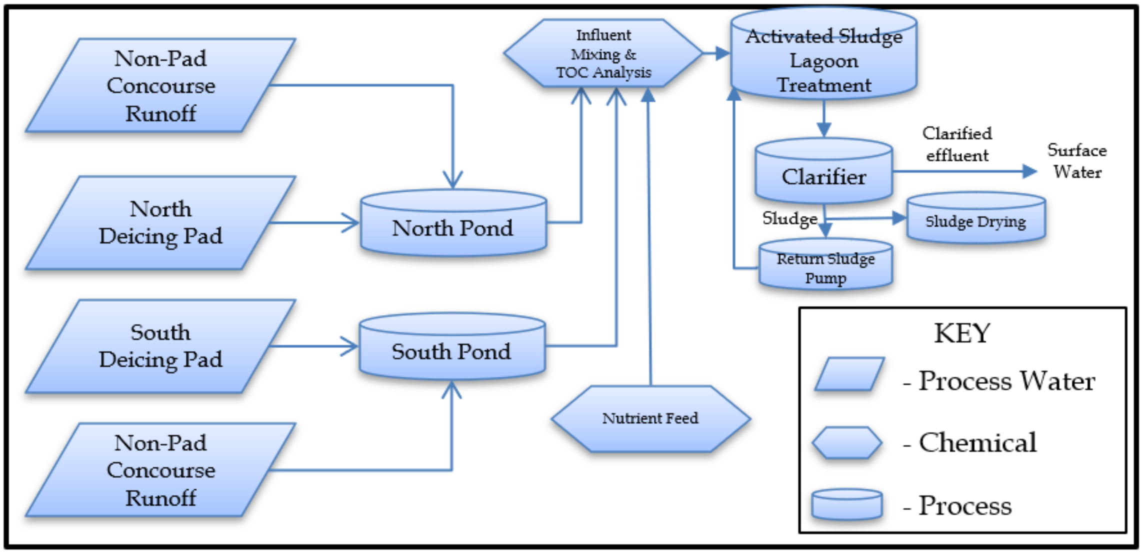

Figure 1. BNA deicer and stormwater management system.

Deicer Treatment Technology Selection Considerations

In the early 1990s, the Metropolitan Nashville Airport Authority (MNAA) experienced issues with low dissolved oxygen and bacterial growth in Sims Branch from the discharge of deicer-impacted stormwater. Initially, MNAA implemented an aerated lagoon technology to provide treatment. The aerated lagoon system was monitored over time to assess performance. Based on this analysis, MNAA decided to convert the aerated lagoon to an activated sludge system in 2014.

A central goal of the conversion to an activated sludge system was to utilize as much of the existing treatment infrastructure as possible while providing upgrades that improved treatment efficiency, effectiveness, and the ability to meet effluent limits. The upgraded activated sludge system provides the following advantages over the aerated lagoon at BNA:

- Control of the influent BOD_5 (via online monitor and parameter correlation) mass loading and nutrient feed rates into the lagoon (aeration basin) to provide a more consistent population of healthier bacteria.
- Increase effective lagoon volume through a step feed system to use a greater portion of the available lagoon volume for treatment and minimize dead zones.
- Better mixing and oxygen delivery to improve treatment effectiveness.
- Increase treatment capacity by returning settled sludge to the aeration basin, which increases the concentration of mixed liquor-suspended solids (greater numbers of bacteria).
- Improved means for settling biological solids and producing clarified water with lower BOD_5 and TSS concentrations.

Deicer Treatment Technology Description

Activated Sludge

See Activated Sludge Treatment Technology Fact Sheet for a general description of the treatment technology. The aeration basin at BNA is a lined structure, approximately 18 feet at its deepest point. Influent flow from upstream storage ponds is mixed with nutrients that are paced to the BOD_5 load rate, with the mixture fed at the head of the aeration basin. The influent flow is also added at three other equally spaced points on the side of the basin in step feed fashion. A total of 12 equally spaced surface aerators/mixers were installed to provide both mixing of the water/bacterial solids and oxygen needed by the aerobic bacteria to grow.

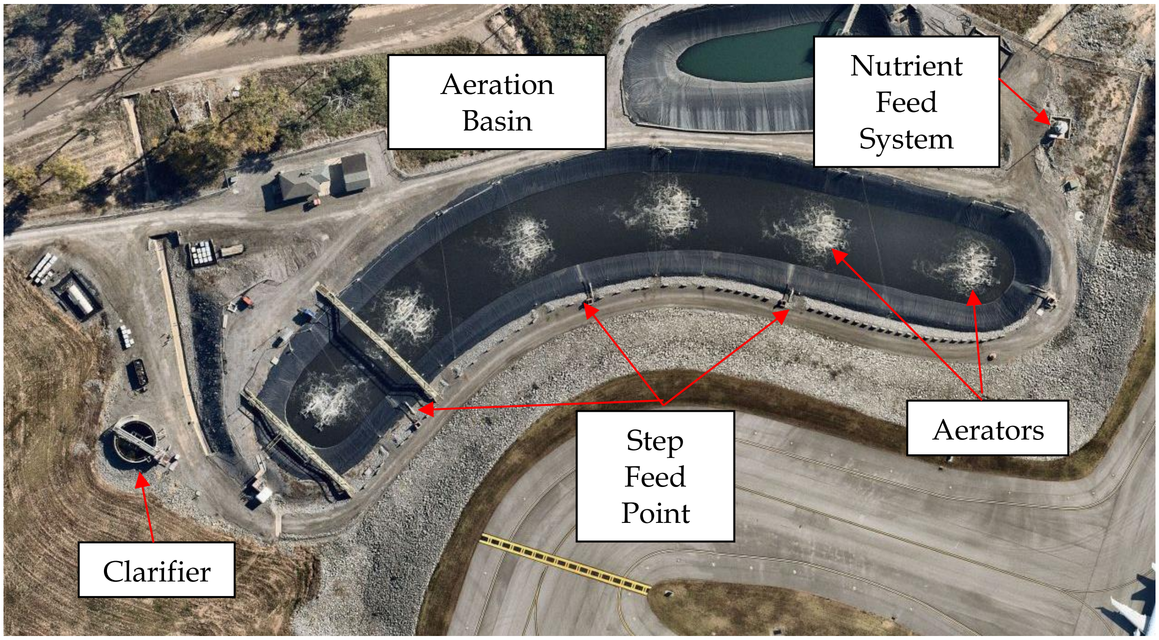

Figure 2. BNA treatment system (Nearmap, November 2022).

Description of Support Systems

The activated sludge system at BNA includes the following support systems:
- Upstream storage ponds.
- Nutrient feed system.
- Online TOC monitor used to help manage mass loads of deicer into the aeration basin, with TOC correlated to BOD_5.
- Clarifier to remove solids and produce low TSS effluent.
- Sludge drying area.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity • North Pond: • South Pond:	 1.1 MG 2 MG	2	3.1 MG
Treatment Unit (Lagoon) Volume	5.75 MG	1	5.75 MG
Treatment Unit (Lagoon) Dimensions • Length • Width at Top of Berm • Depth • Side Slopes	 685-ft 110-ft 18-ft 2.2 to 1	1	890,000 ft^3
Treatment Facility Footprint (Treatment lagoon only)	2-acre total site	1	2 ac.

Table 2. Summary of system performance.

Parameter	Value	Unit
Flow Rates	Typically, 50 to 75, with peak capacity of up to 470	gpm
Treatment Load Capacity	3,000 to 5,000 typically, with peak of 9,000	lbs BOD_5/day
Influent Concentration Range	200 to 2,500	mg BOD_5 /L
Effluent Concentration (average)	<25 < 1 < 30	mg BOD_5 /L mg NH_3-N/L mg TSS/L

BNA Activated Sludge System Changes Since Startup

The following represent changes to the BNA system since 2011 based on interviews with operations staff in 2022 and information from system construction.

1. The aerated lagoon (lined open basin) was retained but converted into an activated sludge system aeration basin. Changes to the lagoon itself include:

    - Existing surface aerators were replaced with new combination surface aerators/mixers. The new aerators provide a higher oxygen transfer and improved mixing rate through the depth and width of the lagoon to optimize biological treatment.
    - Lagoon influent feed was changed to a step-feed system to feed the lagoon at four locations equally distributed along the length of the lagoon.
    - Dissolved Oxygen (DO) and ammonia sensors in the aeration basin at several points through the basin length.
    - Pump station to transfer effluent from the aeration basin to the clarifier.
2. Other changes outside of the lagoon related to the conversion to the activated sludge technology included:
    - Clarifier added to improve settling and effluent quality and to make solids removal easier.
    - Return sludge pump station and piping to return settled sludge from the clarifier to the modified aeration basin.
    - Piping and channels to discharge clarified effluent supernatant (clear) to the receiving stream.
3. Other treatment system changes include:
    - TOC monitoring system for metering flow to the aeration basin to achieve a constant BOD_5 mass loading.
    - New nutrient storage tank, nutrient feeding pumps, and conveyance pipes to pace nutrients to the system influent.
    - Sludge drying system for wasted sludge from the clarifier.
    - New PLCs/SCADA control system.

Lessons Learned from BNA for Airports Considering Selection of Activated Sludge Technology

The following lessons learned are applicable to those considering activated sludge at other airports.

1. Activated sludge system can produce high-quality effluent.
2. The upgraded system is meeting performance expectations for water quality.
3. For those with on-site treatment systems, having the ability to discharge to a POTW under emergency or critical conditions is a significant help in managing compliance risk.
4. The BNA system uses one operator plus one manager.
5. Having sufficient upstream storage capacity is important to being able to optimize treatment performance, in part because of the need to increase and decrease treatment flow rates to adjust to incoming deicer concentrations to achieve a steady mass load.
6. Retrofitting an existing system provides more challenges than designing an activated sludge system from scratch.
7. Initially, operations were contracted to a third party after upgrading to an activated sludge system, but the airport authority decided to change back to in-house staff for consistency in performance and control of decision-making.
8. The decision to retrofit the existing aerated lagoon and convert it to activated sludge, which was based in part on available budget, led to some compromises from an operations perspective, especially related to the flexibility and efficiency of seasonal startup.
9. Climate change may be impacting volume of deicer-impacted stormwater to collect because of warm and rainy periods in winter. This situation has resulted in a deficiency in spent deicer storage capacity in the system.
10. The large open water surface in the aeration basin has the potential to act as a hazardous wildlife attractant; however, the turbulence created by the 12 surface aerators helps to mitigate the impact.

Lessons Learned from BNA for Activated Sludge Operators at Other Airports

The following lessons learned are applicable to those operating activated sludge systems at other airports.

1. The unit process with the lowest flow rate controls the flow rate for the entire treatment system. In the case of BNA, the clarifier flow rate is the controlling process.
2. Starting up an activated sludge system at the beginning of the season typically requires adding extra organic chemicals (glycols or similar compounds) to feed the bacteria to achieve full treatment capacity, adding to O&M costs.
3. Utilizing polymer to aid clarifier settling in an outdoor setting can lead to viscosity issues for pumping of the chemical.
4. Monitoring instruments have a shorter life span than other system components.
5. Balancing nutrient feed rates to provide enough nitrogen and phosphorus to promote bacterial growth without consuming too much oxygen or exceeding effluent criteria for ammonia is one of the biggest operational challenges.
6. The return sludge pumping system rates can help in meeting effluent limits.
7. On days of heavy pavement deicer use, treatment rates appear to be reduced, resulting in the need to reduce flow rates to the treatment system.
8. Nutrient feed from nutrient storage to the influent end of the aeration basin can crystallize and clog nutrient feed piping unless the nutrient pumps are periodically exercised to push new flow through the lines.

Airport Deicer Treatment System Summary 3

Airport: Buffalo Niagara International Airport—Buffalo, NY (BUF)

Treatment Technology: Aerated Gravel Beds

Years Operated: 2009–2023 (Currently Operational)

Deicer Management System Description

In 2009, the Buffalo Niagara International Airport (BNIA) implemented a system for collection and on-site treatment of stormwater containing deicers prior to discharge to an adjacent stream. All stormwater from southeast side of airport, which includes the main terminal and air cargo, is captured for treatment. The treatment system was installed to comply with the New York State SPDES permit that regulates the discharge of organics (Biochemical Oxygen Demand – BOD_5) in the airport's outfall. The captured stormwater is stored in a 3-million gallon underground vault and 5-million gallon lagoon prior to treatment. Onsite treatment consists of an aerated gravel bed (AGB) located on the airside of the airport facility.

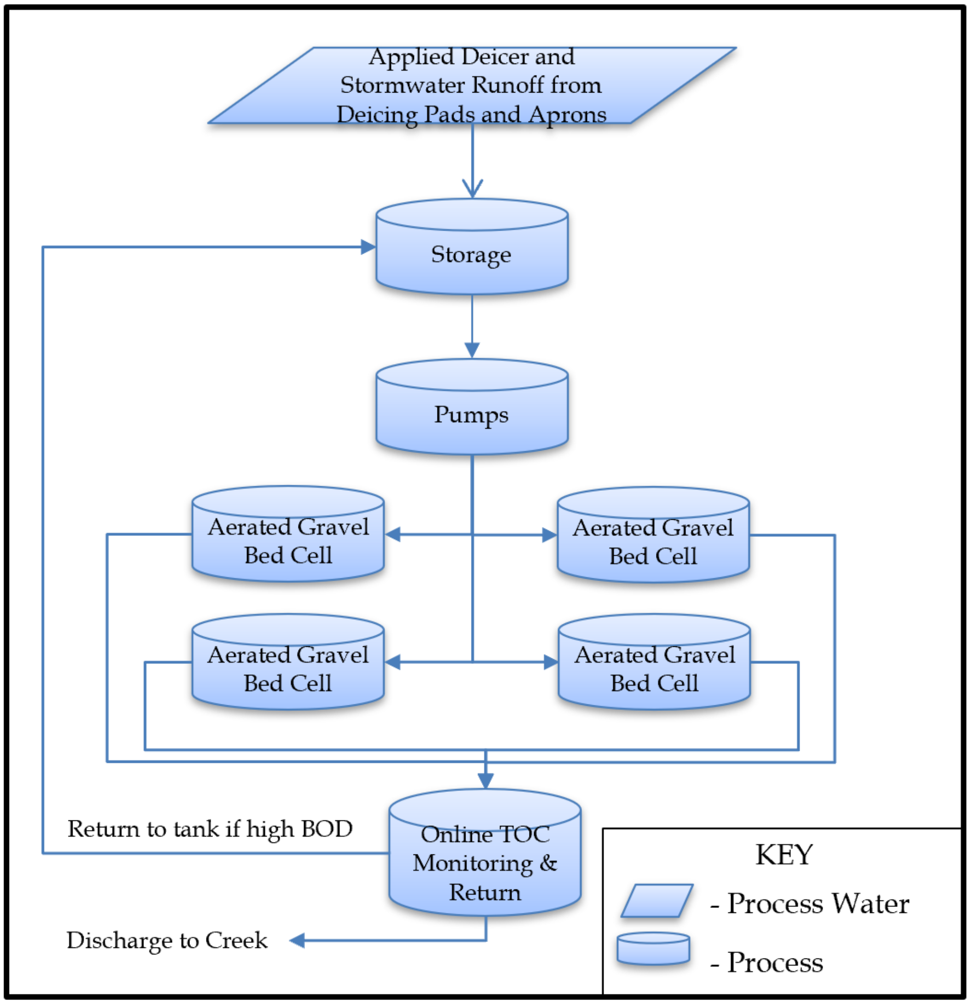

Figure 1. BUF deicer management system process flow diagram.

Deicer Treatment Technology Selection Considerations

The airport's discharge to sanitary sewer is affected by limited hydraulic capacity (4-inch diameter gravity discharge) and as a result, on-site treatment was required to reduce BOD_5 concentrations to acceptable concentrations to route runoff to the surface waters. Factors that were considered in the selection of the on-site aerated gravel bed treatment technology included:

- Project Budget – $10M (2008).
- Limited land availability.
- Low profile system that could be constructed on unused airside land.
- Integration into the existing stormwater management system.
- System that has capacity to accept high variability of flow and strength of stormwater.
- Low operational requirements for staffing.

BNIA was the first airport to select the aerated gravel bed treatment technology. Extensive treatability and pilot scale tests were performed to establish technology capabilities and sizing parameters.

Deicer Treatment Technology Description

Description of Aerated Gravel Bed

Stormwater from storage is pumped into the AGB beds by dedicated dosing pumps. Each pump discharges into a network of submerged, distribution laterals. The laterals are placed uniformly over the surface of the bed and housed within infiltration chambers. Water from the laterals flows downward through the gravel layer and is collected in an underdrain system on the floor of the bed. The underdrains are connected to a hydraulic control structure with an adjustable weir that is used to set the water elevation in the bed. Discharges from the beds flow into a common gravity flow pipe that directs the treated flow to the airport's permitted outfall.

The gravel in the bed is uniform in size and without fines. The surface area of the gravel supports the growth of attached-growth bacteria that form a biofilm over the surface of the submerged gravel. The biofilm grows during the deicing season and degrades in the summer when no deicer is applied. The BNIA system consists of four gravel beds of equal size excavated from an existing open area near the airport's main runway. The gravel beds are vegetated with grasses growing in a mulch surface.

Description of Support Systems

The AGB at BNIA includes the following support systems for the treatment system: aeration system, dosing system, nutrient feed system, and analytical system. The aeration system uses four blowers with compressed air routed to manifold system and aeration tubing in the AGB bed for distribution in the aggregate.

The dosing system for supplying the deicer-impacted stormwater to the treatment system includes four dosing pumps and a dosing tank. The objective of the dosing system is to provide a uniform mass loading to the treatment cells to stabilize the biological population and provide for efficient treatment. Concentrations in the dosing tank are continuously monitored by a Total Organic Carbon (TOC) analyzer. The concentrations are multiplied by the flows pumped into the beds to determine a daily loading. The daily loadings are used to determine the number of blowers in operation and the nutrient requirements. Blower operation is controlled by operations staff and nutrient dosing is automated and linked to loading rates to the beds.

Figure 2. Construction of the BNIA aerated gravel bed.

Treatment System Capacity and Performance Parameters

Table 1. System Component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Underground Storage	3.0 MG	1	3.0 MG
Lagoon Storage	5.0 MG	1	5.0 MG
Treatment Unit Volume	0.70 MG	4	2.8 MG
Treatment Unit Dimensions	166-ft x 300-ft x 5-ft	4	N/A
Treatment Facility Footprint	1.1 acres	4	4.4 ac

Table 2. Summary of system performance.

Parameter	Value	Unit
Design Flow Rates - Maximum	6,152	Gallons per minute
Design Treatment Load Capacity	10,000	lbs BOD_5/day
Design Influent Concentration - Range	50-5,000	mg BOD_5/L
Design Effluent Concentration (average)	30	mg BOD_5/L
Design Treatment Efficiency (average)	90	% Influent BOD_5

Cost Assessment for the BUF Aerated Gravel Bed Treatment System

Table 3. Costs for the treatment system.

Cost Category	Actual
Capital Cost*	$10M in 2008
Annual Operating Cost	Not Provided

* Capital costs are for the treatment system only. Costs do not include site-specific costs for collection, storage, or discharge.

BNIA AGB Changes Since Startup

The following changes have been made to the system since startup:

1. 2020 construction of 5 MG storage lagoon.
2. New stormwater pump station to transfer stormwater to storage lagoon.
3. New snowmelter to manage snow piles.
4. Changed nutrient feed from dry chemical to aqueous solutions.
5. Onsite storage for nutrient solution delivery.
6. New level sensors to monitor levels in tanks.
7. SCADA upgrade, including some sensors to better track flow rates.
8. New TOC meters.
9. Repair of aeration tubing.

Lessons Learned from BNIA for Airports Considering Selection of the AGB Technology

Lessons learned from the AGB system at BNIA:

1. Treatment performance from the AGB is still strong and meeting expectations after 16 years of operation, with greater than 99% removal of BOD_5.
2. SCADA and monitoring upgrades can help reduce operation time for sampling, analysis and adjustments.
3. All piping must have cleanouts and undergo routine jetting to remove accumulated solids.
4. The design of the aeration system, including use of air tubing, with limited cleanout ability results in a maintenance challenge because of chemical scaling. Regular acid cleaning is required to prevent clogging of the air tubing.
5. Adding vegetation to the gravel in the AGB cells in unnecessary. It provides no treatment benefit and causes additional maintenance to be performed.
6. The system went online in spring of 2009 and performed as expected until late December 2009. In late December 2009, the formation of polysaccharides (slime) and foam was observed within the treatment bed. To remedy the reduced treatment performance and remove the polysaccharides, the aeration and nutrient addition were increased. After two months the system began operating at design performance.

Lessons Learned from BNIA for AGB Operators at Other Airports

Conclusions from operation of the aerated gravel bed at BNIA that can be utilized by other airports considering this technology include:

1. AGB performance is based on mass load influent to the system. Frequent small loading is preferred over short, large loading.
2. Equalization of flows and loads is critical to optimizing system performance.
3. Nutrient addition is critical to process performance and must be diligently monitored and controlled.
4. Nutrient solution should be sourced for delivery and storage to the treatment system. Onsite preparation of nutrient solution is laborious and inefficient.
5. Plastics, ear plugs, and other debris may not readily flow or settle and must be removed by physical screening.
6. Analyzers must be cleaned of slime regularly.
7. Stormwater with deicer can be corrosive and corrosive-resistant materials should be used if possible (e.g., stainless steel monitoring pumps).
8. High influent BOD_5 concentrations will result in lower flow rates to the system to maintain constant BOD_5 mass loading rates. At very low flow rates, the uniformity of the distribution of water into the AGBs can be affected unless the influent feed is fed in a periodic rather than continuous manner.
9. Airport is considering nutrient monitoring of the treated effluent stream as part of a feedback loop to help correctly dose nutrient loads at the influent end of the AGB.
10. Clogging of dosing lines by plastics and other debris has been a persistent issue that requires routine jetting of dosing lines. Physical removal by filtering or other means should be considered for flow that is pumped into dosing laterals.
11. No issues have been observed in treating pavement deicers.

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Airport Deicer Treatment System Summary 4

Airport:	Akron-Canton Airport—North Canton, OH (CAK)
Treatment Technology:	Anaerobic Fluidized Bed Reactor
Years Operated:	2007–2023 (Currently Operational)

Deicer Management System Description

In response to effluent limits for propylene glycol (PG) and COD in their NPDES permit, the Akron-Canton Airport (CAK) installed an on-site anaerobic fluidized bed reactor (AFBR) biological treatment system. Aircraft deicing occurs primarily on the South Deicing Pad, with storm water runoff containing deicers collected from an inner and outer ring of collection piping. Collected runoff is routed to one of two 0.75 MG storage tanks, from which it is metered to the AFBR treatment system. Effluent from the AFBR is discharged to a storm water detention basin upstream of Outfall 003. The discharge from Outfall 003 is to the City of Green municipal separate storm sewer, with subsequent discharge to Zimber Ditch. The airport holds and NPDES permit with limits based on dissolved oxygen impacts to Zimber Ditch.

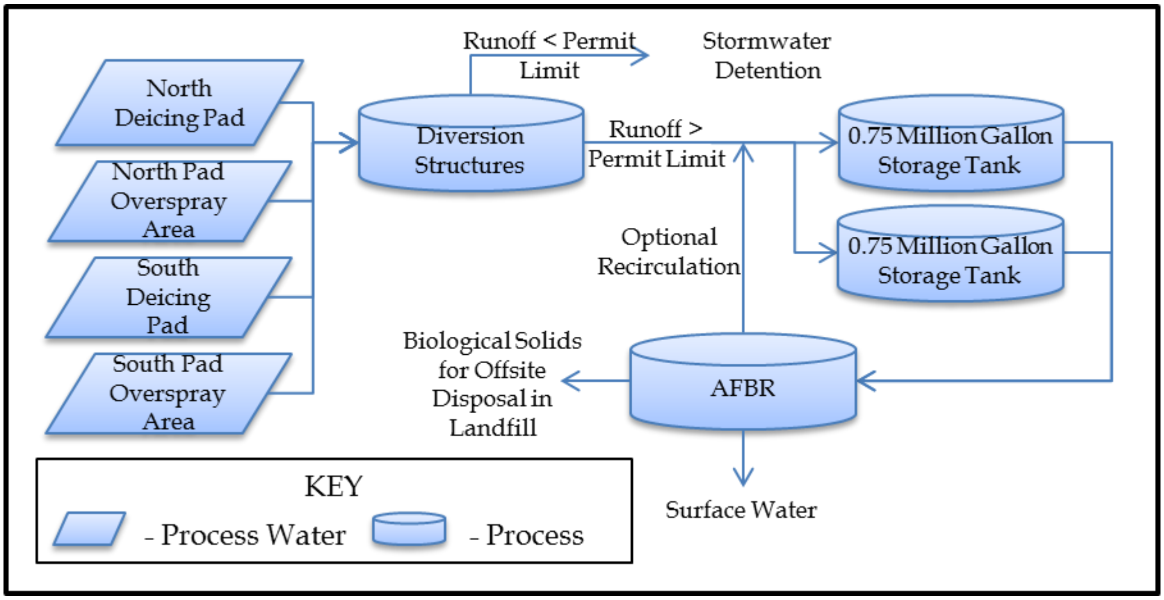

Figure 1. CAK deicing impacted stormwater management system.

Deicer Treatment Technology Selection Considerations

In its decision-making process, CAK placed a high premium on minimizing project costs to support its goal of being the local low-cost provider of air services. Since the capital portion of the treatment system installation was covered by a federal grant, decisions on treatment technologies were primarily driven by two factors: 1) minimizing annual operating and maintenance costs and 2) ability to comply with NPDES permit limits on a consistent and predictable basis. Construction of the deicing pads was an important element in reducing costs because of the reduction in the volumes of water that would need to be stored, conveyed, and potentially heated. When considering treatment alternatives, CAK considered it important to minimize the footprint of the treatment operations to reduce expenditures associated with facility buildings.

Based on an assessment of a wide range of treatment options in 2005, it was determined that discharge to the local sanitary sewer (POTW), recycling, and two types of on-site biological treatment were the most applicable potential treatment and disposal options. The following conclusions on treatment technologies were reached before the AFBR technology was selected:

- POTW (sanitary) discharge was eliminated as a possible treatment and disposal technology due to insufficient capacity at two local wastewater treatment plants. The POTWs were not interested in modifying their plants to accommodate the increased seasonal loading.
- Treatment using membrane filtration or evaporation units, with ultimate transport of the moderately concentrated glycol off-site for recycling, was considered carefully, but was eliminated for several reasons:
    - The additional units needed to reach the PG concentrations in the dilute effluent stream drove up operating costs in relation to biological treatment.
    - CAK had concerns about relying on an outside entity for treatment services.
    - CAK preferred not to be dependent on potentially fluctuating market conditions for recycled glycol.
- Both aerobic and anaerobic on-site treatment biological treatment methods were considered. The anaerobic AFBR system was selected based on the following criteria:
    - Fit of technology capabilities with the high BOD_5 concentration and low flow rates from the deicing pads.
    - Projected effluent PG and BOD_5 concentrations were lower than NPDES permit limits.
    - Footprint for treatment system fits the available space.
    - Lower operating costs.
    - Built-in means for isolating the treatment effectiveness from weather concerns through the use of off-gassed methane as fuel to heat the runoff.
    - Proven success at another airport (Albany International).

Deicer Treatment Technology Description

Anaerobic Fluidized Bed Reactor (AFBR)

See AFBR Treatment Technology Fact Sheet 104 for description of the process.

Figure 2. Biological reactor units (at right) in the CAK AFBR system (courtesy of Gresham Smith).

Description of Support Systems

The AFBR at CAK includes the following support systems for the treatment reactor-separator unit: storage (two 750,000-gallon concrete tanks), influent pumping system, heat generation and exchange loop, chemical feed for nutrient addition and pH control, biogas handling, and biological solids removal and handling. Collected runoff water from the storage tanks is pumped at a flow rate set by the system operators to achieve a constant COD loading as influent COD concentrations change. The cold influent water is heated first by passing it by warm effluent water in a heat exchanger and then by passing it by hot water from a boiler in a second heat exchanger. The hot water is obtained by heating potable water in a boiler using biogas captured from the reactor. The biogas is approximately 70 percent methane and 30 percent carbon dioxide and is used similarly to natural gas. For the CAK system, the heating system burns exclusively self-generated biogas for the entire deicing season, except for initial yearly startup when natural gas is used. Any excess biogas is burned in a flare external to the building. The AFBR technology requires addition of a base chemical (sodium hydroxide) to keep pH in the reactors neutral, as well as addition of various chemical nutrients to support growth of the bacteria. Biological solids exiting the reactor-separator unit with the treated effluent are removed with a dissolved air flotation clarifier. Treated effluent is discharged to CAK’s Outfall 003 detention basin. Biological solids are disposed of in a landfill.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity	750,000 gal	2	1.5 MG
Treatment Unit Volume	18,700 gal	2	37,400 gal
Treatment Unit Dimensions	Reactors: 10-ft dia.	2	N/A
Treatment Facility Footprint	0.2 ac. total site	1	0.2 ac.

Table 2. Summary of system performance.

Parameter	Value	Unit
Flow Rates - Typical - Maximum	<5 50	gpm
Treatment Load Capacity - Design - Actual	3,400 Up to 3,700	lbs COD/day
Influent Concentration Range	34,000 to 86,000	mg COD/L
Effluent Concentration (average)	36 – 280 <10 <1	mg COD/L mg BOD_5/L mg PG/L
Treatment Efficiency (average)	99.5%	% Influent COD load treated

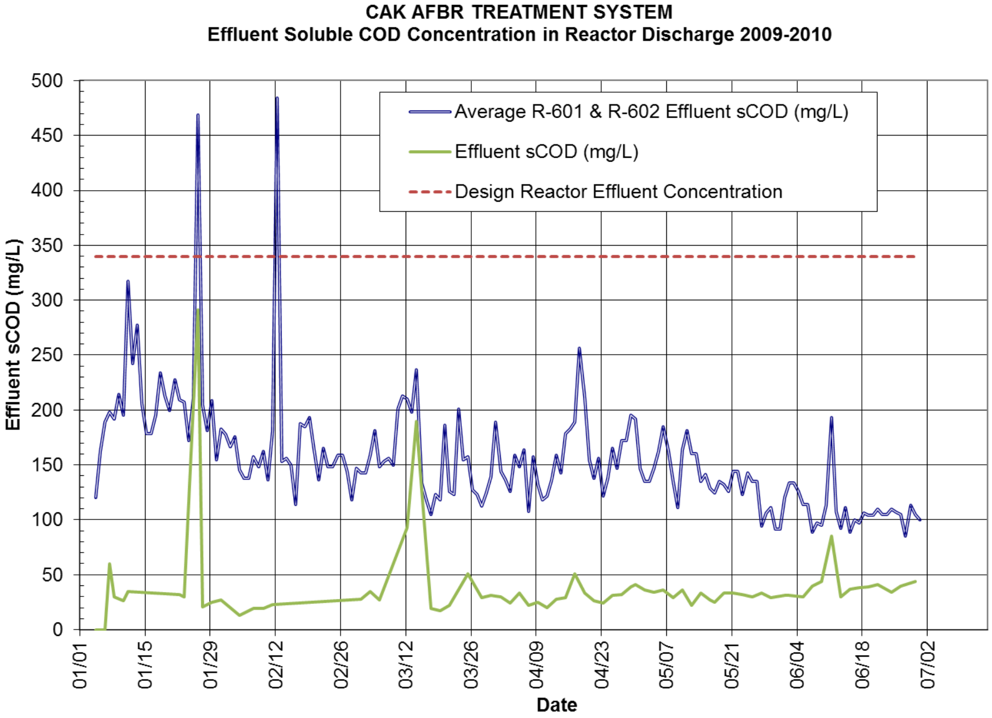

Figure 3. Typical season system effluent concentrations.

Cost Assessment for the CAK AFBR Treatment System

Table 3. Costs for the treatment system.[1,2]

Cost Category	Actual
Capital Cost*	$3.2M in 2007 $0.5M added in upgrades to solids and chemical handling since startup in 2008
Annual Operating Cost**	
- Utilities	$35,000
- Chemicals	$4,500
- Analysis	$5,400
- Material Handling	$11,000
Total Operating Cost (2009)	**$55,900**

* Capital costs are for the treatment system only, including the building and basic building infrastructure. Capital costs do not include site-specific costs for collection, storage, or discharge.

** Operating costs do not include labor costs. The facility uses two operators. Maintenance costs, which vary, are not included.

CAK AFBR Changes Since Startup

The following represent system changes since the 2007 startup based on interviews with operations staff in 2022.

1. No changes have been made to the core AFBR treatment process in the 15 years of system operation.
2. Core equipment and instruments have held up well in the 15 years of operation from a maintenance perspective. Some pump maintenance is required. Some changes were made to address corrosion in gas piping. Steel piping is gradually being replaced with stainless steel piping.
3. An upgrade was implemented to the Dissolved Air Flotation (DAF) system in 2020 to improve the settling of biological solids from the AFBR reactor effluent. The improvements included increased capacity, increased air supply, and an improved chemical feed system. A 2,000-gallon equalization tank with a mixer was added upstream of the DAF to help manage spikes in sheared biomass coming from the AFBR and provide more consistent solids concentrations to the DAF. To optimize DAF performance, the overall flow rate through the AFBR system was increased to up to 15 gpm, which necessitated collecting additional runoff from the outer ring of the deicing pads to lower influent concentrations and allow mass loadings to the AFBR to be maintained. The added air flow to the DAF units did increase foaming, which necessitated adding a defoamer.

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[1] Source of capital cost data: Design (Engineering Report 2006), Actual (Airport Cost Records). Costs are for the treatment system and the building in which it is housed. It excludes costs for deicing pads, storage tanks, and conveyance piping/structures external to treatment system.

[2] Source of operating cost data: Design (Engineering Report 2006), Actual (operating logs for quantities, vendor prices for material, utility records. Costs exclude the costs of the two system operators.

Lessons Learned from CAK for Airports Considering Selection of AFBR Technology

The following lessons learned are applicable to those considering AFBRs at other airports.

1. System performance has been very consistent in terms of effluent quality and treatment efficiency (over 99% removal). The CAK AFBR system has been able to treat at a higher through-put than envisioned during design, running at approximately 18% above design capacity at 4,000 lbs COD/day during normal operational periods. At higher load rates than this, gas production from bacteria in the reactors begins to produce some instabilities in the biomass sludge layer in the reactor.
2. The treated effluent concentration of PG and COD have been within NPDES permit limits during the entire operational run. PG concentrations in the effluent are generally below detention limits in laboratory analysis.
3. Average annual operating costs are approximately $55,000 including utilities, chemicals, analyses, and solids management. The CAK system has used two full-time operators for the system for the entire 15 years of operation. Most maintenance activities at CAK are performed by system operators as part of their duties. The highest maintenance costs to-date were in the first year following operation when adjustments were made to the system.
4. Use stainless-steel materials for gas piping to prevent long-term corrosion.
5. Properly insulate air piping that may pass outside to the flare system to prevent freezing of moisture inside the biogas stream.

Lessons Learned from CAK for AFBR Operators at Other Airports

The following lessons learned are applicable to those operating AFBRs at other airports.

1. Per the system operators, one of the most challenging parts of the AFBR operations is finding the sweet spot to manage the balance between AFBR and DAF performance. Managing the solids from the AFBR system is the most operations-intensive part of the process.
2. Managing solids waste from the reactors and subsequent solids processing is the most time-consuming part of operations.
3. Operators found that running two fluidization pumps for flows entering reactors on a periodic basis helps to manage solids buildup in the reactors.
4. Consider integrating maintenance items for the AFBR system into the airport’s asset management program.
5. Understand that nutrient uptake is larger at startup vs. standard operation.
6. Regardless of the length of the previous deicing season, a substantial amount of biomass stays alive until the next deicing season, resulting in the system being able to operate at a 30%-35% capacity point immediately upon seasonal startup. Two to four weeks are needed to achieve full design loading after seasonal startup.
7. Approximately two weeks are needed to prepare the system for seasonal startup.
8. Challenges of balancing flows between unit processes to achieve optimal performance in each and the overall system.
9. No issues have been reported in treating pavement deicers.

Airport Deicer Treatment System Summary 5

Airport:	Confidential U.S. Airport
Treatment Technologies:	Aerated Gravel Beds
Years Operated:	2022–2023 (Currently Operational)

Deicer Management System Description

The airport facility that is the subject of this fact sheet wishes to remain confidential. Their deicer management operations include the use of deicing pads, with the ability to deice at the gates. Stormwater runoff containing deicer is routed to a diversion system, at which concentrations of Total Organic Carbon (TOC) are monitored to determine if runoff can be discharged or requires treatment. The deicer management system includes storage of stormwater containing deicer that exhibits TOC concentrations greater than the equivalent NPDES permit concentrations for BOD_5. All deicer treatment occurs on-site through the use an aerated gravel bed treatment technology.

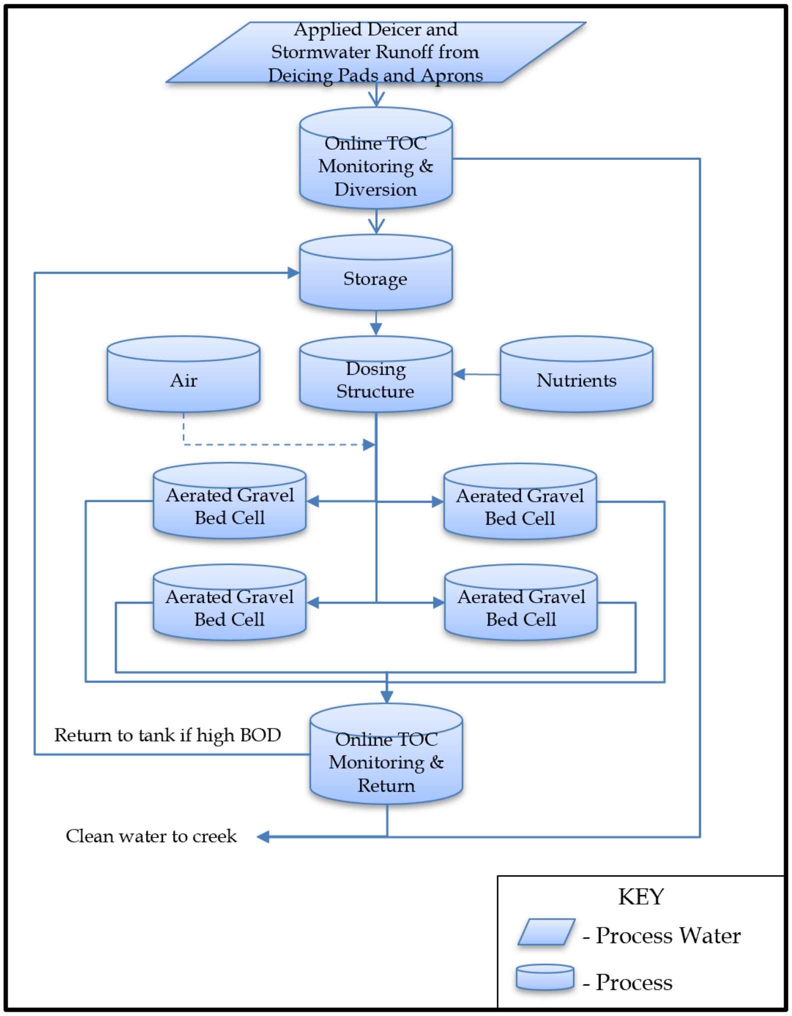

Figure 1. Deicer management system process flow diagram.

Deicer Treatment Technology Selection Considerations

Facility operational needs lead to application of pavement deicer over large apron areas in addition to the application of aircraft deicer. The NPDES permit limits are less than 100 mg/L. The high stormwater volumes, high peak flow rates, and potential for significant BOD_5 from aircraft and pavement deicer led to the need for a deicer management system that could process high flow rates, treat aircraft and pavement deicer, and produce effluent with low BOD_5 concentrations. The local winter weather is highly variable, with the potential for extended periods with little deicer use interspersed with heavy deicing periods associated with snow and ice events. Frost deicing is a regular occurrence.

Multiple deicer treatment technologies were considered but ultimately discarded, including recycling operations (insufficient volumes and concentrations for economical operation), activated sludge (concerns with operational impacts from light deicing periods), and MBBR (concerns with additional unit processes required to process sludge). Discharge of the stormwater to the local POTW was not an available option.

After considering the various treatment technologies, it was determined that the aerated gravel bed treatment technology was the optimal choice for the facility, based on the following considerations:

- Ability to process up to 8 million gallons a day under lower concentrations conditions.
- Ability to function under a range of BOD_5 concentrations expected in the runoff.
- Ability to consistently meet the NPDES permit limits for BOD_5.
- Ability to startup quickly after low deicing periods, including at the start of the winter season.
- Little to no biological sludge to process.
- Relatively passive operations, with the ability for the system run during evening and night shifts without operators on the site.
- Available area to provide the required footprint for both storage and the AGB treatment cells.
- No open water surfaces and associated attraction of hazardous wildlife.
- Ability to meet performance requirements even with intermittent deicing activities.
- Ability to effectively treat runoff when majority of BOD_5 is from aircraft deicers or pavement deicers.

Deicer Treatment Technology Description

Aerated Gravel Bed Treatment Technology

See the Aerated Gravel Bed Treatment Technology for details on the process components.

The AGB system for this airport represents state-of-the-art operation for the aerated gravel bed technology, with multiple options for adjusting to ambient conditions and responding to performance variation. The system is capable of running in parallel flow mode (maximum flow throughput) or series flow mode (best quality effluent).

Figure 2. Aerated gravel bed cell.

Description of Support Systems

The aerated gravel bed treatment system includes the following support systems.

- Above-ground storage tanks.
- Nutrient feed system.
- Aeration system.
- Dosing system.
- Effluent monitoring and return loop to storage tanks.

The system is highly monitored and controlled, with online measurements of water levels, water flow rates, nutrient loading rates, pH, temperature, dissolved oxygen, air flow rates and pressures, and TOC. TOC mass loading and nutrient levels into the aerated gravel bed cells are tightly controlled to maintain consistent bacterial populations, consistent BOD_5 removals, and consistent BOD_5 effluent concentrations as conditions vary.

Treatment System Capacity and Performance Parameters

Table 1: System component capacities.

Component/Parameter	Number of Units	Total Capacity
Storage Tanks	2	Greater than 15 MG
Aerated Gravel Bed Treatment Mass Load Capacity	4	10,000 lbs BOD_5/day
Aerated Gravel Bed Flow Capacity	4	Varies, with 8 MGD Max
Influent BOD5 Concentration Range	4	0 to 10,000 mg/L BOD_5, with higher concentrations possible with longer loading periods
Footprint of AGB Treatment Units	4	4 acres

Table 2: Summary of system performance.

Parameter	Value	Unit
BOD_5 Removal Efficiency	>95%	% influent BOD_5 load treated
Effluent BOD_5 Concentrations	<80	mg/L
Operational Water Temperature	>33	°F

Lessons Learned for Airports Considering Selection of Aerated Gravel Bed Technology

The following lessons learned are applicable to those considering aerated gravel bed treatment at other airports.

1. During the first year of operational treated effluent was able to meet BOD_5 permit requirements throughout the winter.
2. Aerated gravel beds such as the system installed at this facility are one of the more effective solutions for airports with larger volumes of runoff to process.
3. The AGB can consistently achieve low BOD_5 effluent concentrations.
4. Solids production is minimal due to managed bacterial growth, thereby eliminating the need for permanent and costly solids settling, dewatering, and disposal infrastructure.
5. The system requires a significant amount of underground piping. Sufficient space must be provided for the installation of the piping.
6. Water levels can be kept below the gravel surface to avoid attracting birds and growing weeds.
7. Local availability and cost of the gravel that serves as the media surface for bacterial growth may play a significant factor in capital cost. Ideally, limestone is used as the aggregate for the AGB units to provide pH buffering capacity, if needed, but granite or other stone materials can be considered.

Lessons Learned for Airports Operating Aerated Gravel Bed Treatment Systems

The following lessons learned are applicable to those operating aerated gravel bed treatment systems.

1. The system can startup quickly and begin treating within days of initial deicing loading.
2. Providing additional operational control features should be balanced with limiting excessive complexity.
3. In a multi-cell treatment system, operators may want to consider starting up an AGB treatment unit at a time.
4. While the system can utilize a significant amount of monitoring and controls to guide operations, operators should still perform daily visual checks and take daily grab samples to test for TOC, COD, NH_3-N, and Ortho-P along with occasional BOD_5 tests at an off-site lab.
5. As the system starts up, the BOD_5 mass load is gradually increased to build the bacterial population. Depending upon the water temperature, the system takes 1 to 2 days to fully response to mass load increases of 10 to 20%.
6. At the end of the deicing season, some short-term increases in TSS can occur in the effluent when in flow-through mode. At that time of season, operators should run the system in batch mode to digest the solids. However, in the first season of operations, the TSS concentrations after the end of the deicing did not rise above 20 mg/L in the treated effluent.

Airport Deicer Treatment System Summary 6

Airport: Cincinnati/Northern Kentucky International Airport—Kenton County, KY (CVG)

Treatment Technologies: Activated Sludge

Years Operated: 2003–2023 (Currently Operational)

Deicer Management System Description

The Kenton County Airport Board (KCAB), operators of the Cincinnati/Northern Kentucky International Airport (CVG), began to address deicer management issues in the 1990s in response to Total Maximum Daily Load (TMDL)-based criteria applied by the state regulator to the airport's receiving streams and the subsequent inclusion of BOD_5 effluent limitations in the airport's NPDES permit. Core elements of the airport's deicer management system include deicing pads and gate deicing areas, diversion structures to segregate stormwater with and without deicer, pump stations and force mains, and storage tanks. Initially, a mechanical vapor recompression unit was used for the treatment of higher-concentration runoff from the deicing pads, but this was abandoned. An initial sequencing batch reactor system for biological treatment was eventually replaced with an extended aeration-activated sludge treatment system.

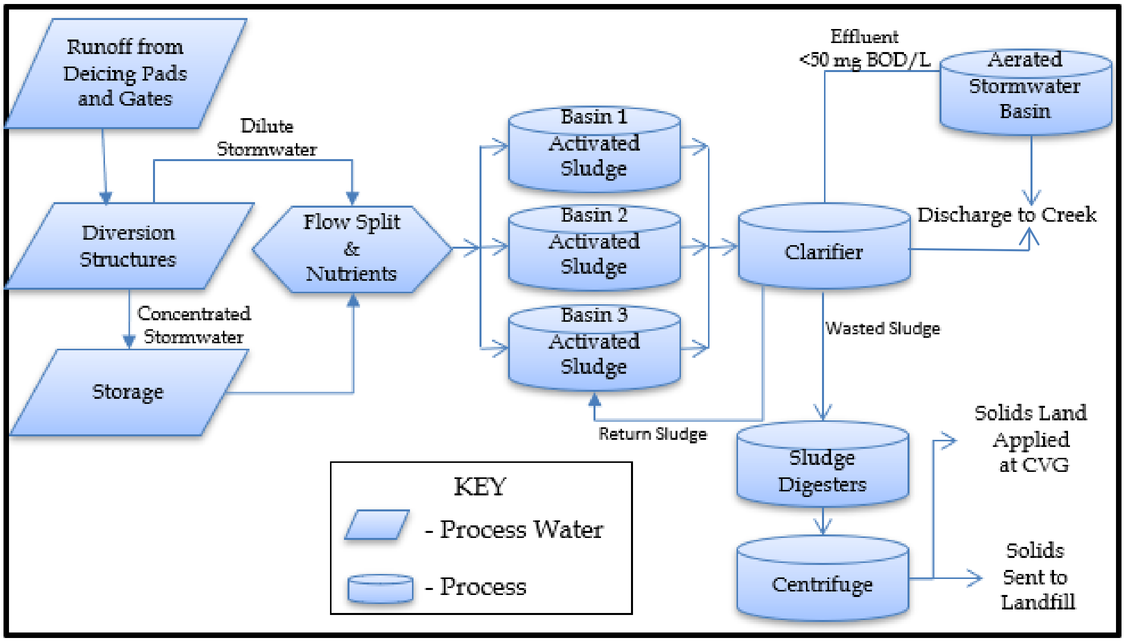

Figure 1. CVG deicing impacted stormwater management system process flow diagram.

Figure 2. Aerial photo of CVG-activated sludge treatment system.

Deicer Treatment Technology Selection Considerations

Deicer treatment at CVG has evolved from discharge to POTW (ended at the request of POTW because of treatment plant impacts) to mechanical vapor recompression of concentrated fluid in combination with aeration of a lagoon for dilute flows to Sequencing Batch Reactors to the current system of activated sludge based on extended aeration technology.

The evolution of treatment technologies at CVG was driven by multiple challenges unique to the site, including:

- Significant amount of at-gate deicing from cargo areas mixed with deicing pad use from commercial airlines, resulting in a wide range of collected BOD_5 concentrations.
- Large collection area with many different subdrainage areas.
- Stringent BOD_5 limits for the stream.
- Historical issues with biofilm nuisance growth in the stream.

The result was the need to collect a large portion of the overall stormwater flows and manager a wide range of concentrations.

The present extended aeration-activated sludge system offers the following advantages to CVG:

- Large treatment load capacity.
- Ability to process large flow volumes.
- Ability to produce effluent with BOD_5 concentrations less than the 85 mg/L permit limit in winter.
- Footprint for aeration basins (4 acres) is smaller than the footprint for the equivalent capacity of the aerated lagoon and aerated gravel bed treatment technologies.

Deicer Treatment Technology Description

Activated Sludge Biological Treatment System

Fact Sheet 101, in Appendix B, contains a general description of the Activated Sludge technology. This airport's particular activated sludge system is designed to promote an extended detention time for the deicer in the treatment system to help manage the variability in deicer loadings and create a more stable bacterial population than conventional activated sludge technology.

The system is aerated using mechanical blowers supplying air through fine-bubble diffusers in fixed distribution piping on the bottom of the aeration basins. Air delivery to the basin can be reduced during periods of low loading, while still maintaining the contact between the deicer and reducing the risk of solids settling out of the water. A clarifier for the removal of solids is integral to the aerated basin unit. The CVG system is designed to treat a maximum of 30,000 lbs BOD_5 /day over an extended period, although due to the variation in deicing conditions and loading, it often runs at loads lower than its capacity.

Figure 3. CVG's activated sludge treatment system aeration basins.

Description of Support Systems

CVG's activated sludge system includes the following support systems:

- Ten pump stations for collection runoff from the airfield.
- Three high concentrate storage tanks (2MG, 3MG, and 3MG).
- One 6MG lined and covered storage basin, used in part to help attenuate flows into treatment.
- Online TOC monitoring and PLC control system to meter flows from the 6MG basin to treatment to help achieve steadier mass loading.
- Chemical nutrient feed system.
- Splitter box to collect flows from stormwater pumps and 6MG basin, provide mixing, provide a location for nutrient addition, and split flows to the three aeration basins.
- Clarifier to remove sludge from the aeration basin, returning a portion to the basin and wasting a portion to the sludge thickeners.
- Sludge thickeners.

- Centrifuge for sludge dewatering.

Because of the various sources of dilute and concentrated stormwater entering the treatment system, the management of flows, loads, and nutrient addition into treatment is a key element of system operations, as is the management of the sludge produced from biological solids.

Treatment System Capacity and Performance Parameters

Table 1. System Component Capacities

Component/Parameter	Number of Units	Total Capacity
Stormwater and Deicer Collection Pump Stations	10	Various capacities
Activated Sludge Treatment Unit Volume	3	14 MGs
Activated Sludge Aeration Basin Footprint	3	4 ac.
Spent Aircraft Deicing Fluid (SADF) Tanks	3	8 MG
SADF Covered Storage Basin	1	6 MGs

Table 2. Summary of System Performance

Parameter	Value	Unit
Flow Rates	Up to 2,000	gpm
Treatment Load Capacity	30,000	lbs BOD_5/day
Influent Concentration Range	25 – 6,000	mg BOD_5/L
Effluent Concentration Range	5 – 80	mg BOD_5/L
Treatment Efficiency	98%	% influent BOD_5 load treated on average
Air Delivery Rate Ranges - Activated Sludge Aeration Basin 1 - Activate Sludge Aeration Basins 2 & 3	1,600 - 2,950 2,900 - 5,300	scfm
Nitrogen addition	130 gallons	Urea Ammonium Nitrate per day (31% UAN)
Phosphorus addition	22 gallons	Phosphoric Acid per day (75%)

CVG Activated Sludge System Changes Since Startup

The following represent system changes since the 2005 startup based on interviews with operations staff in 2022.

1. 6MG in additional storage for moderately concentrated deicer added upstream of treatment to provide both additional storage capacity and equalization.
2. TOC monitoring system to measure organic (deicer) content in 6 MG storage basin and communicate signals to PLC for adjustment of flow rates to hit target BOD_5 mass load rates into the aeration basins.
3. Replacement of flexible aeration tubing in the aeration basin with fixed aeration piping.
4. Replacement of sludge removal mechanism in clarifiers with a chain and flight system for improvement performance and reduced maintenance.

Lessons Learned from CVG for Airports Considering Selection of Activated Sludge Technology

The following lessons learned are applicable to those considering activated sludge at other airports.

1. The activated sludge system has the capacity to remove large amounts of BOD_5 and achieve low BOD_5 effluent concentrations.
2. Mixing of all flows in a common storage unit prior to treatment to feed from a single point is recommended to minimize the impact of mass load variability on treatment. Space and costs should be allocated in design and procurement for this storage upstream of treatment.
3. Utilizing fixed aeration piping instead of flexible aeration tubing reduces the maintenance difficulties of removing sludge from the aeration basin.
4. Activated sludge bacterial populations are more sensitive to periods of little deicer feed than other technologies such as the MBBR or aerated gravel bed, leading to more operational challenges and the potential need to feed extra glycol (or another organic compound) to the aeration basins to sustain the bacterial population.
5. Sludge handling is a major part of the activated sludge operation and may result in the need for more operators than other biological treatment technologies.
6. No issues have been observed from the treatment of pavement deicers vs. aircraft deicers.

Lessons Learned from CVG for Activated Sludge Operators at Other Airports

The following lessons learned are applicable to those operating activated sludge systems at other airports.

1. Four operators are needed to provide the various functions over the course of a day.
2. A highly variable feed into treatment can result in extended periods of unused treatment capacity. If an expansion of capacity is needed, this unused treatment capacity can be utilized by adding more storage and metering deicer into the system at near-constant rates.
3. Having multiple aeration basins provides flexibility for both initial season operations when deicer loads are lower and maintenance.
4. The large BOD_5 treatment capacity of the three aeration basins helps to mitigate the slowing of bacterial activity at cold temperatures.
5. Oversizing aeration to minimize the potential oxygen shortfalls in high-loading periods is important.
6. Nutrient feed is a key element of operations and the mechanism for being able to both deliver and regulate nutrient feed with BOD_5 loads is a key part of efficient and effective treatment.
7. Online TOC monitors are excellent tools for managing mass loadings into treatment, but they are subject to biofilm and require regular maintenance to keep them clean.
8. Hydrogen sulfide (H_2S) gas has been measured in air space in some enclosed structures containing stormwater with deicers, such as pump stations. If control or electrical conduits into these spaces provide air pathways to control panels, it can cause corrosion of wiring and panel contacts. Ensure that air pathways to the panels are sealed.
9. While the aeration basins present a large open water surface, the aeration of the basin creates turbulence at the water surface which acts as a deterrent to birds landing on the surface.

Airport Deicer Treatment System Summary 7

Airport: Denver International Airport—Denver, CO (DEN)

Treatment Technology: Mechanical Vapor Recompression
Distillation
POTW

Years Operated: 2004–2023 (currently operational)

Deicer Management System Description

Denver International Airport (DEN) is owned, operated, and maintained by the City and County of Denver (the "City"). The airport was designed with infrastructure to reduce or control the potential for spent aircraft deicing fluid (ADF) to contribute pollutants to stormwater discharges. Deicer-impacted stormwater is managed as part of DEN's Aircraft Deicing System (ADS). Components of the ADS include dedicated deicing pads, a deicing waste stormwater collection system, low-flow stormwater runoff diversion from the clean stormwater system into the deicing waste stormwater system, storage, a spent deicing fluid recycling plant, and discharge of lower concentration runoff to the POTW. The City contracts an operator to maintain, operate, and manage the ADS.

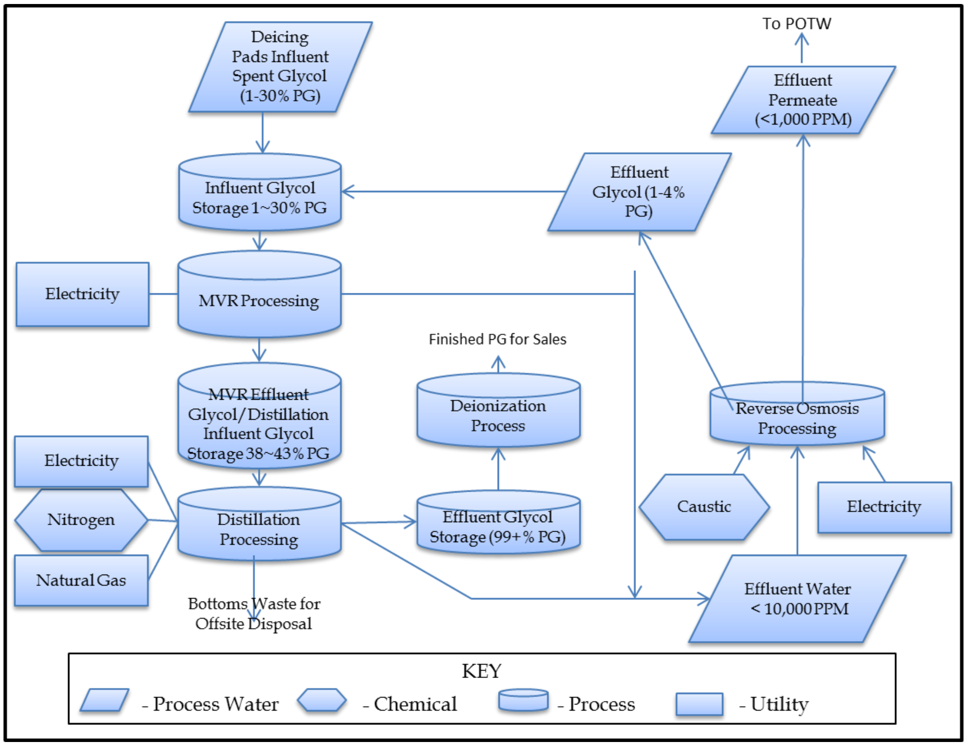

Figure 1. DEN deicing impacted stormwater management system.

Currently, full deicing at DEN is permitted on deicing pads and some aprons while deicing on gates and concourses is limited. Each deicing area has a dedicated collection system that conveys stormwater runoff contaminated with ADF to temporary storage ponds and/or tanks. Conveyance of the runoff is managed through a system of valves and underground piping. Runoff is segregated based on glycol concentration for recycling (high concentration) and discharge to the POTW (low concentration) as described below.

High-concentrate runoff greater than 1% concentration (10,000 mg/L PG) is managed for recycling-based treatment as follows. Deicer-impacted runoff from the four central deicing pads is collected and conveyed to one of five 420,000-gallon storage tanks. In addition, a 4-million-gallon pond (Figure 2) can be used as contingency storage for high concentrate. Fluid from the independent deicing pads is collected in storage tanks of 835,000 gallons and 420,000 gallons, respectively. Collected higher concentrate runoff is conveyed from storage to the recycling plant via a pump and piping system or truck. On deicing areas that are not part of the ADS, a Glycol Recovery Vehicle (GRV) is used to recover all fluids over 1% glycol concentration.

Figure 2. Pond 003A at the glycol recycling facility.

The recycling equipment includes nine (9) Mechanical Vapor Recompression (MVR) units (Figure 4) and a vacuum distillation system to produce 99+% PG. Condensate from the MVR units and distillation systems is monitored for BOD_5 concentrations, with the liquid stored at the Western Airfield Diversion System (WADS) prior to metering to the Metro Wastewater Reclamation District's wastewater treatment plant, the local POTW. The residual waste containing additives and contaminants is removed from the deicing fluid by the vacuum distillation system and is sent off-site for disposal at an approved waste handling facility. The 99% PG product is either sold or further processed to remove contaminants to facilitate meeting the evolving testing requirements associated with producing SAE AMS 1424 Type I deicing fluid.

Figure 3. MVR building.

Lower concentrate runoff from concourses and ramps with less than 10,000 mg/L PG is directed to lined retention ponds and sent to WADS for metering to the sanitary sewer system and subsequent treatment at the local POTW. The effluent discharge limitations to the POTW from recycling operations are:

1. Daily Maximum BOD_5 Load: 0.5 tons
2. Instantaneous Maximum Concentration BOD_5: 1,450 mg/L
3. Maximum Daily Flow Volume: 0.288 MGD

Deicer Treatment Technology Selection Considerations

The City built an on-site distillation plant to recycle spent ADF as part of the original ADS system when the airport was constructed in the mid-1990s. Later, the City added a “pre-concentrator” evaporator system which was operated until 2004. Subsequently, MVR technology was installed at DEN to replace the pre-concentrator system to improve energy efficiency and reduce costs. Currently, both MVR and distillation technologies are used to recycle spent ADF.

In 2022 DEN management initiated a program to replace the existing pre-concentrator and distillation systems with a new distillation system based on the age, condition, and performance limitations of the existing system.

Based on high ADF usage and local climate characteristics, recycling systems were considered ideal treatment technologies for DEN. Spent ADF collected at DEN generally has higher PG concentrations than many other airports because of the low moisture content of snow in the area and limiting deicing to deicing pad areas. With the majority of captured spent ADF able to be economically recycled, large volumes of PG can be reclaimed and sold in secondary industrial markets or reused in the manufacture of Type I ADF. This generates higher revenues related to the sale of recycled glycol which offsets overall ADS management costs.

It is not economical to recycle runoff with PG concentrations less than 10,000 mg/L due to the large water content that must be evaporated. This requires a separate treatment technology, which is currently discharged to the local POTW. DEN has a Contribution Permit for this discharge and pays fees based on volume and BOD_5 load.

Deicer Treatment Technology Description

Descriptions of the MVR and distillation treatment technologies can be found in Treatment Technology Fact Sheet 106. The MVR systems at DEN were designed to treat all spent ADF with glycol concentrations between 1% and 25% and concentrate to a minimum concentration of 38%–55% (Figure 4). The MVR concentrate glycol is routed into intermediate storage tanks and then sent through the distillation system (Figure 5), which generates a distillate of >99% PG. All ADF at DEN is PG-based.

Figure 4. MVR unit.

Figure 5. Distillation column.

Description of Support Systems

The deicer treatment technology at DEN includes support systems for the MVR and distillation systems such as influent filtration systems and effluent “glycol polishing” units.

Each ADF concentrator includes the following support systems: blowers; main plate heat exchanger; stainless steel tanks and piping; scrubber-absorber; and instrumentation: pressure, temperature, and flow transmitters and gauges; control panel with Programmable Logic Controller (PLC).

Stainless steel "hot filter" vessels with 1-micron filter bags are used on each MVR prior to the feed entering the unit. This allows the influent to be filtered while it is hot, to remove as much total suspended solids (TSS) as possible, thus maximizing production throughput and minimizing stoppages due to premature maintenance and cleaning requirements of the MVR heat exchangers.

An activated carbon filtration step was added to the influent of the distillation process to decrease the number of solids and particulate matter that normally would build up in the heat exchangers, causing a loss of heat exchange. Without this filtration step, the system would require frequent shutdowns to perform tedious maintenance. The overall positive result is an increase in performance and productivity of the distillation system.

The distillation system includes the following equipment:

- Numerous pumps and motors.
- Instrumentation: pressure, temperature, and flow transmitters and gauges.
- Control panel with PLC equipment.
- Various motor controllers.

The final step in the recycling process after the fluid has been sent through the MVR systems and subsequently distilled to 99+% PG concentration is a product value-added step called "polishing." The polishing process uses carbon filtration, deionization, and demineralization to remove trace airfield contaminants left in the 99% glycol after distillation. Additional package treatment units have been implemented to further remove contaminants that may facilitate the PG being utilized in the formulation of Type I fluid if SAE testing standards are met.

Treatment System Capacity and Performance Parameters

Component Capacities

Table 1. Overall treatment system component capacities.

Component/Parameter	Size/Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Treatment Unit Dimensions			
• MVR	6-ft L x 20-ft W 21-ft H	9	960 ft^2
• Distillation	45-ft L x 40-ft W x 23-ft H	1	1,800 ft^2
Treatment Facility Footprint			0.12 ac.
• MVR	0.05-acre building	1	
• Distillation	0.07-acre building (34-ft H)	1	

Table 2. Treatment support system component capacities.

Component/Parameter	Size/Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Recycling System Stormwater Storage Capacity	420,000 gallons 835,000 gallons 3,200,000 gallons	5 1 1	6.135 MG
Concentrated Recycled Product Storage Tanks	12' D x 25' tall 20,000 gallons each	7	140,000 gallons
Low Concentrate System (POTW discharge) Stormwater Storage	3.5–34.3 MG	5	77.3 MG

Treatment System Performance

Table 3. MVR system performance.

Parameter	Value	Unit
Flow Rates • Minimum • Average	2 34	Gallons per minute
Treatment Load Capacity	9,700	lbs PG/day
Influent Concentration Range	10,000 - 270,000	mg PG/L
Concentrate (Glycol) Stream Concentration Range	35%–55%	% PG
Effluent (Condensate) Concentration Range	<50 - 600 <50 - 1,000	mg BOD_5/L mg PG/L
Treatment Efficiency	94.1 - 99.7	% Influent PG load removed

Table 4. Distillation system performance.

Parameter	Value	Unit
Flow Rate Range	9.7 - 12.5	gpm
Treatment Load Capacity	63,000	lbs PG/day
Influent Concentration Range	380,000 - 420,000	mg PG/L
Concentrate (Product) Stream Concentration	99–99.5	% PG
Effluent (Condensate) Concentration Range†	5,000 ~ 10,000	mg PG/L

† Condensate from the distillation unit is sent to the MVR for additional treatment.

Table 5. Additional performance data for the MVR system.

Parameter	Single Stage Production	Two Stage Production	
		Stage 1	Stage 2
Influent Flow Rate Range (gph)	150 to 200	170 to 230	130 to 170
Influent Glycol Conc Range (%)	4 to 27	1 to 4	13 to 27
Effluent Streams Produced	Distillate / Concentrate	Distillate / Concentrate	Distillate / Concentrate
Distillate Effluent Flow Rate (gph)	60 to 184	136 to 219	52 to 126
Distillate Effluent BOD_5 (mg/L)	<50 to 6000	<50 to 600	<50 to 600
Distillate Effluent pH	3 to 8	3 to 8	3 to 8
Concentrate Effluent Flow (gph)	12 to 120	8.5 to 61	33 to 102
Concentrate Effluent Concentration (% glycol)	50 to 55	15 to 20	50 to 55
Heat Source	Electric-powered steam compression		
Control System	PLC		
Energy Consumption Information	0.4Kw ger Gal Feed		
Estimate of Waste to be Produced	Sludge and solids negligible and glycol in overheads less than 0.1%		
Maintenance Frequency	Duty cycle of 95% expected depending on influent quality		
MVR Dimensions	20’ (L) x 6’ (W) x 8’ 2” (H), with scrubber 13’ (H) or 22’ (H)		

Table 6. Additional design basis for distillation system performance.

Parameter	Value	Unit
Influent Flow Rate Range	14,000 to 18,000	GPD
Influent Flow Rate Average	9.7 to 12.5	gpm
*Influent Glycol Concentration Range	38 to 42	% Propylene Glycol
Influent Temperature Range	40 to 50	º F
Number of Effluent Streams Produced	2	Distillate and Concentrate
Distillate Effluent Flow Rate Range	5.5 to 7.5	gpm
Distillate Effluent Water Quality Range	0.5 to 1	% Propylene Glycol
Distillate Effluent Water Quality	3 to 8	pH
Product Effluent Flow Rate Range	4 to 5	gpm
Product Effluent Glycol Concentration	99 to 99.5	% Propylene Glycol

*Criteria provided above are based on design change in 2004. These are not the original specifications when the unit was built.

The new distillation system is a two-stage glycol distillation process specifically designed for processing glycol to a purity level to facilitate the use of the processed glycol in certified Type I ADF manufacturing to meet evolving SAE standards. Stage 1 of the distillation takes the 50% glycol water mixture (approximately) and distills it to a concentration of approximately 85% glycol. Stage 2 takes the ~85% glycol mixture and increases the glycol concentration to >99%. The proposed distillation processing capacities include 15 gpm infeed, producing a >99% pure glycol product at a rate of 6.9 gpm. The distillation equipment providing this operating capacity is scheduled to be operational for the 2023–2024 season.

The distillation plant will include redundancies integral to each system. The two-stage distillation system is also designed with modular flexibility where either stage could be operated to create 99% glycol concentration. If Stage 1 fails, Stage 2 could be adapted to accept a lower concentration feed stock and still produce a 99% concentration. If Stage 2 were to fail, Stage 1 could be reconfigured to produce a 99% glycol concentration.

Table 7. Example DEN MVR data (2009–2010 deicing season).

Week	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**Season**
Number of MVR Units	6	6	6	6	8	8	8	8	8	8	8	8	8	
Influent Vol. Processed (gal)	570,777	542,268	555,587	586,543	832,951	723,507	704,000	750,366	804,766	770,043	800,906	766,551	716,590	**9,124,855**
Avg. Influent Glycol Concentration (% PG)	5.0	10.5	12.0	16.0	10.3	17.0	22.5	19.4	16.3	13.5	7.5	5.5	5.5	**12.4**
Vol. of 100% PG in Influent (gal)	28,539	56,938	66,670	93,847	85,377	122,996	158,400	145,885	130,774	103,956	60,068	42,160	39,412	**1,135,024**
Avg. Influent Temperature °C	65	64	61	61	62	67	69	66	72	75	77	76	74	**68**
Avg. Influent Flow Rate (GPH)*	972.5	845	855.1	903.9	1,431.7	1,121.3	1,150.8	1,163.6	1,270.0	1,204.7	1,228.7	1,180.9	1,132.4	**1,112**
Hours of Operation	3,566	3,850	3,898	3,891	4,698	5,158	4,883	5,156	5,072	5,110	5,215	5,189	5,062	**60,748**
Duty Cycle (%) **	94.0	95.0	97.0	97.0	97.0	96.0	91.0	96.0	94.0	95.0	97.0	97.0	94.0	**95**
Effluent Vol. of Distillate gal)	467,599	436,260	442,675	394,482	566,113	472,762	332,578	412,846	504,306	523,080	654,118	664,969	624,052	**6,495,840**
Avg. Effluent Distillate per MVR (BOD$_5$ in mg/L)	3,450	3,723	2,650	2,400	3,196	2,325	1,760	2,160	2,423	3,672	3,946	3,600	3,474	**3,000**
Effluent Vol. of "Concentrate" (gal)	103,178	106,008	112,912	192,061	266,838	250,745	371,422	337,520	300,460	246,963	146,788	101,582	92,538	**2,629,015**
Avg. Effluent Concentration of Concentrate (% PG)	26.0	48.0	48.0	42.0	29.5	45.5	42.5	43.0	43.5	42.0	40.5	40.5	40.0	**41.1**
Vol. of 100% PG in Concentrate (gal)	26,826	50,884	54,198	80,666	78,717	114,089	157,854	145,134	130,700	103,724	59,449	41,141	37,015	**1,080,397**
% Ratio Glycol Reclaimed vs. Infeed	94.0	89.4	90.3	91.7	92.2	92.8	99.7	99.5	99.9	99.8	99.0	97.6	93.9	**95.2**

Note: Data compiled per 28-day period while MVR systems were running.

* Average flow rate of all machines running during this time period.

**Average % hours operation calculated by comparing how many hours the MVRs ran against theoretical hours possible for the time period the machines were running.

*** Balance of PG discharged in distillate effluent to POTW.

Table 8. Example DEN distillation data (2009–2010 deicing season).

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Season
Influent Volume Processed (gal)	143,874	281,391	341,698	215,092	246,194	206,286	213,827	66,847	**1,715,209**
Average Concentration of Influent Glycol (% PG)	42.00%	40.00%	41.00%	41.00%	40.00%	37.50%	35.00%	37.00%	**39.45%**
Volume of 100% PG in Influent (gal)	60,427	112,556	140,096	88,188	98,478	77,357	74,839	24,733	**676,675**
Average Influent Temperature (º F)	50	50	50	50	50	50	50	50	**50**
Average Influent Flow Rate (GPH)	630	600	570	570	600	570	600	600	**592.5**
Average Hours of Operation (HPD)	24	24	24	23.5	24	24	24	23.5	**23.875**
Effluent Volume of Distillate Produced (gal)	86,661	164,601	201,305	146,981	142,674	120,550	131,610	45,355	**1,039,737**
Average Concentration of Effluent Distillate (% PG)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.1%	**1.00%**
Average BOD_5 of Effluent Distillate (mg/L)	6,794	5,864	7,034	7,417	6,777	7,069	7,469	8,143	4,928
Effluent Volume of Product Produced (gal)	57,213	116,790	140,393	68,111	103,520	85,736	82,217	21,492	**675,472**
Average Concentration of Effluent Product (% PG)	99.2%	99.1%	99.2%	99.2%	99.2%	99.2%	99.2%	99.2%	**99.18%**
Volume of 100% PG in Effluent Product (gal)	56,755	115,739	139,270	67,566	102,692	85,050	81,559	21,320	**669,951**
% Ratio of Glycol Produced vs. Glycol Infeed *	93.92%	102.83%	99.41%	76.62%	104.28%	109.94%	108.98%	86.20%	**99.01%**

* Variability per month due to timing of when first and last processing data was recorded.

Cost Assessment for Treatment System

The costs in Table 9 reflect the MVR and distillation treatment technologies from 2012. The Airport was responsible for the capital cost of the recycling building, facility infrastructure, ADF distribution system, ADF distribution tanks, collection piping, collection tanks, and distillation system was incurred by the airport. The vendor operating the system was responsible for the capital costs of the MVR treatment units.

The operating costs to recycle spent ADF are borne by the recycling vendor. The airport covers capital replacement costs for the distillation system when the major components fail. The airport pays the operating costs to manage and discharge all spent ADF less than 1% glycol concentration.

Table 9. Costs for the Treatment System

Cost Category	Actual (2012)
Capital Cost *Collection System,* *Treatment Building and Distillation System* *Treatment Building and System*	 $14.6 Million $2.8 Million
Annual Operating Cost	**$1.5M ~ 2.0M**

*The annual operating costs are typically offset by the sale of the recovered PG.

Lessons Learned from DEN for Airports Considering Selection of MVR, Distillation, and POTW Discharge Technologies

The following lessons learned are applicable to those considering MVR and/or distillation technologies at other airports.

1. MVR technologies are most applicable to airports that generate spent ADF concentrations of 1% and higher.
2. MVR technologies are modular which means they can be installed in a relatively small footprint and can be adjusted to deal with varying influent concentrations.
3. The MVR processing rate (flow throughput) can be limiting and will affect required storage volume.
4. The original MVR and distillation system constructed with the new airport in the mid-1990s ran for over 25 years and is now being replaced.
5. MVR units require an outlet for the effluent water produced such as a POTW or other type of on-site biological system to treat low levels of BOD_5 and glycol.
6. The mass load limit for BOD_5 is a parameter that restricts discharges to the sanitary sewer and in turn, affects the required storage volume. DEN negotiated higher mass loading rates with the POTW.
7. MVR units are more economical the greater the volume of ADF sprayed and captured. The greater the volume reclaimed, the larger the volume of product that can be sold to generate revenues to offset capital and operating expenses. If the volume of influent that is 1% glycol concentration is less than 200,000 to 300,000 gallons a year, then another treatment technology may be more cost-effective than the installation of an on-site MVR system.
8. Few airports spray and recover enough ADF to justify the installation of an on-site distillation system. Although this model has been extremely successful in Denver, many airports could not generate enough glycol to offset the capital and operating expenses of a distillation system. Instead, many airports that have MVR or other recycling systems typically transport partially recycled glycol to centralized distillation plants. Technology has now been developed where modular distillation systems can be installed at smaller airports and then that airport can serve as a centralized distillation outlet for other airports in the region.

Lessons Learned from DEN for Onsite MVR, RO, and POTW Discharge Operators at Other Airports

The following lessons learned are applicable to those operating MVR and/or RO technologies at other airports.

1. Influent glycol concentration is a primary parameter used to demonstrate the performance of the MVR systems. With each deicing event, PG concentrations of spent ADF fluctuate. Collection during storm events can generate influent that ranges from 1% to 25% during any single deicing event. The MVRs are capable of handling these concentrations without any major setbacks.
2. The effluent from the MVR is the influent for the distillation treatment system. Therefore, the concentration of glycol influent sent to the distillation system is directly influenced by the glycol produced by the MVR systems. The distillation system was fed approximately 39% concentration of glycol during the 2009–2010 and 2010–2011 deicing seasons and 45% during the 2011–2012 seasons. As per experimentation in previous years, where 8%–20% glycol concentrations were fed through the distillation system, 99+% product concentrations could not be achieved, and a greater quantity of natural gas was consumed. On average, with the unit being fed 39%–45% glycol concentrations, the unit performs to 100% of redesign expectations.
3. There is a clear correlation showing that PG concentration affects the processing rate. Over the course of the three seasons of data, the MVR systems processed at an average rate of 185 gpm. It appears the units perform best when influent concentrations are between 6.5%–19.5% glycol. Individually, an MVR unit processed 2.3 gpm, which is 91.7% of the 2.5

gpm design specification. During the 2010–2011 deicing season, the MVR average was 19.9 gpm for all machines or 2.48 gpm which equates to 99.3% of design. Adjustments are made on the PLC and the influent and effluent streams are measured on an hourly basis. Operating flow rates between 2.6–2.8 gallons per minute are achievable per MVR unit with influent concentrations between 12%–15%, but other factors such as quality of feed and desired product output also impact processing rate.

4. The quality of influent can be improved by mechanical filtration methods prior to MVR and distillation units.
5. The desired effluent concentration of product produced affects influent processing rate.
6. Daily preventative maintenance should be integrated into operations to optimize equipment performance.
7. Maintaining process variables such as temperature, flow rate, and pressures at consistent set points improves production rates. The effluent concentrations in the distillate have spiked occasionally during the last three deicing seasons.
8. The distillation system can be adjusted to produce a desired glycol concentration product. The higher the glycol content produced the greater the value of the product for resale. The average concentration of effluent product made over the course of three years was 99.13% PG. Although the system has the capability to produce up to 99.5% propylene glycol (PG) concentration, quality and color of the product can be jeopardized when exposed to additional heat. As a result, the operator of the facility maintains a 99.1% concentration target with specific product quality requirements.
9. To increase the amount reclaimed from the MVR systems, adjustments can be made to the scrubber system on the MVR units to reduce the amount of glycol in the distillate stream and increase the amount reclaimed.
10. The DEN distillation system has experienced multiple heat exchanger tube failures due to the age of the components, the incompatibility between the feed/effluent mixture, and the tube material composition. This caused the effluent (distillate) to entrap more and more residue from the decaying exchanger tubes thus driving the overall BOD_5 levels higher as the data indicates. At the same time, influent from the feed/steam heat exchangers will enter the distillate stream bringing the PG 0.4%–0.6% up to 1.0%–1.2%. A combination of these two factors has caused the effluent being removed from distillation to be temporarily sent back through the MVR units to remove the remainder of glycol while the exchangers were replaced.

Documents and Information Review in Development of Airport Summary

All treatment data provided by DEN operational logs.

Financial data provided from the September 2011 *Airport Improvement Magazine* article by Rebecca Kanable, "Denver International and Portland Jetport Stand Ready for New Glycol Regs."

Airport Deicer Treatment System Summary 8

Airport: Detroit Metropolitan Wayne County Airport—Detroit, MI (DTW)

Treatment Technology: Off-Site Glycol Recycling
POTW Discharge

Years Operated: Early 1990s–2023 (Currently Operational)

Deicer Management System Description

The initial deicer management and treatment efforts at DTW involved collecting and storing deicer-impacted runoff with discharge to the local POTW for treatment. In the early 1990s, DTW initiated efforts to reduce the propylene glycol (PG) and Biochemical Oxygen Demand (BOD_5) mass load (lbs/day) being conveyed from the airport to the local POTW. Those efforts included:

- Consolidating the application of PG-based aircraft deicers onto several deicing pads.
- Contracting with a local private local vendor to collect all runoff with greater than 2% PG from the deicing pads and haul it off-site for glycol recycling at the vendor’s facility.
- Use glycol recovery vehicles (GRVs) to collect high-concentration glycol from the gates during frost deicing activities or miscellaneous deicing activities beyond the pad areas.
- Storage and conveyance of more dilute runoff to a POTW.

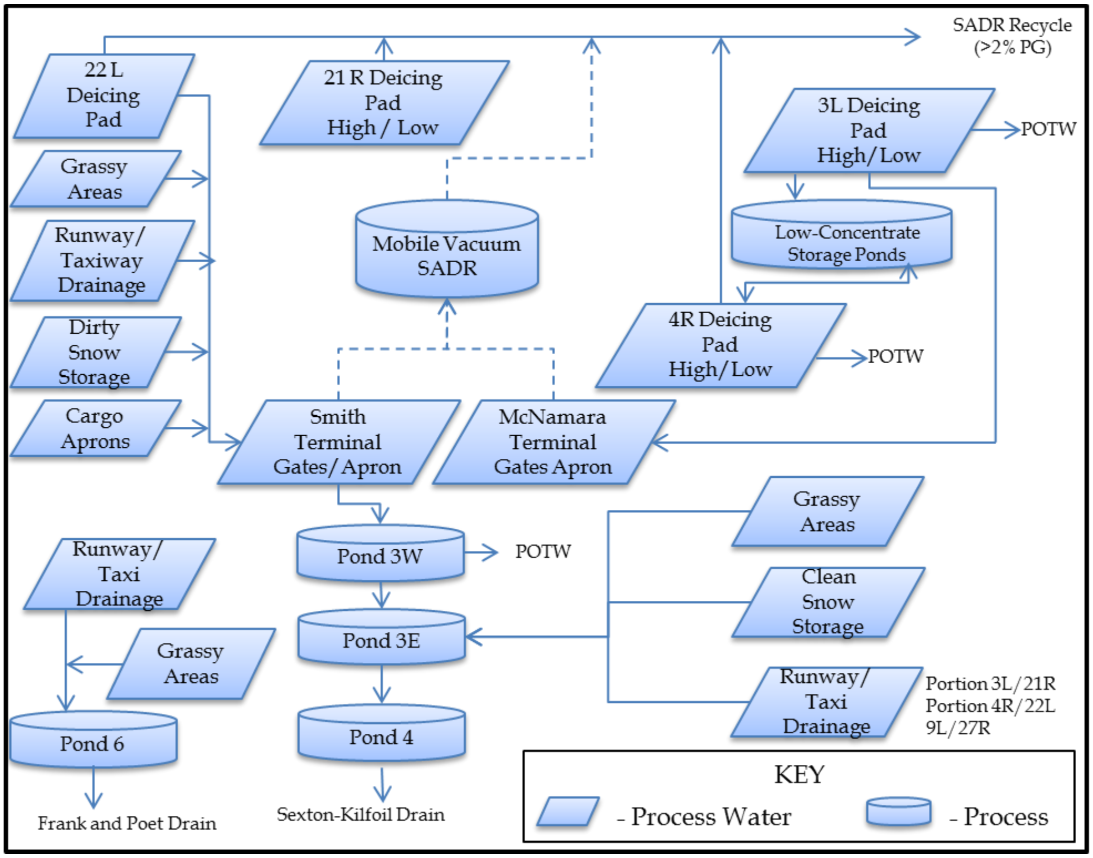

Figure 1. DTW deicing impacted stormwater flow diagram.

Deicer Treatment Technology Selection Considerations

Discharge of all deicer-impacted runoff to a POTW was initially selected as the treatment technology in the early 1990s due to the availability of POTW treatment capacity and relative simplicity of on-site airport operations. However, the initially utilized POTW (local county-owned Downriver Wastewater Treatment Facility) began to experience challenges with treating the large quantities and variability in the DTW stormwater, putting DTW's operations at risk. To reduce this risk, DTW embarked on a program to change deicing locations, the deicer collection method, and the treatment approach.

DTW worked with tenants to determine the mutual benefit of performing most deicing on pads, significantly reducing the stormwater runoff exposed to stormwater. With the PG concentrations from the deicing often high enough for economical recycling, DTW engaged a local vendor to manage all runoff with PG concentrations greater than 2% PG, including hauling the fluid off-site and recycling the glycol in an off-site facility owned and operated by the vendor. No recycling operations are performed on-site at DTW.

While the portion of runoff with PG concentrations greater than 2% captured a significant portion of the applied glycol, large amounts of runoff remained with PG concentrations too low for economical recycling but too high to discharge to surface waters. Given the performance issues of the smaller local POTW, DTW determined that a new force main connecting DTW to the City of Detroit's POTW would provide the needed improved compliance margin-of-safety. DTW constructed a new 5-mile-long force main that connected to the City of Detroit sanitary sewer system at a cost of approximately $11 million. This POTW is able to accept up to 30,000 pounds of BOD_5 per day with a flow limitation of 1 MGD, although the POTW can further limit DTW flows when precipitation events result in the POTW's inflows exceeding 900 MGD.

Deicer Treatment Technology Description

Off-Site Glycol Recycling

See Off-Site Glycol Recycling Treatment Technology Fact Sheet.

Figure 2. Tanker for transport of high-concentrate glycol to an off-site recycling facility.

Description of Support Systems

The industrial recycling treatment system does not require the airport to maintain or operate support systems for treatment.

Treatment System Capacity

DTW does not have any on-site treatment with all glycol recycling performed at a private off-site facility and all lower-concentration runoff treated off-site at a POTW. Total storage capacity for the runoff routed to the POTW is provided in Table 1.

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units
Stormwater Storage Capacity	281 MG

DTW Changes Since Initiation of the Recycling Program

No major changes to infrastructure have occurred recently. The only change noted is the closing of the 21R deicing pads and replumbing 22R to the central pad storage.

Lessons Learned from DTW for Airports Considering Selection of Off-Site Recycling and POTW Discharge

The following lessons learned from DTW are applicable to other airports considering a similar approach to DTW in the management of airport runoff:

1. The minimum PG concentration and volumetric flow capacity of the private off-site recycling vendor and the limitations imposed by the POTW are critical to the management of airport runoff.
2. Adoption of blend-to-temperature deicing fluid systems and six new hybrid deicer application trucks at DTW has unintentionally created a significant reduction in the PG concentrations collected from the deicing pads, resulting in a decrease in the volumes of PG that are recycled and an increase in the volumes of runoff that has to be routed to the POTW. The lower PG concentration in the recyclable fluid also impacts the fee the airport pays to the industrial recycling firm for recycling services.
3. Recycling has generally not proven economical at PG concentration of less than 2% on average. In addition, significant usage of deicing fluid is required to make glycol recycling profitable. Past mid-March in the Detroit area, the PG concentrations in the collected runoff are typically too low for economical recycling, resulting in all discharges of runoff with deicer being routed to the POTW past this point.
4. The airport has been experiencing more rain events in winter over the last ten years, potentially from climate change creating more periods of above-freezing temperatures and rain in winter than in the past. This is reducing glycol concentrations from deicing pads and increasing the portion of the collected runoff that must be discharged to the POTW because concentrations are too low to economically recycle off-site. This has increased overall deicer management costs.

Lessons Learned from DTW for Operators of Off-Site Recycling and POTW Discharge Systems at Other Airports

The following lessons learned are applicable to operators at other airports:

1. DTW no longer uses GRVs because they have become too labor-intensive for the received benefit. Data from DTW operations indicates that 99% of the captured aircraft deicers were

collected from the deicing pads via pad drainage, with only 1% collected by the GRVs. Therefore, GRV use was discontinued.

Airport Deicer Treatment System Summary 9

Airport: Wilmington Air Park—Wilmington, OH (ILN)

Treatment Technology: Reciprocating Aerated Gravel Bed

Years Operated: 2000–2023

Deicer Management System Description

The Wilmington Air Park (ILN) is a cargo-only airport that has been served by a variety of cargo carriers since the 1990s. In 2000, a new deicer management system was installed in response to new limitations in the facility NPDES permit that limited the maximum concentration of BOD_5 in discharges to the smaller streams receiving runoff from the airport. Because of the large deicing and stormwater collection area at the airport, as well as the configuration of the existing airport stormwater infrastructure, the ILN deicer management system was designed as two separate systems on opposite sides of the airport (known as the Lytle Creek and Indian Run Systems). Each system included the collection of deicer-impacted stormwater from existing airport outfalls, temporary storage in lined open basins, treatment of stormwater using the reciprocating aerated gravel bed technology, and the discharge of treated effluent to the surface waters. In recent years, because of the evolution of the cargo service, the Indian Run treatment system (Figure 1) remains active, with the Lytle Creek treatment system having been mothballed because deicing no longer occurs in that drainage area.

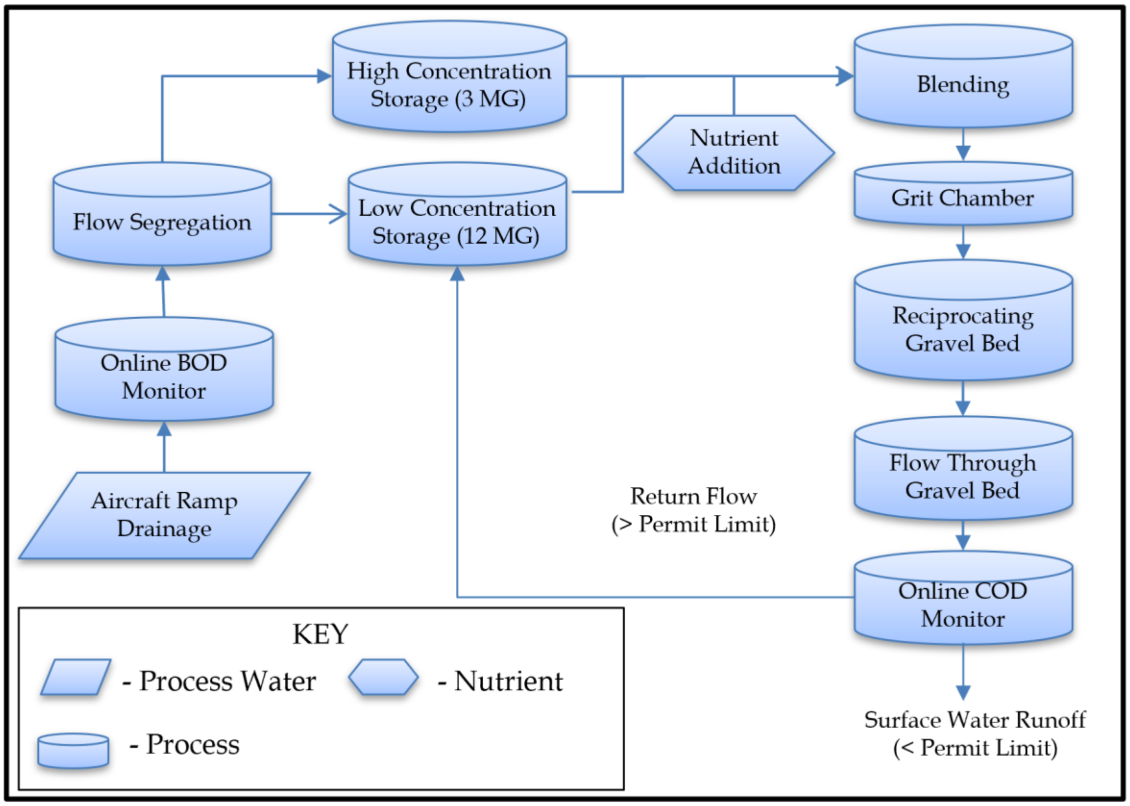

Figure 1. ILN deicer management system.

Deicer Treatment Technology Selection Considerations

In 1995, when initial NPDES permit limits and an accompanying compliance schedule became effective, the airport owners began preliminary evaluation of alternatives for deicer management measures to achieve compliance with conditions in its NPDES permit. The initial work included the evaluation of stormwater characteristics, existing deicing practices, assessment of deicer collection methods, and evaluation of deicer disposal alternatives. A review of deicer application options resulted in a decision to retain at-gate deicing and not install dedicated deicing pads. As a result, runoff from over 800 acres of airfield surface needed to be collected and managed, creating a stormwater runoff with high volume and low to moderate BOD5 concentrations.

Figure 2. ILN reciprocating gravel bed system.

An alternatives analysis was conducted to assess feasible deicer treatment alternatives. Because of POTW capacity limitations, discharge to the sanitary sewer was not an option. An evaluation of glycol recycling was conducted, but with most of the stormwater runoff having concentrations below 1% PG, recycling was determined not to be economically feasible. Once it was determined that on-site biological treatment was necessary, several methods for treatment were considered including anaerobic fluidized bed reactors (AFBR), trickling filters, activated sludge, and gravel beds. Following a multi-year pilot study, a reciprocating gravel bed treatment system, a variant of aerated gravel beds, was selected for the reasons below.

- Ability to treat high volumes of water.
- Alignment of the range of influent BOD_5 concentrations with the capabilities of the technology.
- Ability to treat water to below NPDES permit limits.
- Little to no biological solids production or sludge to manage.
- Relatively passive operational requirements.

- Ability to absorb variation in stormwater characteristics.

Figure 3. Example of bacterial film on bed gravel.

Deicer Treatment Technology Description

Reciprocating Gravel Bed, a Variant of Aerated Gravel Beds

See Aerated Gravel Bed Treatment Technology Fact Sheet 102 for an additional description of the technology. The reciprocating aerated gravel bed technology has been applied for treatment of various types of stormwater and wastewater applications, but ILN is the only deicer treatment application. The ILN gravel beds are constructed as a series of "cell pairs" in which water is pumped between the two gravel beds in the cell pair, alternately exposing one gravel bed to contaminated water in the cell for 30 to 60 minutes at a time and its partner cell to atmospheric oxygen for the same period. After the 30–60-minute period, water is pumped from the full gravel bed to the empty gravel bed, resulting in a reversal of the exposure to water and atmospheric oxygen. The benefit of this type of system is saving capital and operating costs due to the lack of blowers and aeration piping buried in the gravel bed.

Description of Support Systems

The reciprocating subsurface gravel bed systems at ILN included the following support systems:

- over 14 million gallons in up-front storage.
- a grit chamber downstream of storage and upstream of treatment to remove incoming sediment
- nutrient feed system for adding ammonia (for nitrogen) and phosphate to individual basin pairs at the pump stations.
- Parshall flume for measuring effluent flow.
- recirculation line back to storage for situations when effluent BOD_5 concentrations were too high.
- cascade aeration system to increase the dissolved oxygen concentrations in the treated effluent prior to discharge.

- Supervisory Control and Data Acquisition (SCADA) systems, with a Programmable Logic Controller that receives level and pump status data and turns the reciprocation pumps on and off to automatically create the system cycling. The SCADA system is also used to help segregate influent flow with BOD_5 concentrations that could be directly discharged to the streams from dilute runoff that needed to be treated and concentrated runoff that needed to be treated.
- End of treatment train non-reciprocating gravel bed cells to capture solids from the reciprocating cells.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units
Stormwater Storage Capacity	14.4 MG
Treatment Unit Volume	3.6 MG
Treatment Unit Dimensions	3-ac x 7-ft D
Treatment Facility Footprint	3 ac.

Table 2. Design basis for system performance.

Parameter	Value	Unit
Flow Rates - Average - Maximum	413 2,680	Gallons per minute
Treatment Load Capacity	5,700	lbs BOD_5/day
Influent Concentration Range	200 ~ 6,100	mg BOD_5/L
Effluent Concentration (average)	0 - 200	mg BOD_5/L (NPDES permit limit is 200 mg/L)
Treatment Efficiency (average)	96%	% Influent BOD_5 load treated

Cost Assessment for the ILN Reciprocating Gravel Bed System

Table 3. Costs for the treatment system.

Cost Category	Value
Capital Cost	$3.5M in 2000
Annual Operating Cost (2009)	
- Utilities	$44,000
- Chemicals	$24,000
- Analysis	$4,000
Total Operating Cost	**$72,000**

ILN Reciprocating Gravel Bed Changes Since Startup

The following represent ILN system changes since the 2000 startup based on interviews with operations staff in 2022.

1. The Indian Run treatment system remains operational 22 years after startup, but the Lytle Creek system has been mothballed because of changes in deicing areas.
2. Storage, diversion, and blending were added in 2004 in response to an increase in flight operations.
3. The top foot of the seven-foot-deep gravel beds initially consisted of pea gravel, which was intended to provide a higher treatment rate because of the greater surface area. However, the pea gravel tended to clog and was replaced with the larger No. 57 gravel.
4. Operationally, the system proved to have better efficiency at lower flow rates.

Lessons Learned from ILN for Airports Considering Selection of Gravel Bed Technologies

The following lessons learned are applicable to those considering gravel bed technologies at other airports.

1. The ILN treatment system performed as intended when the treatment system BOD_5 mass loading rates were within the system load capacity. NPDES permit limits have been consistently met. Removal efficiency for BOD_5 has averaged 96%.
2. The use of the reciprocating technology to draw in atmospheric oxygen rather than supplying oxygen via blowers has limited performance (mainly mass load treatment rates) at times and the use of blower-driven oxygen supply is recommended for future gravel bed applications to treat deicers.
3. Effluent BOD_5 concentrations less than detection limits of the BOD_5 test can be obtained when water temperatures are less than 40°F if the system isn’t overloaded.
4. Use of variable frequency drives for influent pumps provided a substantial benefit to operations by allowing more careful control of influent loads and should be included in a design.
5. Nutrient addition is crucial. The nutrient delivery system should be sufficiently robust to avoid maintenance issues that disrupt treatment.
6. No differences in the ability of the system to treat pavement deicers vs. aircraft deicers have been observed.

Lessons Learned from ILN for Gravel Bed Treatment Operators at Other Airports

The following lessons learned are applicable to those operating gravel bed systems at other airports.

1. Controlling the BOD_5 mass loading to the system is essential.
2. Pretreatment for removal of sediment and trash upstream of the gravel bed cells is important to eliminate long-term clogging.
3. Nutrient uptake at the start of each season is much larger than after the system achieves a more steady-state condition.
4. Treatment rates drop with the reciprocating system when temperatures are below 38°F, in part because the reciprocation process temporarily exposes water to the air, resulting in some heat loss.
5. When temperatures warm in the spring, the bacterial population grows quickly and can lead to temporary clogging of the cells. Mass loadings in the spring should be carefully managed to avoid this issue.
6. The nutrient feeds can precipitate under the right conditions and clog the lines.
7. Control system equipment can become out of date and potentially hamper operations.

8. Two staff members are generally sufficient to run the system, with it running unattended at times and operators on-call with remote access to alarms and controls.

Airport Deicer Treatment System Summary 10

Airport:	London Heathrow Airport—London, ENG (LHR) Mayfield Farm Catchment (Also see London Heathrow Airport, Summary 17)
Treatment Technology:	Aerated Lagoons Aerated Gravel Beds Natural Treatment Systems
Years Operated:	2001–2023 (Currently Operational)

Deicer Management System Description

London Heathrow International Airport (LHR) is divided into four main catchments designated as northwestern, southwestern, eastern, and southern. Deicing operations drain to either the eastern or southern catchment. The system discharges to surface waters. The British Airports Authority (BAA) commissioned a reed bed treatment facility in 2001 at Mayfield Farm to treat deicing runoff from the "southern catchment" of Heathrow Airport. Due to the expansion of airfield operations, the existing facility was upgraded in 2011 to provide a significant increase in treatment capacity.

The 2011 treatment system upgrade at Mayfield Farm included 3 major "unit processes" downstream of the primary reservoir: a complete mix zone (open water channels containing diffuse aeration) and a partial mix zone (containing the original 2001 floating reed rafts - a passive facultative technology with intermittent aeration zones), the balancing lagoon (an aerated lagoon), and the aerated gravel beds. During winter operations, stormwater is diverted to the primary reservoir when online meters detect high concentrations of organics (Total Organic Carbon - TOC). Stormwater is pumped from the primary reservoir to the treatment system. A simplified schematic of the system is provided below in Figure 1. A diagram of the 2011 upgrade is included in Figure 2, which includes the original and upgraded system side-by-side.

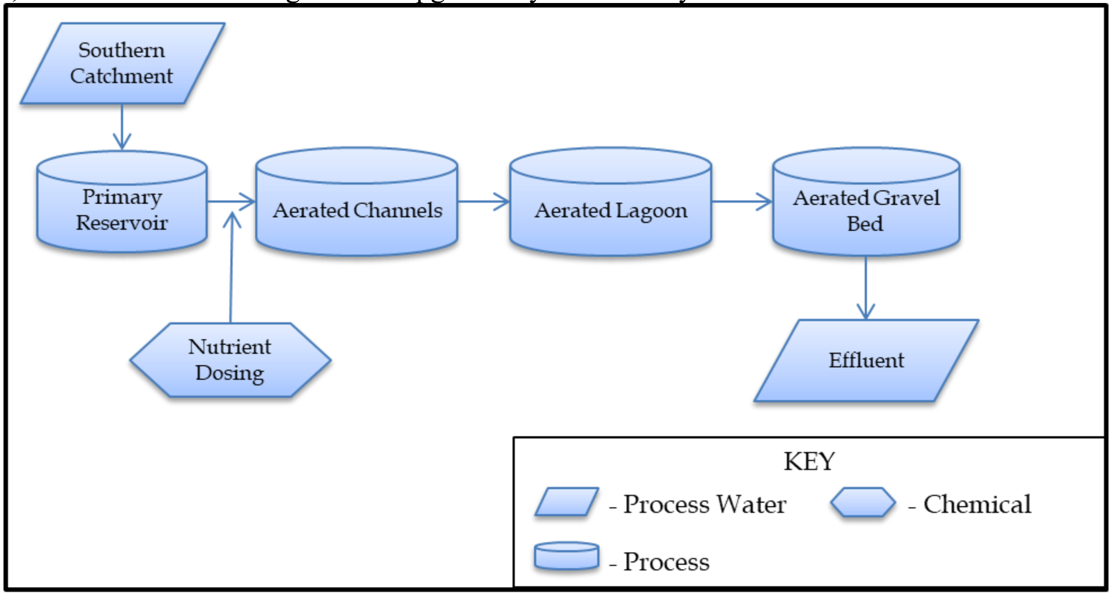

Figure 1. Mayfield Farm stormwater treatment system process flow diagram.

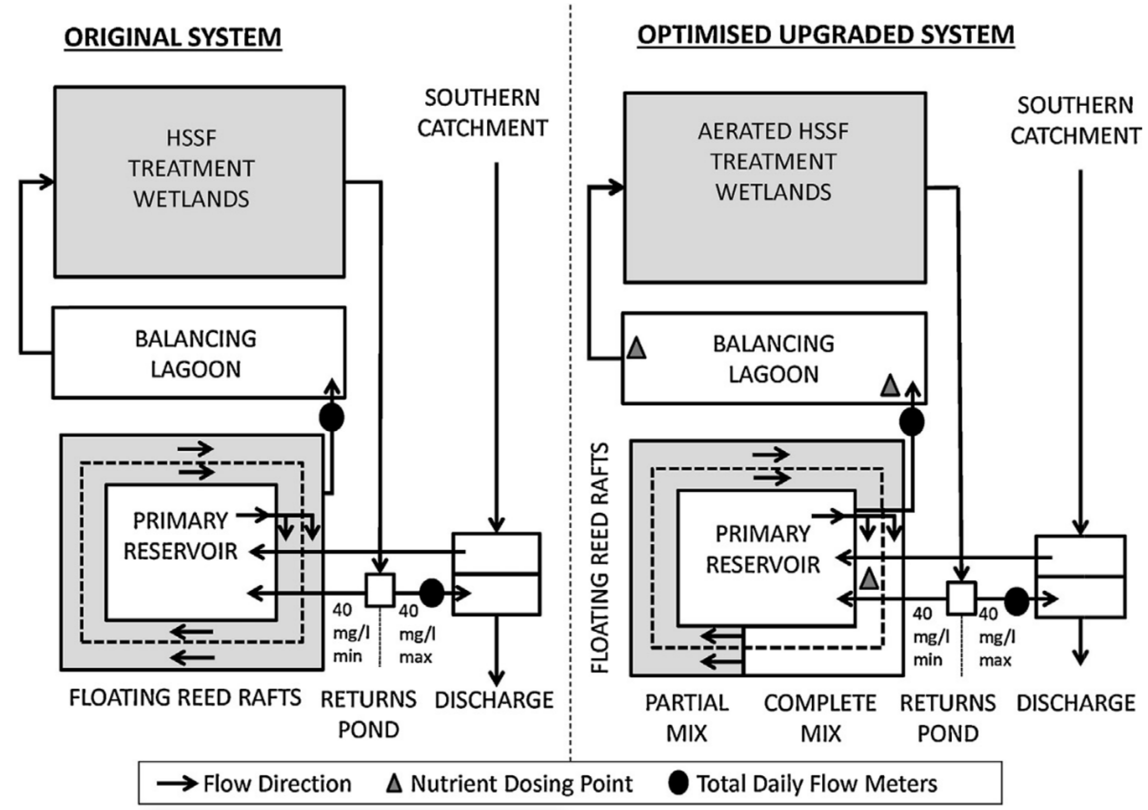

Figure 2. Plan of 2011 upgrade (C. Murphy et al., 2015).

Deicer Treatment Technology Selection Considerations

The reed bed treatment facility commissioned in 2001 at Mayfield Farm had a treatment capacity of 770 pounds of BOD_5. BAA (now Heathrow Airport Limited) decided to upgrade the treatment capacity in 2011. The upgrade included the reconfiguration of existing unit processes and installation of new aeration equipment and a nutrient feed system.

The existing floating reed raft channels were transformed into aerated channels. The channels were designed utilizing aerated lagoon practices. The first part of each channel was designed as a complete mix lagoon. The remainder of the channel was designed as a partial mix lagoon. Floating reed bed rafts were retained in the partial mix zones to improve the sedimentation of the bacterial solids generated in the complete mix zone.

The balancing lagoon was added to provide process flexibility for the treatment train. The lagoon can be employed for either hydraulic equalization or as a middle process in the treatment train. It was designed as a partial mix aerated lagoon.

The final reed bed was upgraded to a planted aerated gravel bed with an increased depth of gravel to increase oxygen transfer. The upgrade included the addition of aeration tubing and the reconfiguration of the flow distribution in the beds from horizontal (left to right) to vertical (diagonally from the sides to drains in the middle).

The following considerations were factors in the selection of the upgrade design:

1. Ability to utilize existing infrastructure at Mayfield Farm.
2. Ability to quickly design and construct the system.
3. Results from an on-site pilot test that demonstrated the capacity of the system.
4. Compliance with “green zone” requirements for the project location

Deicer Treatment Technology Description

The original treatment technology employed at LHR’s southern catchment was a combination of natural treatment systems – specifically lagoons and constructed wetlands. The 2011 upgrade incorporated aeration into the existing passive processes to provide a level of treatment that the “natural” treatment could not provide alone. Fine bubble aeration diffusers were installed into the channels used for the floating reed rafts transforming them into complete mix and partial mix cells commonly designed for aerated lagoons. Suspended diffusers were installed into the balancing lagoon-like designs used for partial mix lagoons. Finally, the constructed wetlands were reconfigured into aerated gravel beds. More information on aerated lagoons and aerated gravel beds can be found in the Treatment Technology Fact Sheets.

Figure 3. Primary reservoir (courtesy of ARM Group LTD).

Figure 4. Complete mix aerated channel (courtesy of ARM Group LTD).

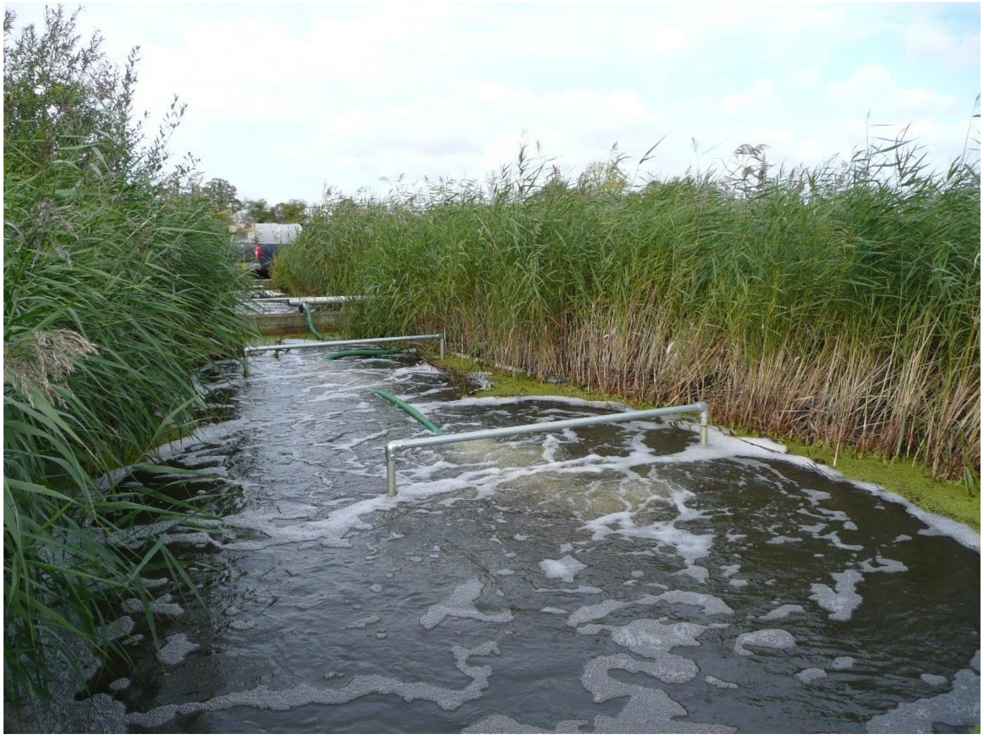

Figure 5. Partial mix aerated channel (courtesy of ARM Group LTD).

Figure 6. Partial mix lagoon (courtesy of Mark Liner).

Figure 7. Aerated gravel beds (courtesy of ARM Group LTD).

Description of Support Systems

The upgrade of the LHR treatment system included the addition of aeration equipment, a nutrient feed system, and related electrical and instrumentation work. The primary reservoir is equipped with floating aerators, which are used at the discretion of the operator.

A nutrient feed system has also been included in the re-engineering of the system. The nutrients are added at various points in the process to support bacterial growth. By adding supplemental nitrogen, phosphorus, and other micronutrients at the influent the aerobic bacteria can properly grow and degrade the hydrocarbons in the carbon-rich stormwater from deicing operations. The nutrient solution is prepared off-site and delivered to a chemical storage tank at Mayfield Farm. The feed system consists of a storage tank and chemical dosing pumps. The nutrient solution is fed to the aerated channel immediately downstream of the primary reservoir.

Instrumentation of the system includes the collection and transfer of signals from blower panels, pumps, and online analytical equipment (Total Organic Carbon, Dissolved Oxygen Probe, Phosphorus Meter, and Flow Meter) to the existing SCADA system operated by Heathrow Airport Limited. The SCADA system is used to monitor the operation of motorized equipment (blowers, pumps, and valve actuators). If the final treated effluent exceeds 40mg/l BOD, the system goes into recirculation back into the primary reservoir.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity	8.0 million gallons	1	8 MG
Treatment Unit Volume *Aerated Channels:* *Balancing Lagoon:* *Aerated Gravel Beds:*	 4.0 million gallons 5.2 million gallons 1.8 million gallons	3	11 MG
Treatment Unit Dimensions	$529{,}000\ \text{ft}^3$ $706{,}000\ \text{ft}^3$ $247{,}000\ \text{ft}^3$	3	$1{,}482{,}000\ \text{ft}^3$
Treatment Facility Footprint *Aerated Channels:* *Balancing Lagoon:* *Aerated Gravel Beds:*	 2.5 ac. 2.0 ac. 5.1 ac.		9.6 ac.

Table 2. Summary of system performance.

Parameter	Value	Unit
Design Flow Rates - Average - Maximum	 634 (40) 1,268 (80)	 gpm (lps) gpm (lps)
Design Treatment Load Capacity	7,700	lbs BOD_5/day
Design Influent Concentration	<500	mg BOD_5/L
Design Effluent Concentration (average)	30	mg BOD_5/L
Design Treatment Efficiency (average)	88%	kg BOD_5 (6 yr average)

The facility has numerous online TOC monitors that are used to measure real-time values of organics within the system. This data is logged along with related flow rates. The operation of the upgraded system began in February 2011 and, since then, the performance has been continuously monitored, analyzed, and compiled by airport staff and consultants.

Cost Assessment for the LHR Aerated Gravel Bed Treatment System

Table 3. Costs for the treatment system.

Cost Category	Projected at Initial Implementation	Actual
Capital Cost *2001*[1]*:* *2011:*	 $30M* in 2001 $4.5M** in 2011	 $27M* in 2001 Not Available
Annual Operating Cost**	$250,000	Not Provided

* Data Based on conversion: $1.40 = £1.00

** Data Based on conversion: $1.60 = £1.00

Operational effort and cost consist primarily of the management of pump, aeration, and nutrient feed systems. Biomass levels are monitored and managed as needed.

LHR Mayfield Farms Biological Treatment System Changes Since Startup

1. Upgrade of natural treatment elements to the engineered system providing aeration and nutrients to promote significantly greater growth of bacteria and degradation of deicer.
2. Online meters were switched from BOD to TOC meters.
3. Only one dosing point was used for nutrients instead of the four included in the design.
4. Increased sampling and analysis of water chemistry to quickly spot and rectify operational issues.

Lessons Learned from LHR for Airports Considering Selection of Aerated Lagoon and Aerated Gravel Bed Technologies

The following lessons learned are applicable to airports considering aerated lagoons or aerated gravel bed technologies.

1. Equalization of flow and loads from deicing events is critical in obtaining control of process performance.
2. Nutrient dosing is necessary to achieve good performance.
3. Nutrient solution delivered to the site greatly facilitates the handling of the solution by operations staff.
4. Loads to the treatment system are event-driven and highly variable in terms of flows and concentrations.

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[1] "Mayfield Farm Constructed Wetlands" Constructing Excellence (2006)

Lessons Learned from LHR for Airports Operating Aerated Lagoons and Aerated Gravel Beds

1. Online TOC monitors are favored over online BOD monitors.
2. Nutrient solution can crystallize and block dosing lines. Nutrient lines must be accessible, and designed for regular cleaning/rinsing/replacement.
3. Measures must be made to accommodate routing of tanker trucks around the site.
4. Preliminary testing demonstrated that aeration and nutrient addition greatly improved performance in comparison to unaerated beds without nutrient addition.
5. Automated nutrient control should be designed and configured by systems integrator. The nutrient feed should be regularly evaluated for accuracy and proper operation.

Documents and Information Review in Development of Airport Summary

ARM Group Limited. (2017). *6 Year Asset Review Operation and Performance Report (2011/2017).* Rugeley, Staffordshire: ARM Group Limited.

Murphy, C., S. Wallace, R. Knight, D. Cooper, and T. Sellers. (2015). Treatment Performance of an Aerated Constructed Wetland Treating Glycol from De-icing Operations at a UK Airport. *Ecological Engineering*, 117–124.

Airport Deicer Treatment System Summary 11

Airport:	Oslo Gardermoen Airport—Oslo, Norway (OSL)
Treatment Technology:	Off-Site Moving Bed Biofilm Reactor Off-Site Recycling
Years Operated:	1998–2023 (Currently Operational)

Deicer Management System Description

The Oslo Airport, Gardermoen (OSL) currently has approximately 6,000 to 12,000 annual deicing operations. A deicer collection system was constructed as part of the new airport construction in 1998. The Aircraft Deicing Fluid (ADF) applications at OSL are integrated into the deicing management system. The ADF applied at OSL includes Type I and Type II ADF, monopropyleneglycol only.

Figure 1 provides a general deicer management system flow diagram. In general, runoff from three dedicated deicing pads, as well as runoff from key taxiway/runway areas where deicing fluids generally drip from the aircraft, is collected for on-site storage and subsequent off-site treatment through a variety of treatment mechanisms.

Runoff from each of the deicing pads is segregated by concentration and routed into a series of low (<2% PG concentration), medium (>0.2%, <2% PG concentration), and high-concentration tanks (>2% PG) at individual storage tanks located near the deicing pads. The purpose of segregation is to supply downstream treatment processes with concentration ranges optimal for the following particular treatment capabilities:

Table 1. Management of aircraft deicing impacted stormwater at OSL.

Concentration	Collection and Treatment
>2% PG	The high-concentration runoff is pumped off-site to a local glycol processing facility that further concentrates glycol for subsequent trucking to a chemical industrial facility in Germany for distillation into a pure glycol product.
>0.2%, < 2% PG	Conveyed to the Gardermoen sewage treatment plant as a carbon source for the denitrification process.
<0.2% PG	Conveyed to the Gardermoen sewage treatment plant for treatment as sewage in MBBR system.

Source: Per Espen Jahren, Water Management Systems. Oslo Airport, Norway.

Other than collection of aircraft drip and shear from targeted areas, runoff from taxiways and runways is generally not collected, but percolates into the soil alongside these areas. OSL monitors concentrations of COD in the groundwater to confirm the natural attenuation of the deicing chemicals from these areas.

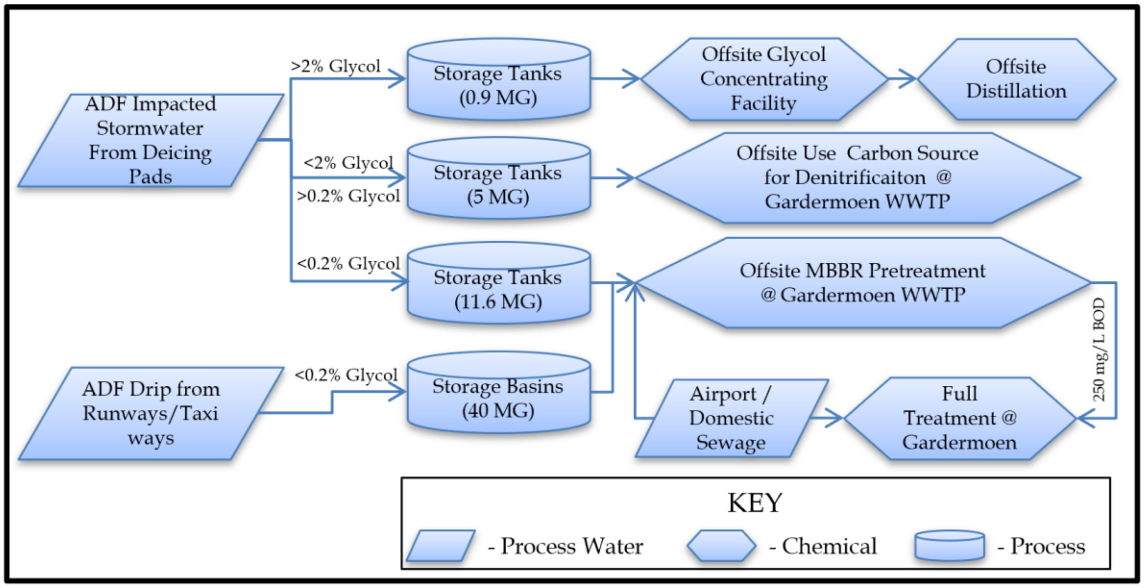

Figure 1. OSL deicing impacted stormwater management system process flow diagram.

Deicer Treatment Technology Selection Considerations

OSL is located on the largest unconfined aquifer in Norway, resulting in strict regulations to minimize the environmental impact on the groundwater system. Environmental regulations limit the acceptable concentration of Chemical Oxygen Demand (COD) in the groundwater to 15 mg COD/L on airport property and 0.5 mg COD/L off airport property during spring/snow melting periods. The regulatory limit for deicing fluid concentration in surface waters outside airport property is 0.5 mg/L glycol, formate, or acetate.

To mitigate impacts from deicing activities at the airport on the aquifer the Norwegian pollution control required OSL to not affect:

1. Groundwater balance
2. Groundwater quality
3. Natural erosion processes in the ravine system
4. Surrounding water resources

During the planning phase of OSL, it was determined that the local wastewater treatment plant did not have the capacity to treat the combined wastewaters from the local municipalities in addition to that from OSL. Therefore, in 1994, the Norwegian pollution control authorities concluded that a new semi-regional wastewater treatment plant should be built. During the planning process of the new wastewater treatment plant, testing demonstrated that the glycol in the runoff could be used as an external carbon source for biological denitrification as a substitute for the commonly used ethanol or methanol. Combining the treatment of the wastewater and the deicer contaminated stormwater into one treatment facility became a primary design focus.

The Gardermoen sewage treatment plant [GRA] was then constructed to treat wastewater from the surrounding municipalities of Ullensaker and Nannestad, as well as sanitary wastewater from OSL. Deicer-contaminated stormwater from OSL is treated in the winter and spring seasons at GRA.

Deicer Treatment Technology Description

The OSL deicer treatment system is unique compared to other airports because the biological treatment process at nearby Gardermoen sewage treatment plant [GRA] is capable of treating large volumes of deicer-contaminated runoff from the airport mixed with domestic sewage.

The treatment technology at the Gardermoen Sewage Treatment Plant (referred to hereafter as GRA) that is used to treat the combined sewage-deicer flow is a moving bed biofilm reactor (MBBR) with dissolved air flotation (DAF) pretreatment unit (referred to hereafter as IPT**)**. See the MBBR Treatment Technology Fact Sheet 107 for specific information on the MBBR process.

The IPT system at Gardermoen is dedicated to pretreating ADF-impacted stormwater conveyed from OSL. The IPT system discharges into and blends with GRA's primary effluent. GRA's biological process includes a seven-stage MBBR process with anoxic and aerobic reactors, providing organic and total nitrogen and total phosphorous removal.

The mixing of stormwater and sanitary wastewaters is likely to have beneficial effects compared to treating stormwater alone, because of the heat and nutrients supplied to the biological process from the sanitary wastewater, as well as the creation of a more stable organic and hydraulic load and a more stable sludge volume and quality suitable for sludge dewatering and handling.

Table 2. System component capacities (per Espen Jahren, Water Management, Oslow Airport, Norway).

Component/Parameter	Size / Capacity	Number of Units	Comments
ADF runoff storage Capacity, for recycling	3,500 m^3 0.9 million gallons	One tank at each deicing pad and two connected buffer tanks.	>2% glycol
ADF runoff storage Capacity, Carbon Source for denitrification	19,000 m^3 5.0 million gallons	One tank at each pad and two buffer basins	<2%, >0.2 % glycol
ADF runoff storage Capacity, For delivery to sanitary sewage treatment	44,000 m^3 11.6 million gallons	One tank at each pad and two buffer basins	<0.2% glycol
Runway deicer runoff Capacity.	150,000 m^3 (39.6 M-gal)	5 basins	2 x 9.2 M-gal. 3 x 6.6 M-gal.
ADF capacity in pre-treatment unit	Max 9,900 lbs COD/day. Max 26,400 gal/hour		
ADF consumption in denitrification unit	Approx. 280-ton glycol/year (470-ton COD/year)		
Runway deicer capacity	Max 2,200 lbs COD/day and 1.31 MGal/day.		Seasonal assimilation to/from deicer Winter/Summer

Conversion factors: 1 kg glycol = 1.68 kg COD and 1 US-gallon = 3.785 L

Dedicated IPT System [MBBR-DAF] for Stormwater Pretreatment

ADF-contaminated runoff containing less than 0.2% glycol is mixed with primary settled municipal wastewater and sent through the pretreatment MBBR process [IPT], which consists of two (2) aerobic MBBRs operated in parallel followed by dissolved air flotation (DAF) clarification.

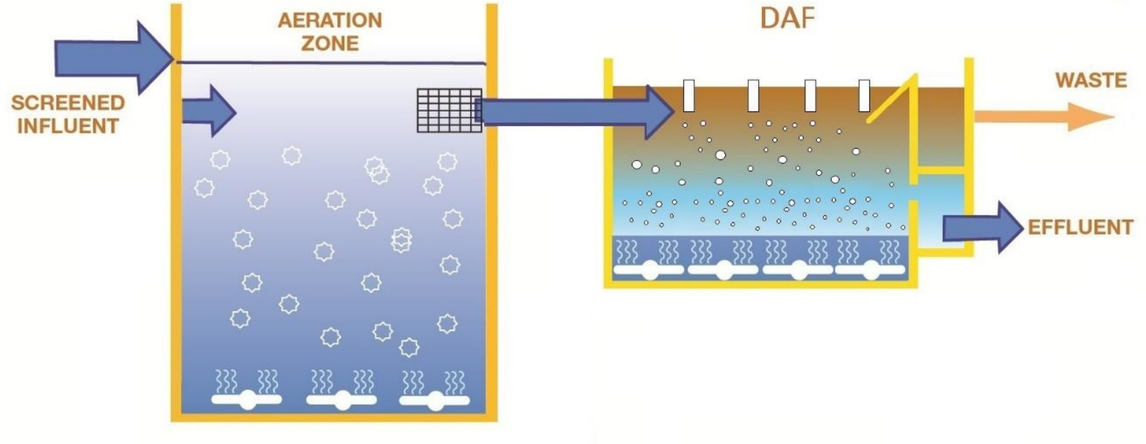

Figure 2. IPT System located at Gardermoen STP.

Above system accepts OSL Deicer Impacted Stormwater <0.2% Glycol
Includes two (2) parallel aerobic MBBRs followed by Dissolved Air Flotation (DAF)

The design criteria for the pre-treatment plant [IPT] dedicated to treating stormwater collected and conveyed from OSL is outlined in Table 3.

Table 3. IPT system design criteria for OSL stormwater conveyed to GRA.

Parameter	**Maximum Load**	**Average Load**
De-Icing Fluid (kg COD/d)	4,500	2,667
Municipal WW (pre-settled) (kg COD/d)	2,650	1,700
Design Flow (m^3/day)	8,000	5,000
Air Demand (Nm^3/h)	4,800	3,100
IPT Process Description Two (2) Parallel Aerobic MBBRs	690 m^3 each, 1,380 m^3 total 6.5-meter side water depth and 60% fill of K1 media [protected fixed film surface area of 500 m^2/m^3] at design loads Average (surface area loading rate) SALR 10.5 gCOD/m^2-day at 5-7°C	

While there were no IPT system effluent limitations, the goal was to achieve approximately 80% removal of COD or to remove organic matter so the concentration of COD leaving the IPT system matched typical municipal wastewater (approximately 250 mg/L COD).

The information on actual system performance (Figure 6) was derived from facility data averaged from 29 April 2004 through 23 June 2004.

Table 4. Actual IPT system performance.

Parameter	Value	Unit
Flow Rate, average, to 2 MBBR trains	0.523	MGD
Actual COD Treatment Load Rate	3,038	lbs/day
Influent COD Concentration		
- Average TCOD	766	mg/L
- Average sCOD	555	mg/L
MBBR Effluent sCOD Concentration (before DAF Clarification)		
- Average	110	mg/l
sCOD SALR	3.17	g sCOD/m^2-d
Treatment Efficiency	80%	% Influent sCOD load treated in 1 aerobic stage

Full Gardermoen Sewage Treatment System [GRA]

The GRA treatment plant was designed for 50,000 people or 5.83 MGD (dry weather flows) and 8.24 MGD (wet weather flows). The treatment plant was placed online in September 1998. The process flow scheme uses fine screens, grit removal, primary sedimentation, biological treatment, flocculation, and dissolved air flotation for treating the influent wastewater to an annual average of 70% Total nitrogen removal, phosphorus to less than 0.2 mg/L, and BOD to less than 10 mg/L.

Influent wastewater enters fine screens and grit chambers to remove any large particles entering the facility. Wastewater then flows to primary sedimentation tanks where coagulants might be used to remove any particulate matter. Each of two (2) biological treatment trains is described below, and details are given in Figure 3. The system includes two (2) parallel 7-Stage MBBR-DAF trains, and note that there is UV disinfection on the outlet.

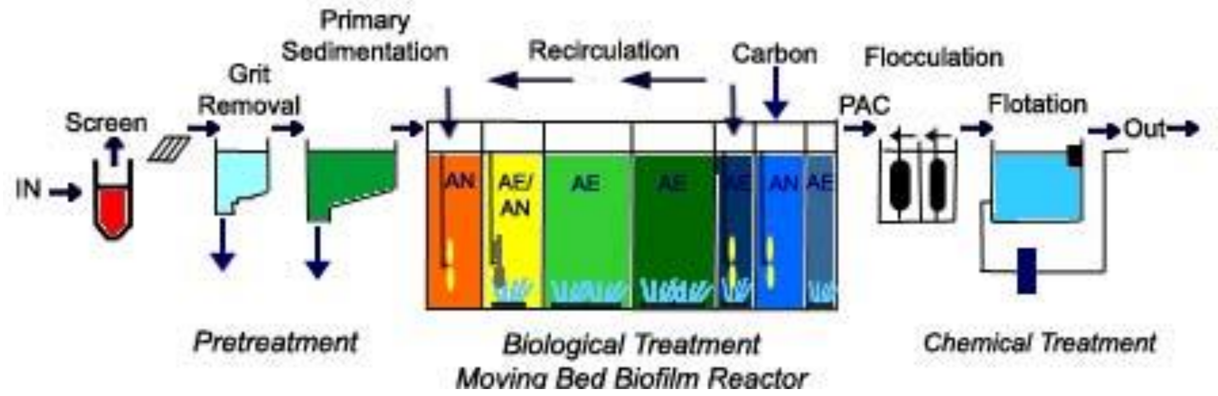

Figure 3. Gardermoen STP [GRA] biological treatment process.

Wastewater then enters the first of seven moving bed reactors operated in series, labeled R1-R7. R1 and R2 are operated as pre-denitrification reactors in summer to achieve 80%+ removal of Total Nitrogen removal and to save on external carbon use in the post-denitrification reactor. R1 and R2 are operated as aerobic BOD removal and nitrification reactors in winter when the temperature of the wastewater and nitrification rates decrease. R3 and R4 are always operated as aerobic reactors for BOD removal and nitrification. R5 acts as an oxygen depletion reactor. The wastewater exiting R5 is either recirculated to the first reactor or sent directly to R6. R6 is the post-denitrification reactor to which external carbon is added.

External carbon dosing is controlled using online dissolved oxygen (DO), temperature, and nitrate-nitrogen sensors such that the STP's final effluent average total nitrogen (TN) concentration is typically less than 3 mg/L. The facility is required to provide 70% average annual TN removal, but the average removal is 85% and with optimal carbon-to-nitrogen ratio control (5.5:1), greater than 94% TN removal is provided. De-icing fluid from the Oslo airport is used during the winter months. Either methanol or ethanol is used during the summer months. An assimilation of denitrifying bacteria to/from deicing fluid is conducted seasonally, whereby blended carbon sources are used and the ratio of each is increased or decreased over a period of several weeks.

R7 is aerobic and used to burn off any excess carbon added to R6.

The GRA MBBR process effluent is also clarified using DAF, with integral coagulation and flocculation for total phosphorous removal. UV Disinfection is performed on secondary DAF effluent prior to discharge.

Table 5. GRA Municipal MBBR-DAF process details [Source: Kaldnes Miljoteknologi (KMT acquired by Veolia) Case History].

Parameter	**Metric**	**US**
Design Flow		
Dry	22,100 m^3/day	5.83 MGD
Wet	31.200 m^3/day	8.24 MGD
Primary Settling Area	420m^2	4,520 ft^2
Water Depth	3.3 m	10.8 Feet
Total Surface Area		
Moving Bed Biofilm Reactors		
Number of Trains	2	2
Total Empty Bed Volume	(5,790m^3)	204,445 ft^3
% Fill of Media in Reactors	42-67%	42-67%
Water Depth	6.5 m	21.3 feet
Dissolved Air Flotation		
Total Surface Area	195 m^2	2,100 ft^2
Water Depth	2.5 m	8.2 feet
R1 (Anoxic/Aerobic) 67% fill	420 m^3	14,830 ft^3
R2 (Anoxic/Aerobic) 67% fill	420 m^3	14,830 ft^3
R3 (Aerobic) 67% fill	695 m^3	24,540 ft^3
R4 (Aerobic) 67% fill	695 m^3	24,540 ft^3
R5 (Anoxic/Aerobic) 42% fill	180 m^3	6,356 ft^3
R6 (Anoxic/Aerobic) 67% fill	375 m^3	13,241 ft^3
R7 (Aerobic) 51% fill	110 m^3	3,884 ft3

The information on actual system performance (Table 6) was derived from facility data averaged from January 1999 through June 2006.

Table 6. Actual System Performance (Rusten and Odegaard 2007).

Parameter	**Value**	**Unit**
Flow Rates	1.5386	Million Gallons per Day
Actual COD Treatment Load Rate	8,379	lbs/day
Actual TN Treatment Load Rate	640	lbs/day
Influent COD Concentration - Average	653	mg/L
Influent TN Concentration - Average	49.84	mg/L
Effluent COD Concentration - Average	30	mg/l
Effluent TN Concentration - Average - Low Concentration Capability	7.34 < 2	mg/L at C/N ratio <5:1 mg/L at C/N ratio 5-10:1
Treatment Efficiency	95% 75-85% >= 94%	% Influent COD load treated % Influent TN load treated at C/N ratio ~2.5:1 % Influent TN load treated at C/N ratio >= 5.5:1

Lessons Learned from OSL for Airports Considering Selection of MBBR Technology

Conclusions drawn from the operation of the MBBR at GRA that can be utilized by other airports considering implementing this technology include:

1. The MBBR technology is located in an enclosed facility, with the cold stormwater influent mixed into warm sanitary wastewater. This results in less treatment at cold temperatures compared to some other deicer treatment systems.
2. The MBBR technology typically has negligible effluent concentrations of BOD_5 (3.2 mg/L) and COD (25 mg/L).
3. The municipal wastewater MBBR system is operated year-round, treating deicer-contaminated stormwater from OSL in winter and spring. The year-round operation allows a healthy bacteria population capable of treating the seasonal stormwater runoff. Assimilation of denitrifying bacteria to/from ADF is conducted seasonally.
4. Nutrient balance is provided by the municipal wastewater.
5. Some municipal wastewater treatment plants need sources of carbon to facilitate the process of removing nitrogen from wastewater (the denitrification process). Airports may want to engage local wastewater treatment authorities to assess if there is a need. If so, it could be a lower-cost method than other alternative off-site destruction methods for disposing of the concentrate. The biggest obstacles to utilizing collected deicer contaminated stormwater as a carbon source for denitrification are:
    a. Means of transportation and transportation costs from the airport to the treatment plant since it cannot be discharged to the sanitary sewer system.
    b. Means of storage for the deicer at the treatment plant.

c. Means of metering in the deicer into the denitrification process, given the potentially changing deicer concentrations.
d. Matching the quantity of carbon needed for denitrification with the quantity of deicer that is available. This can be problematic since the availability of deicer is variable.
e. Large-volume storage facilities must be available in order to provide an even delivery to the sewage treatment plants.

Lessons Learned from OSL for MBBR Operators at Other Airports

The following lessons learned are applicable to those operating MBBRs at other airports.
At initial

1. *Influent Deicer Concentrations.* The collected deicer contaminated stormwater sent to the pretreatment MBBR [the IPT process] contains less than 2,000 mg PG/L or approximately 3,400 mg COD/L. Prior to treatment in the MBBR, the deicing-impacted stormwater is mixed with the influent sanitary wastewater. Sanitary wastewater typically ranges between 250 and 800 mg COD/L (Metcalf & Eddy 2003). Mixing the sanitary wastewater with the deicing impacted stormwater typically reduces combined concentration before treatment by the MBBR and dampens the peaks. Mixing the sanitary wastewater with the deicing-impacted stormwater increases the temperature of the deicing-impacted stormwater and provides nutrients required for biological treatment and cellular reproduction in the biofilm. Higher concentration stormwater runoff is used as a carbon source for the denitrification process in the municipal treatment system at GRA.
2. *IPT System.* The presence of sanitary wastewater sources provides a steady baseline mass loading that likely stabilizes the biological population in the IPT system, potentially making for a more robust system in the face of the more fluctuating deicer load contribution.
3. *Treatment Efficiencies.* The MBBR has demonstrated a 96% removal efficiency for COD.

Documents and Information Review in Development of Airport Summary

Metcalf & Eddy. (2003). *Wastewater Engineering, Treatment and Reuse*. New York: McGraw Hill Publishing.

Rusten, B., and H. Odegaard. (2007). *Design and Operation of Nutrient Removal Plants for Very Low Effluent Concentrations, Proceedings of the Water Environment Federation, January 2007,* 25(2): 1307–1331.

Airport Deicer Treatment System Summary 12

Airport: Portland International Airport—Portland, OR (PDX)

Treatment Technology: Anaerobic Fluidized Bed Reactor
POTW Discharge

Years Operated: 2011–2023 (currently operational)

Deicer Management System Description

In response to effluent limits for Biochemical Oxygen Demand (BOD_5) in their NPDES permit and Industrial User Permit for discharges to the sanitary sewer, the Port of Portland (Port) constructed an airport-wide deicer management system in several phases at the Portland International Airport (PDX) that included the construction of an on-site anaerobic fluidized bed reactor (AFBR) treatment system in 2011. The deicer management system includes segregation of clean, dilute, and concentrate deicer runoff collected from multiple sub-drainage areas using online Total Organic Carbon (TOC) monitoring; a total of 5 MG of high concentrate runoff storage and 26 MG of dilute storage; AFBR treatment of concentrated runoff with discharge of treated effluent to the sanitary sewer; and metering of dilute runoff to either the Columbia Slough or the Columbia River. The maximum allowable mass loads of deicing compounds that can be discharged to the sanitary sewer, Columbus Slough, and Columbus River are regulated by Industrial User Permit and NPDES Permit limits.

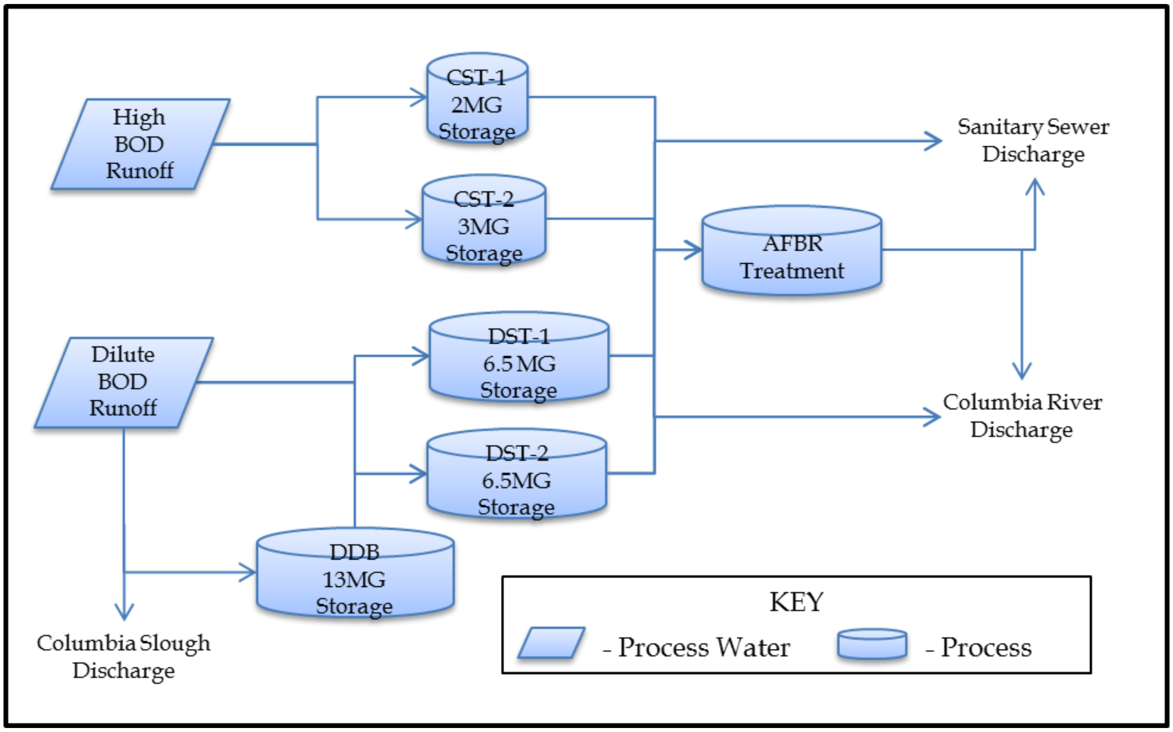

Figure 1. PDX deicer management system flow diagram.

Deicer Treatment Technology Selection Considerations

The Port determined through modeling and other calculations that the mass loading limits in the PDX NPDES and Industrial User Permits were restrictive enough that a combination of storage and on-site treatment was needed to meet deicing operational needs and maintain permit compliance.

Figure 2. PDX on-site treatment facility site (courtesy Gresham Smith).

A wide variety of deicer treatment technologies were considered for PDX, including chemical treatment, reverse osmosis, and various types of biological treatment. An AFBR treatment facility was chosen because of the following:

- Demonstrated ability to treat deicer-impacted runoff.
- Ability to consistently and predictably achieve desired effluent concentrations, despite the great potential for variability of flows and concentrations entering the concentrate storage tanks.
- Ability to withstand the potential intermittent availability of deicer without needing to re-seed the system.
- Mass load treatment capacity and influent concentration range that matched the site’s needs.
- Ability to remove a high percentage of influent $BOD_{5.}$
- Footprint that fits available space at the site.
- Alignment with existing PDX’s existing airport-wide deicer collection system that segregated flows into dilute and concentrate streams.

Deicer Treatment Technology Description

Anaerobic Fluidized Bed Reactor (AFBR)

See AFBR Treatment Technology Fact Sheet 104 for a general description of the AFBR technology. The PDX AFBR system generally follows this description.

Figure 3. Reactor units in the PDX AFBR system.

Description of Support Systems

The AFBR at PDX includes the following support systems for the treatment reactor-separator unit:

- Storage (one 2 MG tank and one 3 MG tank for concentrate deicer runoff).
- Influent pumping system.
- Heat generation and exchange loop.
- Chemical feed for nutrient addition and pH control.
- Biogas handling.
- Biological solids removal and handling.

Collected runoff water from the concentrate storage tanks is routed to a small holding tank, and then pumped to the AFBR at flow rates that vary with influent TOC concentrations to meet the goal of constant TOC influent mass load. The cold influent water is heated first by passing it by warm effluent water in a heat exchanger, and then by passing it by hot water in a second heat exchanger. The hot water is obtained by heating potable water in a boiler using biogas captured from the reactor. The biogas is approximately 77 percent methane and 23 percent carbon dioxide and is used similarly to natural gas. For the PDX system, the heating system burns self-generated biogas during the bulk of the season, except for initial yearly startup when natural gas is used. Any excess biogas is burned in a flare external to the building. The AFBR technology requires addition of a base chemical (sodium hydroxide) to keep pH in the reactors neutral, as well as addition of various chemical nutrients to support growth of the bacteria. Biological solids exiting the reactor-separator unit with the treated effluent are removed with a dissolved air flotation clarifier under certain conditions. The treated effluent from the reactors can be routed to bypass the dissolved air flotation clarifier, with the biological solids discharged to the sanitary sewer. Biological solids that are removed from the effluent are disposed of in a landfill.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Treatment Unit Volume	29,000 gallons	2	58,000 gallons
Treatment Unit Dimensions	Reactors: 14-ft dia.	2	N/A
Treatment Facility Footprint	0.28 ac. Building	1	0.28 ac. building

Table 2. Summary of system performance.

Parameter	Value	Unit
Flow Rates - Average - Maximum	 10 - 30 200	gpm
Treatment Load Capacity - Design - Actual	 6,600	lbs BOD_5/day
Influent Concentration Range	1,000 to 30,000	mg BOD_5/L
Effluent Concentration (average)	<150 < 100 < 10	mg COD/L mg BOD_5/L mg PG/L
Treatment Efficiency (average)	>99.4%	% Influent COD load treated

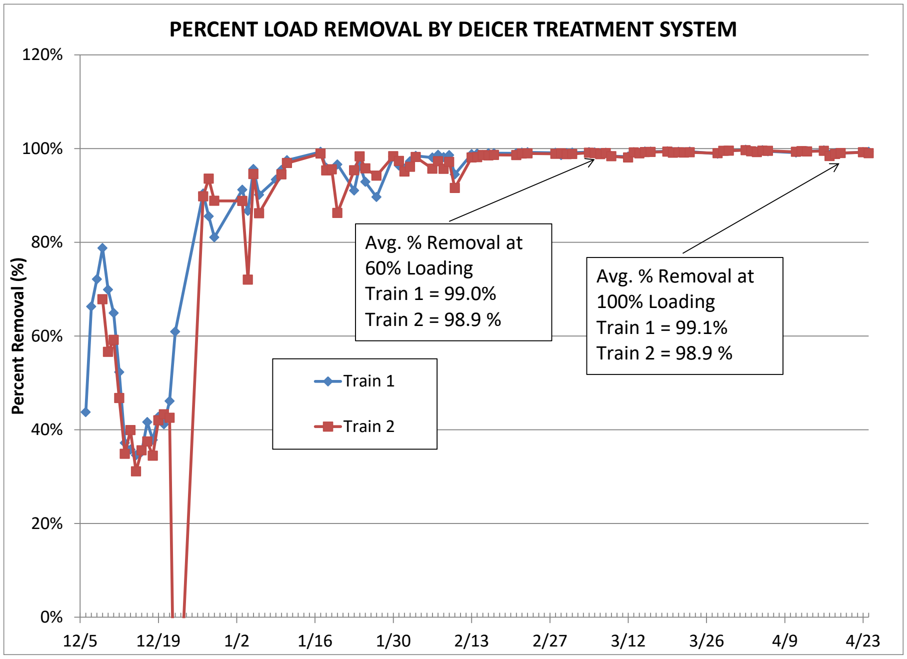

Figure 4. Actual system treatment efficiency performance for example season.

PDX AFBR Changes Since Startup

The following represent system changes since the 2011 startup based on interviews with operations staff in 2022.

1. No changes have been made to the core AFBR treatment process in the 11 years of system operations.
2. No additional storage or treatment capacity has been added since 2011.
3. Small-scale improvements were made to AFBR support systems, including the nutrient feed pumps and the influent/effluent heat exchanger.
4. The initial operational guidelines called for the use of micronutrients to supplement the nitrogen and phosphorus macronutrients that are necessary for bacterial growth. Over time the micronutrient feed has been discontinued with no clear negative effects.
5. PDX was able to work with the state regulatory agency to change effluent limits for discharges into the Columbia River to be in terms of TOC instead of BOD, allowing the effluent TOC monitor to be used to govern discharges. This provided greater confidence that limits are consistently met.

Lessons Learned from PDX for Airports Considering Selection of AFBR Technology

The following lessons learned are applicable to those considering AFBRs at other airports.

1. The PDX AFBR has consistently met and generally exceeded design expectations for mass load capacity, percent removal, and effluent quality. The two AFBR reactors both perform well but not exactly the same.
2. No difference has been observed in the treatment of aircraft vs. pavement deicers.
3. The system starts up very quickly each season without a need for reseeding of bacteria. Methane production for use in heating influent water occurs within 4 to 5 hours of seasonal startup.
4. During lighter winters, the AFBR runs for 2 to 3 months. In heavier winters, the AFBR runs for 4 to 5 months. Seasonal run times will vary by climate and deicer use.
5. Two operators are generally sufficient to run the system on a 24/7 basis in winter.

Lessons Learned from PDX for Airports Operating AFBR Systems

The following lessons learned are applicable to those operating AFBRs at other airports.

1. At initial startup of the system, acquisition of the appropriate type of healthy bioseed is critical. The bioseed must be obtained from a similar type of anaerobic operation.
2. It is not necessary to purchase bioseed for the startup of subsequent seasons.
3. Most of the system challenges at PDX have been with the off-gas processing system and heating system, including the influent heat exchange system which is occasionally prone to plugging.
4. Smaller pumps such as those used for sampling have been the biggest maintenance challenge.
5. Managing incoming trash from the airfield has been a challenge, even with the presence of basket strainers to protect the treatment system.

6. A well-planned and thorough commissioning of the system, including performance-based commissioning once bioseed is added is critical to successful system implementation. This includes testing the biogas handling system under field conditions.

Airport Deicer Treatment System Summary 13

Airport:	Edmonton International Airport—Edmonton, Alberta (YEG)
Treatment Technology:	Aerated Gravel Beds Off-Site Recycling
Years Operated:	2001–2023 (Currently Operational)

Deicer Management System Description

The deicer management system at Edmonton International Airport (YEG) includes three dedicated deicing pads, with two of the pads normally in use. Spent aircraft deicer from the pads is routed to a holding tank, where it is pumped to tanker trucks and hauled off-site by a third party for processing at an off-site recycling facility in Calgary.

The original system diverted higher concentration stormwater into a 90,000 m^3 (24 MG) pond, known as the Gun Club Pond (GCP), and lower concentration stormwater into a 287,000 m^3 (76 MG) Detention Pond (DP). In 2016, a North Retention Pond (NRP) and South Retention Pond (SRP) were installed to provide 180,000 m3 (47 MG) of lined storage. Water from the storage ponds is pumped to Aerated Gravel Bed (AGB) treatment trains and subsequently discharged to adjacent Whitemud Creek. Two AGB treatment trains were installed in 2011 and another two were installed with the 2016 upgrade. The existing GCP has not been decommissioned however it is only utilized during emergency scenarios (Edmonton Regional Airports Authority, 2017).

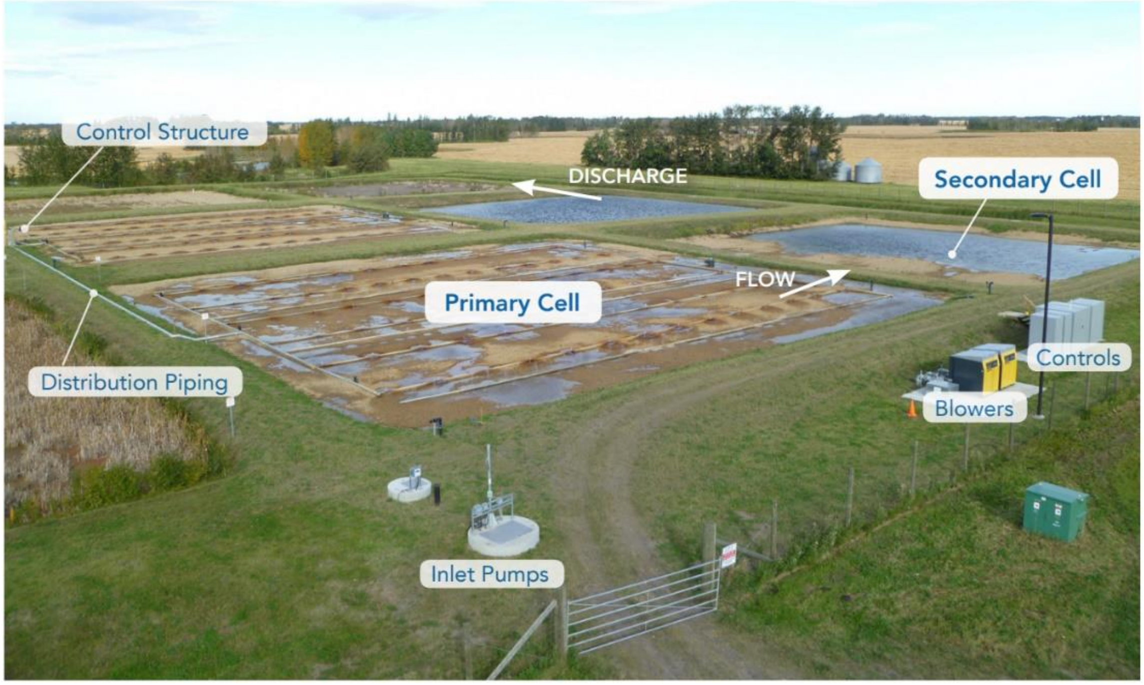

Figure 1. System layout (Edmonton Regional Airports Authority, 2022).

The upgraded treatment system consists of parallel trains. The first cell of each train is an aerated graved bed. The second cell is a surface flow wetland. The upgraded system is sized to treat the stored volume within the desired summertime treatment period.

Deicer Treatment Technology Selection Considerations

The primary considerations for the airport in the selection of the upgraded treatment technology were low capital cost, a system that was compatible with the existing system, the ability to provide sufficient treatment load, and the ability to reliably meet effluent limits.

Deicer Treatment Technology Description

YEG uses a combination of Passive Facultative Treatment (See Treatment Technology Fact Sheet 108) in the form of a horizontal subsurface wetland and Aerated Gravel Beds (See Treatment Technology Fact Sheet 102). A schematic of the process is included in Figure 2 and flow distribution and aeration/collection piping are shown in Figures 3 and 4, respectively. Figure 5 provides a photograph of the completed 2016 AGBs.

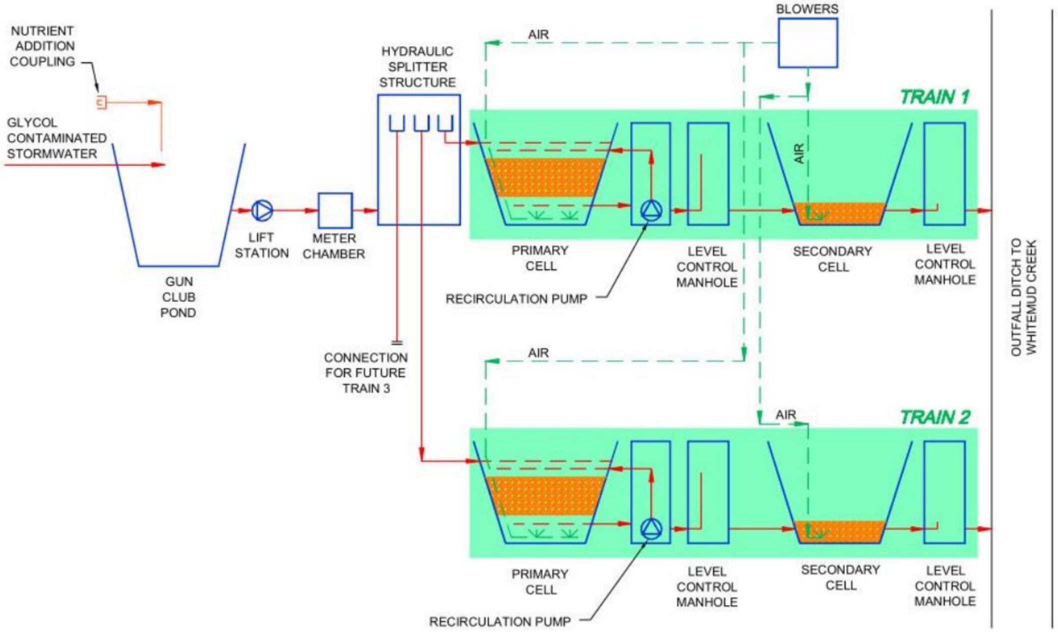

Figure 2. Schematic of the treatment system (du Toit, Liner, Dechaine, & Given, 2013).

Figure 3. Vertical flow distribution system.

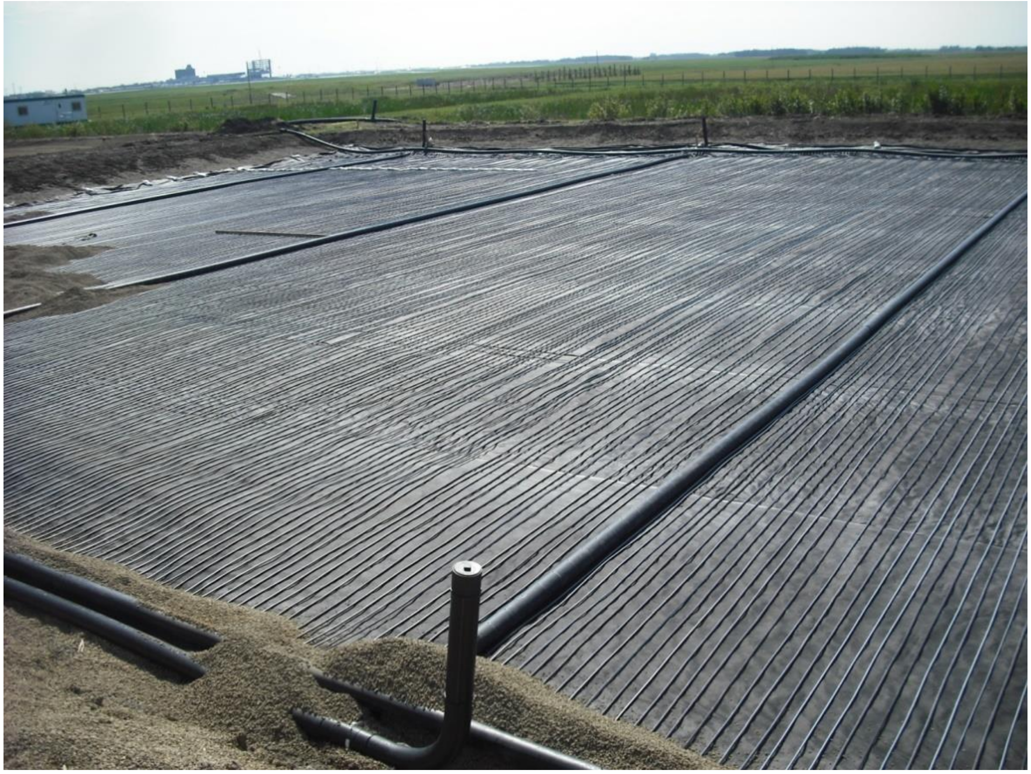

Figure 4. Installation of drain and aeration lines.

Figure 5. 2016 Upgrade with the terminal in the background (courtesy of M. Liner).

Description of Support Systems

Influent from storage lagoons is pumped into an above-ground splitter structure that divides flow between the trains. Influent pumps (two) have variable frequency drives. Water from the splitter structure flows by gravity to influent dosing and nutrient addition lines lay atop the aerated gravel bed. Flow from the dosing line travels downward through the gravel to drains on the floor of the cells. A recirculation pump is installed in a sump prior to the effluent structure and is designed to provide water recirculation during seasonal start up. Each recirculation pump is sized for 350 gpm. An irrigation propeller pump is used for the high-flow, low-head system.

Effluent from the aerated gravel bed flows by gravity to the constructed surface flow wetlands (second cell). Influent is distributed along the leading edge of the system and picked up in a drain line running along the opposite side. The water level in this cell is to be maintained at a one-foot water depth.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity	90,000 m3 (23.8 MG)	2	180,000 m3 (47.6 MG)
Treatment Unit Volume	140,000 gallons	2	280,000 gal
Treatment Unit Dimensions	141-ft L x 141-ft W x 3-ft $3^1/_3$-in D	2	130,400 ft^3
Treatment Facility Footprint	0.45 ac. Per train 2.5 ac. total site	2 1	2.5 ac.

Table 2. Summary of system performance.

Parameter	Value	Unit
Flow Rates		
- Minimum	6 (95)	lps (gpm)
- One Pump	37 (586)	lps (gpm)
- Two Pumps	48 (761)	lps (gpm)
Treatment Load Capacity	2,085	lbs BOD_5/day
Effluent Concentration (average)	100 <<100	mg PG/L mg BOD_5/L
Treatment Efficiency (average)	98%	% Influent COD load treated

The upgraded system was started in the spring of 2012. Deicer-impacted stormwater enhanced with nutrients was gradually loaded into the system in a flow-through manner following a two-week acclimation period in which effluent was recirculated. A figure illustrating the decrease of COD over the sampling period is provided in Figure 6 below.

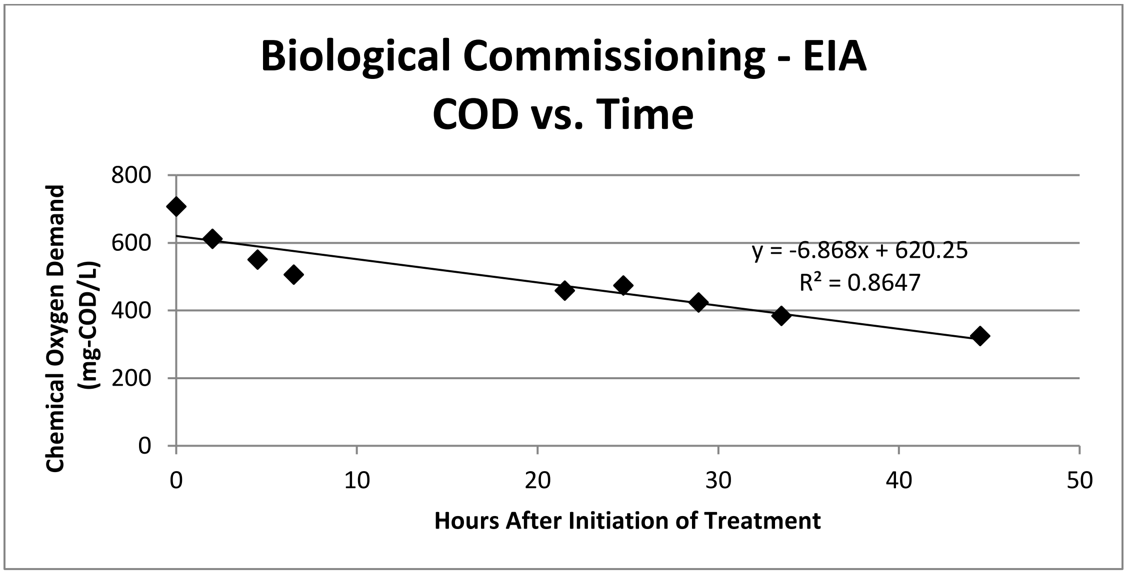

Figure 6. COD removal after initiation of treatment.

Figure 6 illustrates a near-linear decrease in COD concentrations over time at approximately 7 mg-COD/L per hour (168 mg-COD/L per day). It is expected that after all biodegradable contaminants are degraded the COD values will level out to a practical “floor” representative of the non-biodegradable fraction of organics in the water. Photos below provide a visual confirmation of treatment after 24 hours of operation.

Figure 7. Influent (left) and effluent (right) samples after 24 hours of operation.

YEG Aerated Gravel Bed System Changes Since Startup

- In 2011, the existing Natural Treatment System was partially converted to an Aerated Gravel Bed treatment system. Two additional AGB treatment trains were added in 2016
- Improved monitoring and controls with PLCs added
- Two new lined lagoons added in 2016
- System upgrades were driven to manage a rapid increase in deicer use that matched the growth in airport operations during the period.

Lessons Learned from YEG for Airports Considering Selection of AGB Technology

The following factors are critical to effective and efficient performance in the YEG Aerated Gravel Bed system:

1. The YEG AGB includes upstream storage and equalization, with storage of stormwater containing deicers occurring from the beginning of the deicing season until the spring thaw, at which time the treatment system operates to avoid temperature-based impacts.
2. Groundwater level control drains should be incorporated around lined lagoons.
3. Communication between the design team and airport on initial treatment criteria and system treatment capabilities is important to understanding expected performance under different conditions.
4. Expandability of the system should be factored in to account for future growth.

Lessons Learned from YEG for AGB Operators at Other Airports

Lessons learned from the AGB system at YEG that are applicable to other AGB operations include:

1. Applying nutrients one time upstream of the treatment system was deemed the most cost-effective means to add nitrogen and phosphorus to the influent flow. Additional augmentation of nutrients may be necessary to make up for nutrients that are depleted during the storage period.
2. The ability of the AGB to start up and shut down effectively is a critical factor since the system is uniquely designed to provide treatment of stormwater in the thaw period of the spring.
3. Aeration tubing system requires the ability to perform acid cleaning to remove scaling. There is some evidence of aeration tube fouling that may be linked to iron oxidation; there are high iron concentrations in the area groundwater.
4. Two operators are used for the system, with work performed by in-house staff
5. No issues have been reported with the treatment of pavement deicer.

Documents and Information Review in Development of Airport Summary

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Airport Deicer Treatment System Summary 14

Airport: Halifax Stanfield International Airport—Halifax, Nova Scotia (YHZ)

Treatment Technology:
Mechanical Vapor Recompression
Distillation
Aircraft Deicing Fluid Blending

Years Operated: 2004–2023 (Currently Operational)

Deicer Management System Description

Halifax International Airport (YHZ) employs three deicer treatment technology elements: a mechanical vapor recompression system (MVR), a distillation system, and a process for blending concentrated recycled glycol from the distillation system, with a chemical ad pack to meet the criteria for use of the reclaimed fluid for deicing.

Deicer Treatment Technology Description

Mechanical Vapor Recompression System

A description of the MVR treatment technology can be found in the Treatment Technology Fact Sheet 106.

Figure 1. YHZ glycol recycling facility.

Distillation System

Since 2012, YHZ has added a distillation process for further processing the concentrate product that is produced by the glycol concentrators on site. See Treatment Technology Fact Sheet 105 for a general description of the distillation treatment process. The product from the MVR concentrators has a glycol concentration of approximately 50%. This 50% product is then processed by the distillation system to create a 99.5% pure glycol product and a water distillate by-product. The wastewater is purified to adequate purity levels for direct discharge to the local municipal wastewater treatment facility, the same as the water from the MVR concentrator.

The distillation process was custom designed for the purification of collected SADF in a multistep process that takes the 50% glycol feedstock and removes water and impurities. The resultant recycled glycol has comparable purity and quality characteristics to virgin glycol. This glycol is then blended into certified SAE AMS 1424 Type I ADF.

The distillation process utilizes a natural gas-fired thermal fluid heater as the energy/heat source for the process. The distillation columns are fed from a thermal fluid heater integrated with heat exchangers for transferring energy into the separation process.

The distillation equipment includes the distillation plant, feed pumps and filters, transfer pumps, fluid quality sampling and analysis equipment, and processing and storage tanks.

The process equipment is made primarily from stainless steel materials to ensure the purity of the glycol is not negatively impacted. Stainless steel construction also provides long-term durability of the equipment.

The distillation process produces a waste steam made up of separated impurities and some sacrificial glycol. This waste compound is generically referred to as “sludge” and is disposed of by being trucked to an off-site waste treatment facility. The waste stream has a relative volume of approximately 5% of the volume fed into the process.

The equipment is PLC-controlled. The entire process can effectively be managed and operated by a single operator per shift. Typically, the system operates 24 hours a day, 7 days a week during the season, while feedstock exists to be processed.

Type I ADF Blending Process System Description

Aircraft Deicing Fluid (ADF) blending takes place at the YHZ facility. This is accomplished by blending the 99% pure glycol product produced in the distillation process with a certified chemical add pack according to an approved recipe. The ADF that is manufactured is an SAE AMS 1424 Type I ADF.

The ADF manufacturing is accomplished by blending the ingredients in a blend tank. The process is a batch process, where the various ingredients are pumped into the blend tank according to a pre-established volume, derived by the target blend volume in accordance with the certified formula. The established volume of 99% pure glycol product is pumped into the blend tank, and then the set volume of the chemical add pack, also referred to as “slurry”, and finally the set volume of deionized water.

The ingredients are added to the blend tank and the fluid is circulated according to an established SOP to achieve the target dispersion. After the mixing, the fluid is quality checked, and once confirmed to meet certification targets, is pumped into a holding tank and ready for sale.

Description of Support Systems

The MVR at YHZ includes the following support systems:

- Two (2) “low” concentrate tanks capable of storing a combined 846,000 gallons

- One (1) “high” concentrate tank capable of storing 66,000 gallons
- Filtration system
- Dissolved Air Flotation (DAF) unit
- Chemical feed system
- Blowers with variable frequency drives
- Heat exchangers
- Scrubber-absorber
- Electrical service and control system
- Solids disposal

Filtration systems installed to treat influent on the MVR units are an integral part of the overall recycling system. The DAF unit is an effective and considered an integral part of the recycling process. Stainless steel "hot filter" vessels with 1-micron filter bags are also used on each MVR prior to the feed entering the unit, which allows the influent to be filtered while it is hot, in an effort to remove as much TSS as possible. Each type of filtration method increases influent throughput production by minimizing stoppages due to premature maintenance and cleaning requirements of the MVR heat exchangers.

The DAF was designed as a support system for the MVR units to treat as much of the contaminants that make up TSS in the spent ADF as can be drawn out before the fluid is processed. Utilizing the DAF increases production, and with less contamination of dirt in the MVR heat exchanger plates, the downtime for maintenance and cleaning is significantly reduced. The DAF adjusts the pH to a neutral level by reading and injecting caustic with a pumping system. With the fluid at neutral pH, a flocculent chemical is added to the fluid. This fluid is then injected into the fluid-filled DAF unit along with air drawn in through the DAF pump. This mixture binds the contaminants (smaller than 1 micron) together to make larger particles that float with the air that was injected. These accumulated contaminants form a floating “cake” on the top of the fluids, which is skimmed off and disposed of. The fluids under the cake, now filtered by the DAF, are drawn into the MVR units for processing. The concentrate is stored in a tank for interim storage until it can be further processed through a distillation process into a 99% glycol product for use in the manufacture of SAE AMS 1424 Type I aircraft deicing fluid.

The control system includes many warning and emergency controls that if in the event of any mechanical failure or fluid overflow situations, the sensors shut off the units automatically. This was installed to minimize manpower requirements so that in most cases the facility can be run with one person.

Heat exchanger plate changes are anticipated every 170,000 USG on average. Downtime per shutdown is approximately 12 hours per machine for total maintenance.

Solids from processing in YHZ filters are dried and sent to a landfill. Tank sludge at season end is disposed of at an off-site treatment plant.

Treatment System Capacity and Performance Parameters

The processing rate of the distillation system was designed to produce approximately 25,000 gallons of 99% pure glycol product per month from a feedstock of a 50/50 glycol-water fluid.

Table 1. Glycol Distillation Component Capacities

Parameter	Low End	Target/High End
Glycol Percentage of Feed	44% glycol	48–52% glycol
Glycol Percentage of Final Product	98.0%	99.5–99.9%
Input Feed Rate	1.5 gal/min	1.8–2.0 gal/min
Number of Effluent Streams	3 streams – Concentrate, distillate, waste sludge	3 streams – Concentrate, distillate, waste sludge
Product Output Rate	0.6 gal/min	0.7–0.8 gal/min
Distillate Effluent Flow Range	0.8 gal/min	1.0–1.1 gal/min
Distillate Effluent Water Quality	<600 COD in mg/L	<600 COD in mg/L
Sludge Rate	0.1 gal/min	0.1 gal/min
Product Output pH	6.0 pH	7.0/8.0 pH
Monthly Product Output	21,000 gal	26,500–29,000 gal

Table 2. Example YHZ MVR Performance Data (2009–2010 Deicing Season)

Stage One	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Season**
Influent Volume Processed (Liters)	285,258	962,200	1,071,267	1,048,233	1,256,418	1,157,428	547,684	**6,328,488**
Average Influent Glycol Concentration (% EG)	6.9%	3.7%	4.6%	5.1%	4.3%	3.1%	1.5%	**4.2%**
Effluent Volume of Concentrate Produced (Liters)	83,328	266,124	334,766	332,045	349,691	270,055	106,638	**1,742,647**
Average Effluent Concentration of Glycol Produced (% EG)	14.0%	14.0%	14.0%	14.0%	14.0%	14.0%	14.0%	**14.0%**
Stage Two								
Influent Volume Processed (Liters)	0	294,078	289,742	356,237	380,658	235,500	212,223	**1,768,438**
Average Influent Glycol Concentration (% EG)	0.0%	14.0%	14.0%	14.0%	14.0%	14.0%	14.0%	**14.0%**
Volume of 100% EG in Influent (Liters)	0	41,171	40,564	49,873	53,292	32,970	29,711	**247,581**
Effluent Volume of Concentrate Produced (Liters)	0	60,535	75,403	89,617	101,056	52,072	50,935	**429,618**
Average Effluent Concentration of Glycol Produced (% EG)	0.0%	53.0%	50.5%	52.0%	54.6%	53.0%	53.0%	**52.7%**
Volume of 100% EG in Glycol Produced (Liters)	0	32,084	38,079	46,601	55,177	27,598	26,996	**226,533**
Combined Discharges from Both Stages								
Total Distillate Discharged to Sanitary (Liters)	165,396	785,907	854,841	768,398	1,053,244	1,157,206	561,469	**5,346,461**
Average Effluent Concentration of Distillate (mg/L EG)	<100	<100	< 100	< 100	< 100	< 100	< 100	**< 100**
% Ratio of Glycol Reclaimed from Stage 2 vs. Infeed	N/A	77.9%	93.9%	93.4%	103.5%	83.7%	90.9%	**91.5%**

Lessons Learned from YHZ for Airports Considering Selection of MVR, Distillation, and ADF Blending Technologies

The following lessons learned are applicable to airports that may be considering selecting MVR, Distillation, and/or ADF Blending technologies.

1. One of the biggest implementation and management challenges is determining the volume of spent deicer storage that is required, especially given the variability in weather conditions.
2. MVR units are more economical the greater the volume of ADF sprayed at the airport, and more importantly, the more glycol that can be captured at the airport for recycling. The greater the volume reclaimed, the larger the volume of product that can be sold to generate revenues to offset capital and operating expenses. Sale of the treated EG can reduce operational burdens and concerns associated with extensive trucking operations during winter weather events.
3. The MVR technology can be effective for airports that consistently have variability in weather patterns and in influent concentrations.
4. The MVR can successfully conduct "Two Stage" processing to efficiently remove large volumes of water in very dilute glycol concentration streams.
5. The MVR concentrators are modular, which means they can be installed in a relatively small footprint and can be adjusted to deal with varying influent concentrations or infrastructure needs.
6. If an airport generates a significant volume of spent ADF then on-site recycling can be more cost-effective than transporting the fluid to an off-site facility.
7. Filtration systems are an integral part of the glycol recycling process with MVR technology.
8. The DAF system is a viable support technology to improve processing rates as well as other mechanical filtration methods to minimize equipment maintenance associated with heat exchanger plate fouling.
9. The MVR at YHZ requires additional treatment of the MVR distillate such as a POTW or RO treatment system to be discharged to surface waters.
10. Before an on-site recycling facility was established at YHZ, all spent ADF was trucked to an off-site disposal facility in Debert, Nova Scotia. With the increase in volumes of ADF being applied at YHZ and the increase in volumes collected of spent ADF, trucking off-site almost became unsustainable. An average season at YHZ could generate 240 tanker trailer loads that would have to be trucked off-site. In addition, the cost was significant, since each load would experience a four-hour turnaround and unpredictable weather conditions during the winter that could halt transportation altogether. This impacted the availability of on-site storage to support deicing operations. With an on-site recycling facility, fluid is transferred quickly and manpower requirements are reduced. The recycling contractor staff is cross-utilized to conduct collection operations, recycling activities, and the management of wastewater discharges. The fluid is processed on-site and adequate storage can be maintained for deicing operations.
11. The recycling contractor leases the airport land for the glycol processing facility as well as the airside tanks at YHZ. The contractor supplied and installed the tanks, building, recovery trucks, and processing equipment for the Halifax site. YHZ supplies the deicing pad and pumping systems and owns the drain-blocking devices used in the spent ADF collection infrastructure.

Lessons Learned from YHZ for Airports Operating MVR, Distillation, and/or ADF Blending Systems

The following are lessons learned applicable to airports operating MVR, distillation, and/or ADF Blending systems.

1. The ability to adjust the MVR systems in response to variability in influent glycol concentrations is crucial.
2. Influent quality is improved by filtration methods prior to treatment.
3. The desired effluent concentration of product affects influent processing rate.
4. Daily preventative maintenance is integrated into operations in order to optimize equipment performance.
5. Maintaining process variables such as temperature, flow rate, and pressures at consistent set points improves production rates.
6. MVR heat exchangers require more maintenance and cleaning when dealing with ADF with higher concentrations of thickening agents, such as Type IV ADF.
7. Based on feedback from the recycling operator, the MVR "up-stages" the concentration of spent EG to increase flow rates through the MVR units. In reference to the data, it is apparent that each concentrator running "Stage 1" can process at least double the amount of influent when compared to a concentrator running "Stage 2" with higher concentration glycol. This is very beneficial since this technique removes water from storage tanks more quickly than single-stage processing and keeps adequate storage for future storm events.
8. Although the distillate effluent concentrations are low, additional treatment of the low-concentration distillate is typically necessary. The MVR treatment system may commonly be installed at airports where there is an outlet for the effluent water produced such as a POTW or other type of system to treat low levels of COD and glycol.
9. Each MVR at YHZ can be adjusted to produce a desired glycol concentration product. The MVR units produce two effluent streams and the desired concentration set points in each effluent stream directly impact the performance of the MVR concentrators. The operators have the ability to adjust various parameters on each MVR via the PLC and can do so as conditions or influent characteristics change. In Stage 1 of the processing phase, the effluent glycol that is produced averages 14% EG. This glycol concentration is continually monitored to balance the parameters on the machine to increase the processing rate of the low-concentration influent and to ensure that the effluent glycol produced is of a concentration that is ideal to feed Stage 2 of the processing step. At Stage 2, the effluent glycol level is also crucial as the recycling contractor has a goal to produce a minimum of 50% EG. At this level and higher, the contractor can sell the glycol and generate revenue to offset the expenses of the recycling operation.
10. The second effluent stream produced from the MVR units is "distillate." This is the distilled water that is continually monitored to ensure glycol levels remain below 100 mg/L EG and BOD is below 300 mg/L to comply with the wastewater discharge permits. Based on the data, the MVR systems demonstrate that they are able to continually achieve distillate levels below the 100mg/L requirement. BOD target concentrations are met through monitoring oCOD concentrations and applying a site-specific correlation factor for COD to BOD. If the wastewater is not within the target concentration range, it can be sent through an aerator system prior to discharge.

Airport Deicer Treatment System Summary 15

Airport: Zurich Airport—Zurich, SWTZ (ZRH)

Treatment Technologies: Natural Treatment System
Distillation

Years Operated: 2002–2023 (Currently Operational)

Deicer Management System Description

ZRH is Switzerland's primary airport, transporting approximately 24 million passengers annually. The airport covers a total area of 800 ha (1976 acres), including 250 ha (617 acres) of impervious area. Permit limits for stormwater discharges to the river Glatt require concentrations less than 10 mg/L BOD_5 and less than 20 mg/L dissolved organic carbon (DOC). As a result, much of the deicer-impacted runoff from the airport has to be collected for treatment at the airport.

In 2002, ZRH constructed a system for collecting, storing, and treating deicer-impacted stormwater featuring passive, in-ground biological treatment. Testing of the system and establishment of operating parameters occurred over a five-year period from 2002 to 2007. Two forms of natural treatment technologies, infiltration basins, and spray irrigation-fed soil treatment, are used to treat low- and moderate-concentration fractions of runoff, respectively. The airport also uses distillation for the treatment of highly concentrated runoff to obtain a recyclable product.

In the ZRH Deicer Management System, represented schematically in Figure 1, approximately 70% of the aircraft deicer is applied on two central deicing pads, with most of the remainder applied at the terminal aprons. Runoff containing spent deicing fluid is collected from the deicing pads, terminal apron, remote deicing areas, and several taxiways. All but 250 hectares of airport surface area is currently collected. However, based on pressure from regulators, ZRH is planning to expand the area of runoff collected and treated. Currently, ZRH collects and treats 75% of the carbon contained in deicer-impacted runoff. By the year 2015, this share is expected to be increased to 95%.

Online Total Organic Carbon (TOC) meters at various locations are used to measure the concentration of the collected runoff. The runoff is diverted to one of three locations based on concentration, as shown in Figure 1. The runoff is stored in underground reservoirs prior to treatment and disposal. The airport has 5.3 million liters of storage tanks available for runoff.

Through over five years of pilot testing and monitoring, ZRH determined that a high degree of control of the quantities and timing of discharges to treatment is necessary to achieve the desired effluent quality.

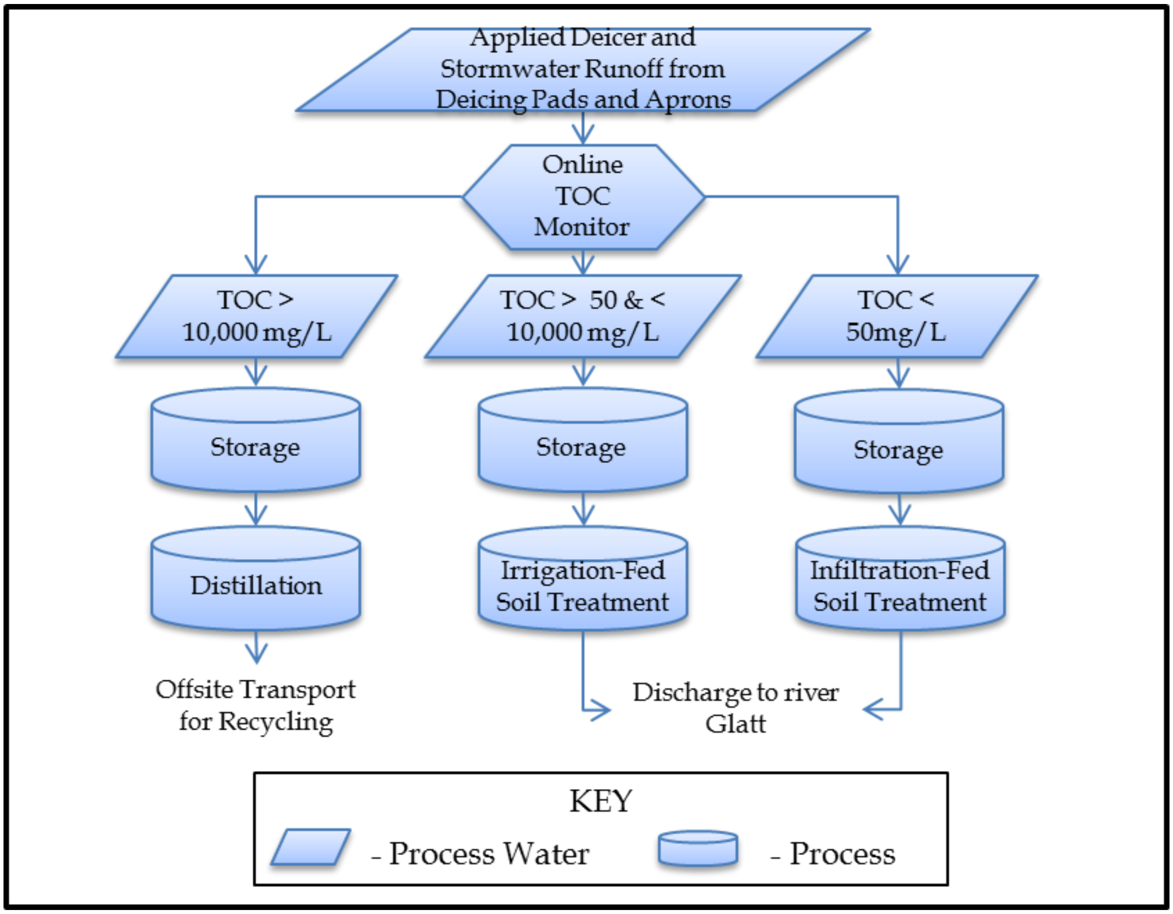

Figure 1. ZRH deicer management system.

Deicer Treatment Technology Selection Considerations

In the 1990s, the local Swiss state (Canton) began pressuring the Zurich Airport Authority (ZAA) to meet cantonal concentration limits for discharges from ZRH to the river Glatt. To reduce impacts to the Glatt from deicing operations, a deicing task force, comprised of the department of water protection and hydraulic engineering and Swissair was created. The task force began evaluating treatment methods appropriate for reducing discharges from the airport to below the cantonal concentration limits.

ZRH evaluated discharge to the local POTW (Werdholzli), in-situ soil treatment, aerated gravel beds, and an aerobic membrane bioreactor as potential treatment technologies. The natural biological methods included two passive treatment alternatives: root (reed) bed wetland treatment and spray irrigation treatment.

Pilot studies were conducted for root bed sewage, spray irrigation, aerated gravel beds, and the aerobic membrane bioreactor. All of the treatment methods demonstrated the ability to reduce concentrations from deicing operations at ZRH to below the cantonal concentration limits. However:

1. The Werdholzli POTW treatment capacity was determined to be inadequate to treat the flows or loads from ZRH.

2. A reed bed wetland-based treatment system was tested and had some success in treatment, but it was determined not to be a desirable long-term option because of the following:
    a. Odor issues.
    b. It was an obstacle to aviation activities.
    c. Required too much space.
    d. Required too much maintenance.
    e. The effectiveness of treatment depended greatly on starting conditions and other factors difficult to control.
    f. A large initial capital investment would be required.
    g. Maintenance costs were high.

The spray irrigation in-situ soil treatment technology tests demonstrated that the technology would require the lowest investment and lowest operational costs. Additionally, spray irrigation was selected because:

1. It is suitable for low concentrations.
2. ZRH has land available for irrigation.
3. The ZRH climate is suitable for winter-time irrigation.

The spray irrigation system was tested from 2002-2007 as described below and has been operational since. The testing was performed to establish the parameters for controlling influent flows to the irrigation system based on ambient conditions.

ZRH also has a second passive Natural Treatment System, described as Infiltration Basins, which treat the lowest concentration fraction of runoff (<50 mg/L TOC). Runoff for this system is supplied via piping rather than spray irrigation. In recent years, a distillation system was also added Off-Site to increase the concentration of runoff with greater than 1% concentration.

Deicer Treatment Technology Description

The irrigation and infiltration-fed treatment technologies below the ground surfaces at ZRH are classified as “Natural Treatment Systems” in this guidebook. The systems are considered relatively passive operationally because there is no active control over the biological treatment that occurs in the soil and media in the in-ground systems (e.g., there is no aeration, nutrient addition, mixing, etc.). There is, however, significant active control over the timing and degree to which the treatment areas are loaded with deicer-impacted stormwater. The systems are considered facultative from a biological treatment standpoint because, without active aeration, it is reasonably likely that the bacteria degrading the deicer are a mix of bacteria types or bacteria that can function under both aerobic and anaerobic conditions. The focus of this summary is on the two biological technologies, although basic parameters of the distillation system used to treat the bulk of the deicer loading are provided. General descriptions of the Natural Treatment System and Distillation technologies are provided in the Treatment Technology Fact Sheets 108 and 105, respectively. The specific applications of the technologies used at ZRH are described below.

1. *Infiltration Basins (for TOC <50 mg/L)*
   The lowest concentration portion of the runoff (<50 mC/L) at ZRH is treated with a Natural Treatment System technology described by the airport as infiltration basins. The basins include a vegetated 30 cm top layer of humus (degraded organic material) on top of a sand and stone gravel layer. A liner is located under the gravel layer to seal the treatment units and prevent contamination of groundwater. Treated water is collected with a perforated pipe and discharged to the river Glatt. Approximately 47% of the total surface runoff volume and 0.3% of the total spent deicer mass load is treated in the infiltration basins.

Figure 2. Surface of ZRH infiltration basin.

2. *Spray Irrigation In-Situ Soil Treatment Technology (for TOC >50 mg/L, <10,000 mg/L)*
   The spray irrigation in-situ soil treatment at ZRH is a highly controlled system for managing the spraying of deicer-impacted runoff to the soils based on ambient conditions and runoff characteristics. The irrigated areas cover approximately 21 hectares (51 acres). The irrigated areas are in the infield grass areas outside of the safety areas adjacent to the runways. The irrigation system requires a complex series of pumps, pipes, and approximately 700 pop-up sprinklers with heated heads to prevent the mechanism from freezing in winter. The irrigation pumps are fed from six reservoirs which can hold a total of approximately 4,500 m^3 (~1.2 million gallons). The irrigation system can process approximately 25 liters per second

   While irrigation could take place year-round, due to relatively low storage capacity, irrigation is operated from October to April. The flow rates pumped through the irrigation system are controlled based on continuous measurement of several different parameters, including:

   - Influent and effluent TOC concentration
   - Groundwater depth
   - Precipitation
   - Wind speed
   - Air temperature
   - Soil temperature

The airport has developed ranges for these ambient conditions that are acceptable to achieve the desired effluent quality. The system has TOC (DOC) load targets on an hourly, daily, and total load based specific to irrigation areas that are not to be exceeded. Vegetation is also monitored. The procedure for monitoring and controlling flows to the irrigation system is largely automated. The monitored area is divided into four quadrants.

No irrigation can occur under the following conditions:

- Rainfall of over 0.2 cm per hour
- Rainfall of over 1.5 cm per day
- Air temperature of less than minus 15° Celsius
- Soil temperature of less than minus 2° Celsius
- Wind greater than 6 meters/sec
- Groundwater less than 0.5 m below the surface

Pollutants are degraded biologically primarily in an aerobic zone at the top 20 cm of the soil. Based on testing, degradation is most complete at a depth of 80 cm. Treated water from the irrigation system passes through perforated pipe drains that were originally installed at the airport to reduce the airport groundwater elevations. Therefore, unlike some other in-situ-based soil treatment systems, ZRH has the opportunity to monitor the treated concentrations. This monitoring led to the understanding that the loadings of deicer-impacted stormwater to the soil needed to be controlled based on the factors shown above. The monitoring and control system helps to reduce the exposure of the treatment system to stressful conditions. The treated water is discharged to the river Glatt. Typical detention time in the soils associated with the irrigation system is 7 days.

The irrigation areas are located in the infield areas adjacent to runways and taxiways, although outside of the runway safety areas.

Figure 3. ZRH irrigation system

3. *Distillation*

Distillation is used for high-concentration spent deicing fluid collected from two deicing pads. The high-concentration portion of the collected runoff is processed with an on-site distillation treatment plan paid for and run by a deicing chemical company. If the average concentration is below 5% glycol, the distillation process is not economically reasonable because of electricity costs. Collected concentrations sent to the distillation system range from 5% to 10%. The distillation process produces a concentrated and dilute stream. The concentrated stream from the distillation process contains an average of 60% glycol and is transported off-site by the operator for reuse. The dilute stream from this process is mixed back into the runoff storage system for treatment by the irrigation system. Approximately 5% of the total surface runoff volume and 37% of the total spent deicing fluid load is treated in the distillation system.

Figure 4. ZRH distillation system.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Total Size/Capacity
Stormwater Storage Capacity	1.325 million gallons
Current Irrigation System Footprint	21 ha (50 acres)
Infiltration Basins Footprint	2.7 ha
Planned Expansion to Infiltration Basin	1.9 ha

Table 2. Summary of system performance.

Parameter	Value	Unit
Flow Rates - Average	 396	gpm
Actual COD Treatment Load Rate - Average - Maximum	 1,280 4,460	lbs/day
Effluent COD Concentration - Average	 20~32	mg/l
Effluent TOC Concentration - Average	 4.4~8.3	mg/L
Treatment Efficiency	98.7%	% Influent COD load treated

Lessons Learned from ZRH for Airports Considering Selection of Natural Treatment Systems and Distillation Technologies

1. Based on the measurements taken at ZRH, the Natural Treatment System technology utilized here is well suited for the higher volume, lower concentration fractions of the collected deicer-impacted stormwater. At ZRH, a high percentage of runoff volume, but a relatively low percentage of the total spent deicer load is treated in the passive biological treatment systems.
2. While there is no active control of the treatment elements such as oxygen supply and nutrient addition that is seen with other biological treatment systems, ZRH employs an extensive effort to control the timing of when the systems are fed with deicer impacted water, the mass loading rates, and the flow rates. The information used to control the influent flows is based on ongoing monitoring of ambient conditions, including real-time monitoring of multiple parameters. Therefore, while the treatment portion of the technology is passive, it would not meet performance criteria without a high active control of the loading of deicer-impacted stormwater into the treatment areas.
3. ZRH spent five years performing extensive monitoring of the system performance and conditions that might affect performance. This resulted in the control system for the treatment system operation being based on field-collected data. Because of this extensive testing period, ZRH has developed a high degree of predictability of the treatment system's performance.
4. Many passive, natural biological treatment systems that use soil or media for treatment frequently have limited monitoring of influent pollutant concentrations and no means of measuring effluent concentrations. ZRH demonstrated that influent and effluent measurements are critical to achieving the desired treatment effectiveness.
5. Like many biological treatment systems, while influent TOC concentrations are measured, the flow into the treatment systems is essentially controlled based on TOC mass loading rate rather than concentrations. If collected concentrations are high, the flow rate to the treatment areas is reduced.
6. The most extensive testing of the irrigation system was performed between 2002 and 2007. During the 2003/4 Deicing Season, only five out of 834 samples exceeded the effluent limit of 20 mg/L Dissolved Organic Carbon (DOC). The average DOC concentration of the treated water in the irrigation system in that season ranged from 4.4 to 8.3 mg-C/l, which is 1 to 3 mg-C/l above the natural DOC level.
7. Although the ZRH irrigation and infiltration basin systems are considered passive from a treatment standpoint, capital cost for the entire system is high because of the extensive

amount of monitoring, storage, pumping, and piping that is needed. ZRH had one advantage in cost that not all airports will have – a readymade pipe drainage system in the soil of the irrigated areas that was installed originally to drain groundwater. Operation of the system requires costs for monitoring, power, and operations.

Lessons Learned from ZRH for NTS and Distillation System Operators at Other Airports

The following lessons learned are applicable to those operating these technologies at other airports.

1. Treatment in the irrigation-fed system occurs as the infiltrating water passes through bacteria located primarily in the top 80 cm (32 inches) of the soil. Overall, approximately 98% of the applied organic carbon is removed by the bacteria, with 90% of the removal in the top 20 cm (8 inches).
2. Water, soil, and air temperature are all factors in the NTS performance and ZRH has determined the ranges in which effective performance can be achieved. System input is affected by the temperatures.
3. Published data from 2005 indicates carbon inputs into the soil of 4,622 kg-C (2001/2) and 17,120 kg-C (2003/3). During the same periods, irrigation areas were 3.5 ha and 16.7 ha respectively. These yield loading rates of 132 g-C/m^2 and 102 g-C/m^2.
4. The degree of saturation of the soils with water from precipitation or groundwater is important. A saturated top layer is not conducive to treatment.
5. Wind speed is a factor in determining the feasibility of using the irrigation system at any given time because of a desire to avoid irrigation on roads and taxiways.
6. The hydraulic conductivity of silty soils for the NTS would make getting sufficient detention time for treatment to get acceptable treatment more of a challenge.

Documents and Information Review in the Development of Assessment

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Airport Deicer Treatment System Summary 16

Airport: Gerald R. Ford International Airport —Grand Rapids, MI (GRR)

Treatment Technologies: Off-Site Recycling System
Natural Treatment System

Years Operated: 2015–2023 (Currently Operational)

Deicer Management System Description

The GRR deicer management system includes deicing on aprons, the use of an online Total Organic Carbon (TOC) monitoring for segregation of runoff into high and low concentration streams, a spent glycol recovery system for high concentrate runoff with detention, and a natural treatment system (NTS) for treatment of low concentration runoff, before long-distance piping to a large receiving stream.

Runoff from aprons is continuously monitored, with the high concentrate diverted to underground storage tanks prior to pick up and hauling by a private recycling firm. Low concentrate flows of varying flow rates are routed to the stormwater detention basin with attenuated flows routed to the adjacent NTS prior to the discharge into Thornapple River.

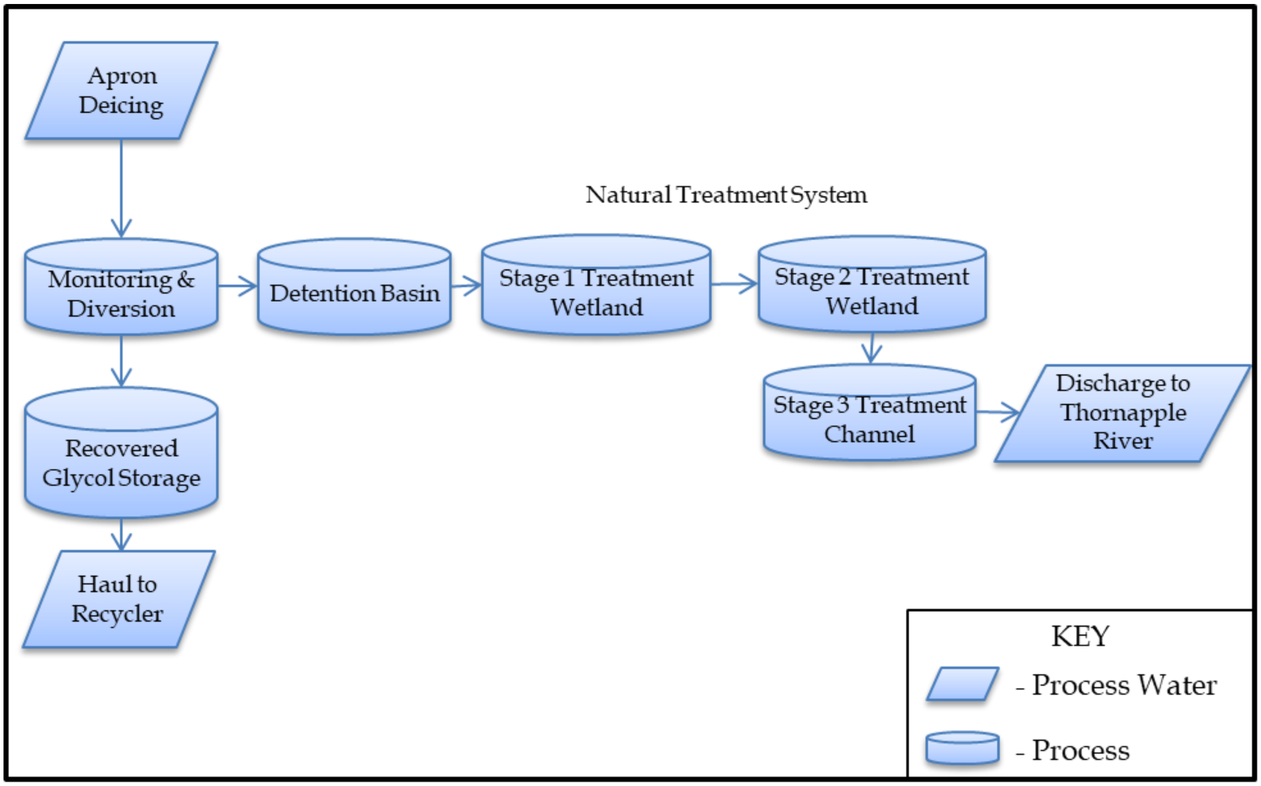

Figure 1. GRR deicer management system process flow diagram.

Figure 2. Aerial photo of GRR natural treatment system.

Deicer Treatment Technology Selection Considerations

Treatment technology selection considerations included:

1. Re-routing stormwater from the Airport's North Detention Basin to a new outfall at the Thornapple River with a higher available assimilative capacity than smaller local streams.
2. Taking advantage of the relatively close proximity of a private recycling firm.
3. Simple and uncomplicated design for the operation of the NTS
4. Cost-effectiveness of construction and operation of the NTS.
5. Ability to meet NPDES permit requirements.

Deicer Treatment Technology Description

Natural Treatment Biological Treatment System

The GRR system is intended to provide removal of BOD_5 for stormwater not sent off-site for recycling. The required effluent limits for surface water discharges are high. As a result, the NTS is not designed to achieve low effluent concentrations.

The Stage 1 treatment beds are unsaturated, vertical-flow, constructed wetlands that are pulse-fed by dosing siphons. Each of the six beds covers approximately 0.4 acres for a total of 2.4 acres. Within the treatment beds, dosed influent percolates downward through layers of aggregate. The aggregate is layered from finer aggregate (at the top of the bed) to coarser aggregate (in the bottom drainage layer). The aggregate is sized to slightly retard downward flow in upper layers comprised predominantly of sand. Water is then conveyed more rapidly down to lower gravel drainage layers.

Treated flow at the bottom of each media bed is collected and conveyed in multiple parallel rows of sequential drainage chambers and discharged passively to the Stage 2 treatment beds.

The Stage 2 beds are about half the surface area of Stage 1 and, like Stage 1, are comprised of layered sand and gravel of specified sizes, and flows are collected with a similar network of drainage chambers. After passing through Stages 1 and 2, flow is channeled to the discharge point for conveyance to Thornapple River.

The treatment system includes a passive bypass for flows that exceed the influent dosing capacity for Stage 1.

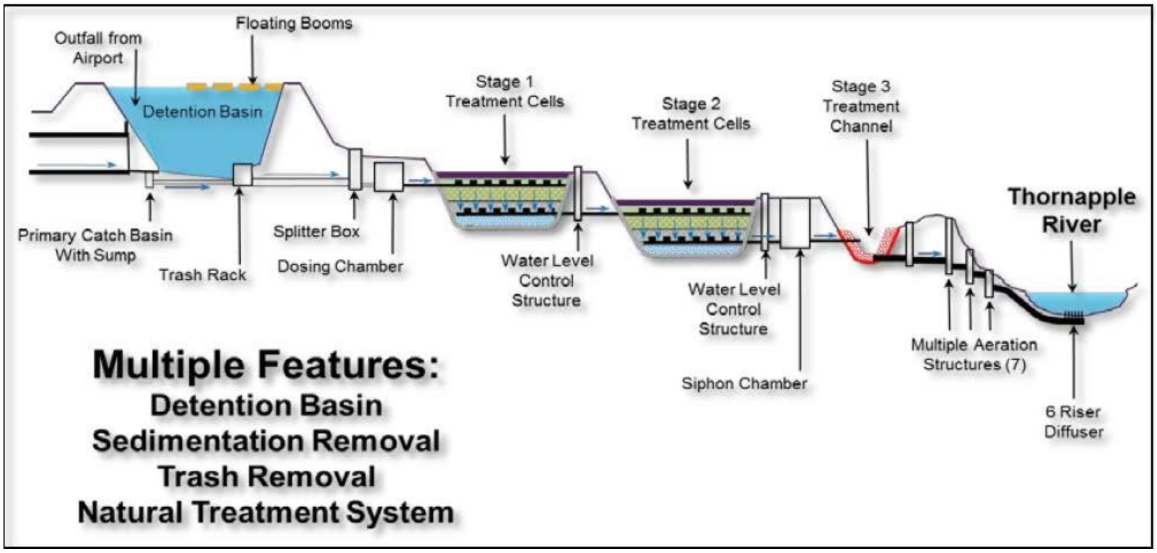

Figure 3. GRR natural treatment system cross-section schematic.

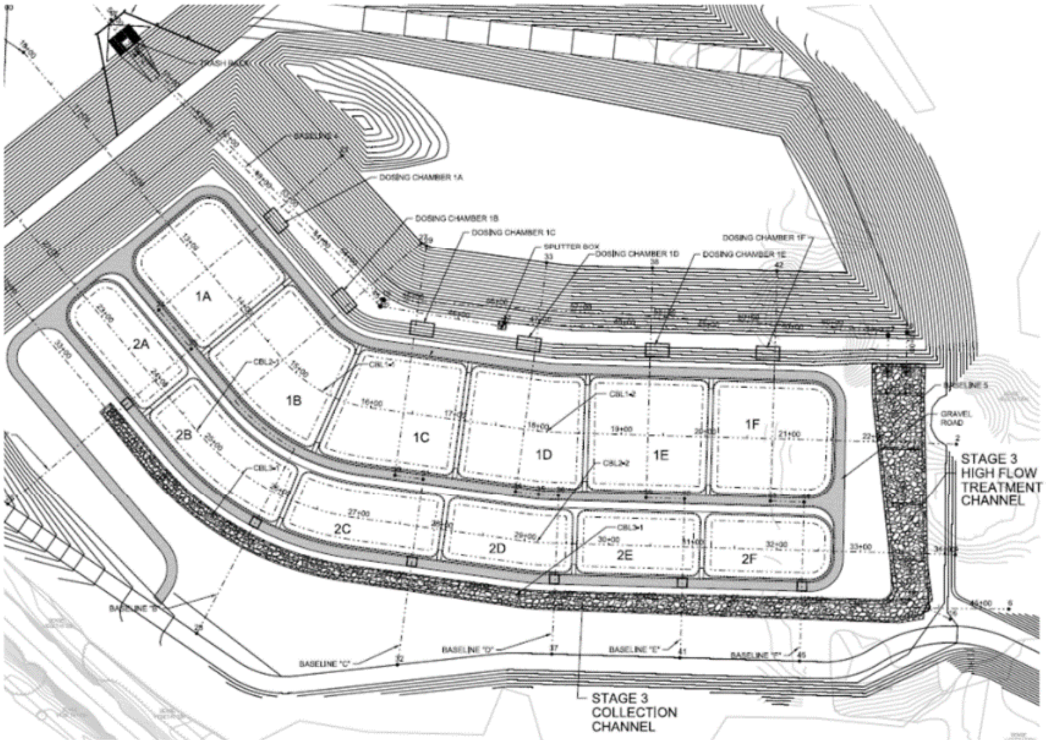

Figure 2-1. GFIA NTS Layout

Natural Treatment System for Stormwater Runoff, GFIA, Michigan

Figure 4. GRR natural treatment system layout.

Figure 5. Photo of GRR natural treatment system (courtesy Gresham Smith).

Description of Support Systems

The detention basin regulates the flow, provides for suspended sediment removal, has an inlet grate (trash rack) to stop water-borne debris, and uses floating booms to collect floating objects.

The influent dosing system evenly distributes flow between the treatment beds. The system includes piping between the detention basin and a dedicated splitter structure. The splitter structure divides below the dosing chambers.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities.

Component/Parameter	Number of Units	Total Capacity
NTS Flow Capacity	1	8.24 CFS (5.3 MGD)
NTS Load Capacity	1	2,763 lb-BOD_5/d
NTS Footprint	1	4 acres

Table 2. Summary of system performance.

Parameter	Value	Unit
Design Flow Rate – Base	2,450	gpm
Design Flow Rate – Maximum (Including By-pass)	11,770	gpm
Design Treatment Load Capacity	2,763	lbs BOD_5/day
Design Loading Rate	50	g-O2/m2/d
Removal Percentages (depending on snowfall)	44-91%	ADF Removal

The following data represents the reported values for Carbonaceous Biochemical Oxygen Demand ($CBOD_5$) at the effluent monitoring point for outfall 011. Data for influent concentrations and flows are not available.

Table 3. GRR natural treatment system effluent quality.

End of Reporting Period	mg $CBOD_5$/L
11/30/2019	990
12/31/2019	375
1/31/2020	1050
2/29/2020	1720
3/31/2020	1610
4/30/2020	406
12/31/2020	1360
1/31/2021	2840
2/28/2021	7350
10/31/2021	35
11/30/2021	1650
12/31/2021	1690
1/31/2022	2270
2/28/2022	3130
3/31/2022	722
3/31/2022	1870
4/30/2022	120
5/31/2022	15

Cost Assessment for GRR Natural Treatment System

Table 4. Costs for the treatment system.

Cost Category	Actual
Capital Cost	$20 million (Kent County Department of Aeronautics, 2015)
Annual Operating Cost Data	Actual monetary data not available. <1 Full-Time Equivalent staff used

GRR Natural Treatment System Changes Since Startup

1. Nutrient addition was not included in the original natural treatment system operation. After two years of operation, a nutrient supply was added to enhance the growth of bacteria growing on the NTS media. The purpose of the nutrient addition was to improve treatment and reduce the formation of polysaccharides that were a source of clogging for the media.

Lessons Learned from GRR for Airports Considering Selection Natural Treatment Systems

The following parameters are critical to the success of the GRR natural treatment system:

1. Upstream flow attenuation helps regulate flow to treatment to avoid overloading and exceedances of the treatment system's hydraulic capacity.
2. Screening of solids and debris in the NTS system is important to reduce both the short-term and long-term risks of clogging the NTS media.
3. Having favorable topography that supports gravity flow through the system, if available, can reduce pumping and operational needs.
4. Natural treatment system requires large land areas to achieve BOD_5 removal as they are not an efficient treatment technology. Having the land available at GRR between the airfield and the outfall location was a major benefit.
5. It is important to have early community/regulator engagement.

Lessons Learned from GRR for Airports Operating Natural Treatment Systems

General insights from the operation of this system that could be applied elsewhere include:

1. Online monitoring for organics (TOC) may require technical support beyond normal operations support.
2. Uncovered water bodies may be prone to algae growth.
3. Placing rip rap in conveyance channels can mitigate algae growth.
4. The economics of glycol recycling levels will fluctuate based on market-specific factors, as well as the use of hybrid deicing trucks and blend-to-temperature operations.

Documents and Information Review in Development of Airport Summary

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Airport Deicer Treatment System Summary 17

Airport:	London Heathrow International Airport—London, ENG (LHR) Eastern Catchment
Treatment Technology:	Moving Bed Biofilm Reactor
Years Operated:	2020–2023 (Currently Operational)

Deicer Management System Description

The London Heathrow International Airport (LHR) is divided into four main catchments designated as northwestern, southwestern, eastern, and southern. Deicing operations drain to either the eastern or southern catchment. Heathrow Airport Holdings commissioned a moving bed biofilm reactor treatment system to upgrade the pollution control system on the Eastern Balancing Reservoir (ERB) in 2019.

The MBBR was chosen because of its relatively small footprint and ability to provide high-rate removal during peak deicer season and idle or “dwell” during the off-season. The 2019 upgrade integrated the MBBR process into the existing pollution control system depicted. The MBBR process flow diagram is provided in Figure 1. Influent to the MBBR process originates from a diversion structure in the balancing reservoir and is directed to MBBR treatment tanks. After the MBBR, effluent flows to coagulation and flocculation units that combine and enlarge bacterial floc for improved solids separation. The flocculated solids are filtered through a disc filter. The effluent from the disc filter is returned to the clean side of the middle, balancing the reservoir prior to discharge to the River Crane.

Solids removed by the disc filter are thickened to 6% dry solids using a drum thickener. Polymer is added to thickened sludge and waste solids are hauled for off-site disposal. Sludge generation is approximately ten (10) loads per month of filter-drum operation. Each load measures twenty-five (25) cubic meters (m^3). Solids from the disc filter backwash are directed to the dirty side of the upper balancing reservoir.

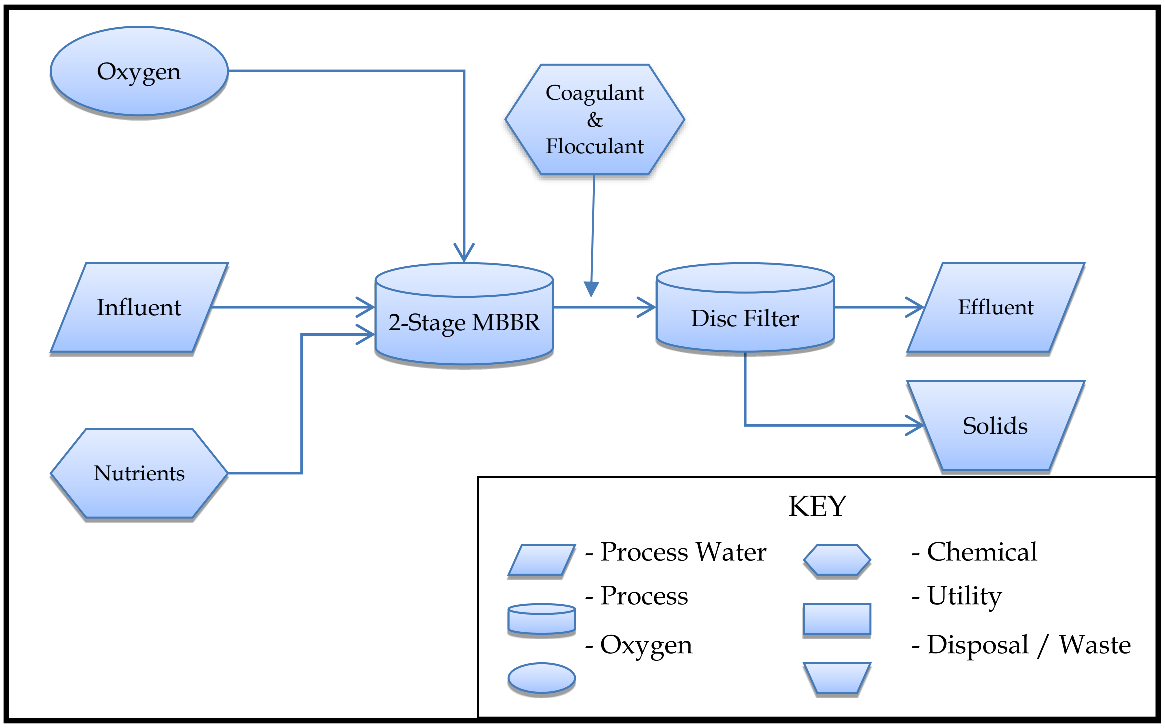

Figure 1: Deicer impacted stormwater treatment system process flow diagram.

Deicer Treatment Technology Selection Considerations

Considerations for selection of the MBBR process:

5. The MBBR upgrade implemented in 2019 was based on providing final effluent suitable for discharge to the River Crane such that the final effluent shall "do no harm." Moreover, the Airport is committed to supporting improvement to the River Crane through its membership in the Crane Valley Partnership.
6. The system must be kept in a semi-ready state throughout summer for use during cold spells when deicing fluid may be used.
7. The system must fit adjacent to and integrate with the existing pollution control system at the Eastern Balancing Reservoir.
8. The process footprint must have a small footprint to be located in the area available for the project.

Deicer Treatment Technology Description

The 2019 upgrade included MBBR and disc filter technologies to provide high-rate organic removal and capacity. A more detailed description of the MBBR technology and costs can be found in the Treatment Technology Fact Sheet 107. The MBBR system was planned as part of the 2015 improvements to the ERB (Heathrow Airport Limited, 2015). Figure 2 provides the plan for the original preferred approach to include a treatment system adjacent to the ERB.

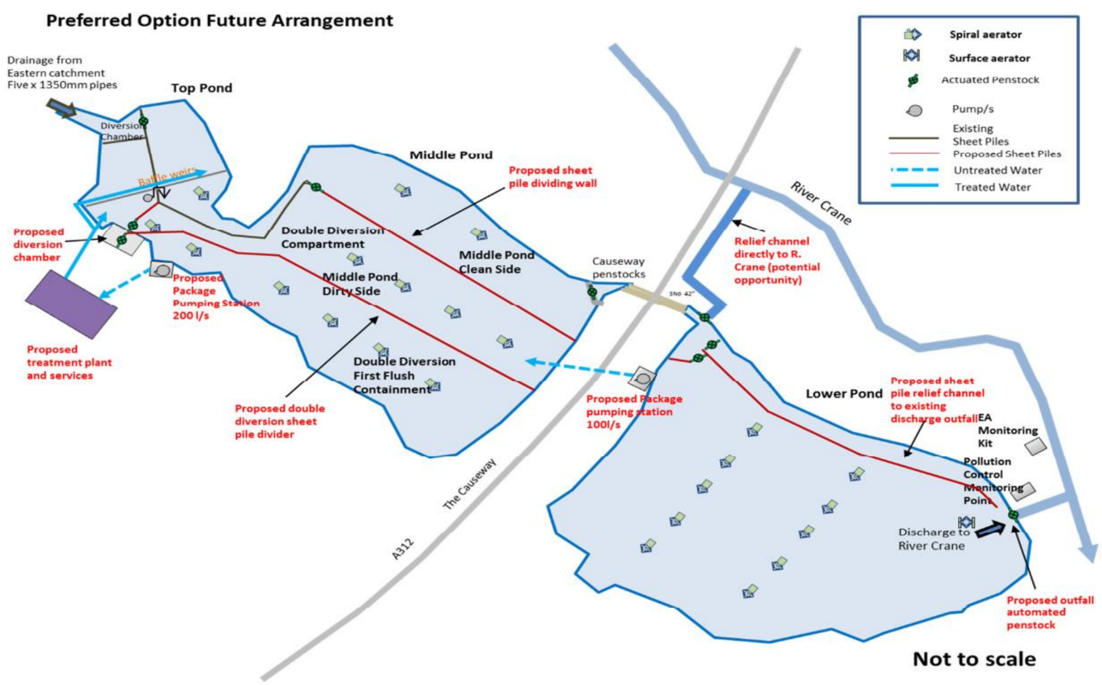

Figure 2. Eastern balancing reservoir upgrade scheme (Heathrow).

Figure 3 provides a photograph of the MBBR open-top tanks. The MBBRs are typically operated as a 2-stage system, in series; however, process piping allows for the operation of the two MBBRs in parallel with one another. Three (3) positive displacement blowers, operated as duty, alternating, and standby, provide process air required to support the biofilm technology and to pass air/oxygen into the MBBR tanks via diffusers located on the bottom of each tank. Coagulant, flocculant, sludge holding tanks, disc filter, and drum thickener are located on the same concrete pad as the MBBRs. Photographs of the disc filter and adjacent equipment are provided in Figures 4 and 5.

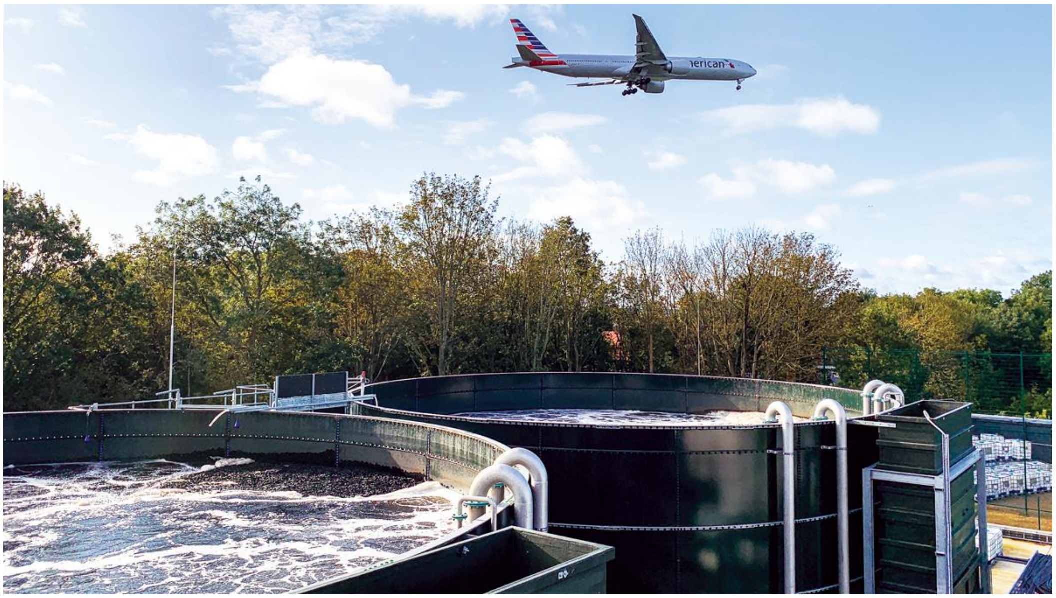

Figure 3. MBBR (Water Projects, 2022).

Figure 4. Disc filter (**Airport World,** ***2021).***

Figure 5. Disc filter and piping (**Enviropro*****, 2022).***

Description of Support Systems

The upgrade of the LHR treatment system included the addition of aeration equipment, a nutrient feed system, and coagulation/flocculation chemical dosing. Electrical and instrumentation systems were also included per industry and airport standards, which includes integration into the airport's SCADA system.

Treatment System Capacity and Performance Parameters

Table 1. Component Capacities

Parameter	**Design Value**	
Design Loading	5,000 kg COD/d	6,300 lbs BOD/d
Design Flow	720,000 L/hr	3,175 gpm
MBBR Tanks	Two at 1,100 m^3 each - 2,200 m^3 total Approximately 14.7 meters diameter and 6.5 meters side water depth	

No information on system performance is available currently.

LHR MBBR Changes Since Startup

The system has only been in operation since the start of the 2020-2021 deicing season, which includes periods of low travel during COVID. No major changes have been made since the startup. However, the airport conducts regular "stand back" reviews to evaluate the need for system improvements.

Lessons Learned from LHR for Airports Considering Selection of MBBR Technology

1. Understand the peak and minimum loading conditions associated with organic loading and provide both load and flow equalization or a system that can operate with varied flow and loading.
2. Aerated biological processes foam when they are heavily loaded, i.e., during growth cycles, and when they are minimally loaded, i.e., during endogenous decay cycles. Design should consider foam mitigation via load balancing or foam control via spray systems.
3. Operational effort and cost consist primarily of the management of pump, aeration, and nutrient feed systems. Biomass levels are monitored and managed as needed. The system is operated by a contract operations group.
4. Air conditioning in motor control center to keep variable frequency drives cool.
5. Place inlet and outlet points of influent and effluent further apart to prevent short-circuiting.

Lessons Learned from LHR for Operators at Other Airports

1. Caustic has been dosed for a short time to manage pH issues during recirculation.
2. Originally, the concept involved the operation of the biofilm reactors for two (2) days per week and allowing them to dwell for five (5) days per week, but operators are considering spreading the flow and load to allow better management of blower speed and biological foam created during peak loading and extended dwell times.

Documents and Information Review in Development of Airport Summary

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Airport Deicer Treatment System Summary 18

Airport:	Minneapolis-St. Paul International Airport (MSP), MN
Treatment Technology:	Mechanical Vapor Recompression Off-Site Recycling POTW Discharge
Years Operated:	Early 1990s–2023 (Currently Operational)

Deicer Management System Description

The glycol recovery program at MSP includes a collection of aircraft deicing fluid at five deicing pads, 11 containment areas using plug and pump methods, and inlet covers and sweeping using Glycol Recovery Vehicles (GRVs) in non-containment areas. The stormwater pipes in the containment areas are blocked with compression plugs that create localized storage for the capture of deicing chemicals and runoff.

Glycol captured at any location is directed to storage tanks at the on-site MSP Glycol Management Facility storage (Figure 1). The captured volume is regularly checked for PG concentration and segregated into low and high-concentration streams. High-concentration runoff is further concentrated on-site by a contractor-operated Mechanical Vapor Recompression (MVR) process and subsequently hauled off-site to a secondary recycling facility for further processing and resale on the glycol market. Low-concentration stormwater is routed to the sanitary sewer for treatment at a local POTW.

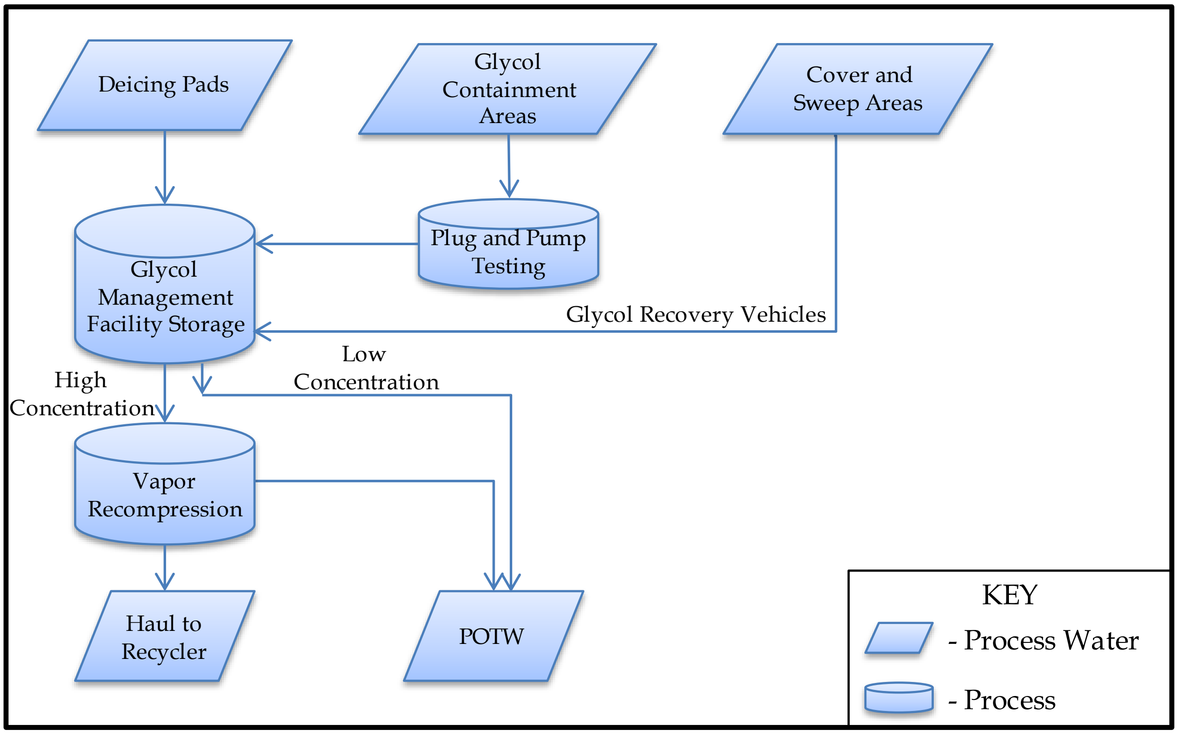

Figure 1. MSP glycol management diagram.

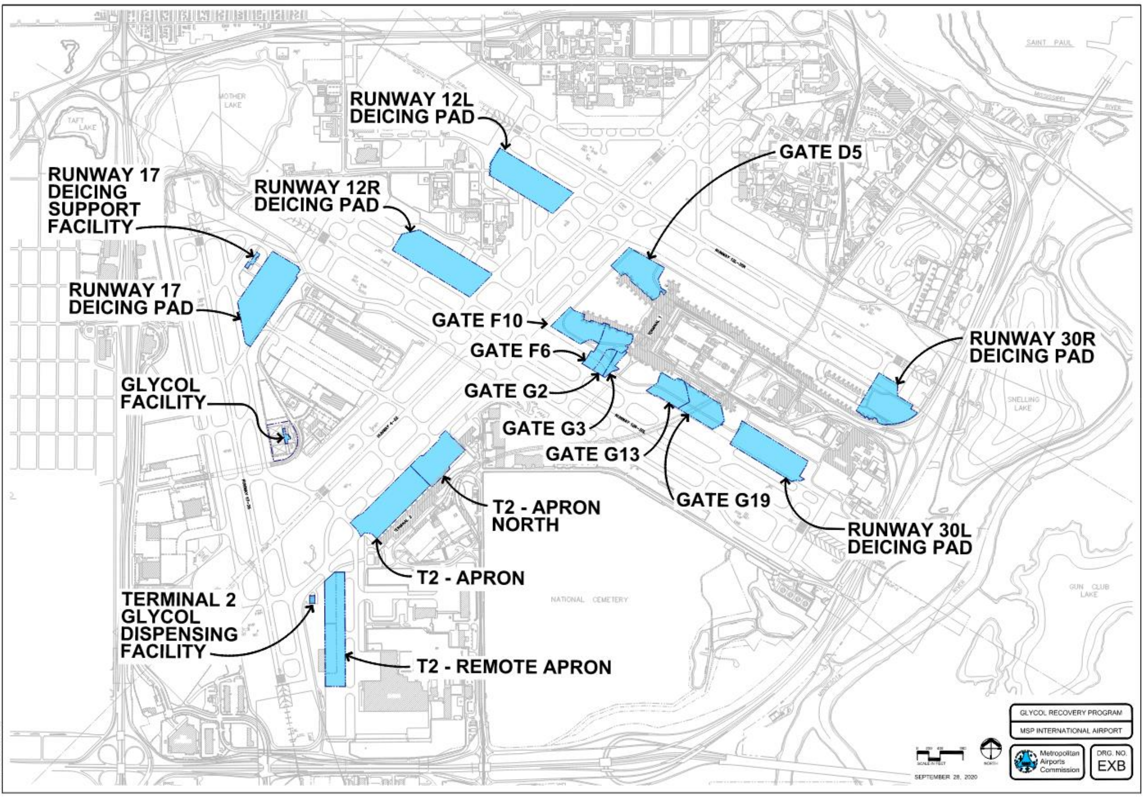

Figure 2. MSP drainage and containment areas (Metropolitan Airports Commission).

Deicer Treatment Technology Selection Considerations

MSP is a hub airport in a cold climate and is well suited for deicing pads and glycol recycling. The high volumes of deicing fluid used, coupled with the high concentrations in the captured runoff, make recycling an attractive management approach.

The relatively low POTW surcharge costs support a store-and-release approach for runoff that is not suited for recycling. MSP is permitted to discharge 20,000 lbs-BOD_5/d to the POTW.

Deicer Treatment Technology Description

Onsite MVR and Off-Site Recycling

High concentrations of spent aircraft deicing fluid from the MSP storage facility are further concentrated on-site using an MVR process to evaporate a large portion of the water in the high-concentrate collected stream. A privately contracted firm operates the on-site Glycol Recovery Facility. The MVR process effluent is transported to a private recycling facility located approximately 700 miles from MSP. The private recycler further concentrates the glycol for reuse and resale. The recycled glycol is not used directly in the reformulation of deicing fluids. The airport authority is not directly involved in the on-site recycling processes or the off-site transport for final processing.

See the treatment technology fact sheets for MVR and off-site recycling for more information on the technology functions.

Additional information on the number of MVR units used by the private recycler was not available.

Figure 3. Concentrate storage at the glycol management facility.

Description of Support Systems

The contract to operate the recycling operations is between the major airline at the airport and a private recycler. The private recycler is fully responsible for all support systems related to recycling that are downstream of the storage tank at the Glycol Recovery Facility.

Additional information on the pretreatment and post-treatment processes to support the MVR system was not available.

Treatment System Capacity and Performance Parameters

Table 1. System component capacities

Component/Parameter	Size / Capacity of Treatment Units	Number of Treatment Units	Total Capacity
Stormwater Storage Capacity	3.5 MG	3	10.5 MG

No system performance data was made available for the recycling process.

MSP Deicer Treatment System Changes System Startup

The glycol recovery program at MSP has had the following notable changes in recent years:

1. Elimination of some plug-and-pump sites to increase deicing pad usage.

Lessons Learned from MSP for Airports Considering MVR, Off-Site Recycling, or POTW Discharge

The following lessons learned are applicable to those considering a glycol recovery program like the one at MSP:

1. MSP has a good and long-standing relationship with the POTW and its staff. This allows potential issues to be addressed easily and with a high level of understanding of airport operations.
2. Inner and outer collection zones on deicing pads are conducive to efficient segregation of high and low concentrations that are split between the recycling efforts and POTW discharge.
3. The increased use of forced-air, blend-to-temperature facilities, and blend-to-temperature trucks has reduced glycol use per plane but has also made the collected deicer more dilute. More dilute flows shift the balance between recycling high concentrate and discharging dilute to POTW toward the POTW discharge.
4. Airline preferences for deicing at gates vs. deicing at pads will change from time to time; at the gate, deicing reduces the on-the-ground time, and deicing pads free gates more quickly. The deicing location (gate vs. pads) affects the quantity of stormwater collected and its concentration, which affects the split between dilute flows to POTW and concentrate flows to recycling.
5. The type of aircraft being deiced can be disruptive to deicing practices and related glycol recovery efforts. This is particularly the case with wide-body aircraft.

Lessons Learned from MSP for Airports Operating MVR, Off-Site Recycling, or POTW Discharge System

The following lessons learned are applicable to those operating similar glycol recovery programs at other airports:

1. Lock in a long-term agreement with POTW.
2. The success of the program is largely associated with the buy-in by the people that are part of the program, including seeking to understand the bigger picture of the program’s mission.
3. Relationships with airlines that deice and their operators, including buy-in on the operations, costs, and impacts to the airport’s glycol recovery and treatment program are crucial.

Airport Deicer Treatment System Summary 19

Airport:	Portland International Jetport—Portland, ME (PWM)
Treatment Technology:	Mechanical Vapor Recompression (MVR), Distillation Aircraft Deicing Fluid Blending
Years Operated:	2010–2023 (Currently Operational)

Deicer Management System Description

The Portland International Jetport (PWM) has both passive and active collection systems in place for the capture of spent aircraft deicing fluid (SADF). All aircraft deicing fluid (ADF) that is applied at PWM is Propylene Glycol (PG) based. Deicing has been conducted at terminal gates and remote deicing pads.

Active collection involves the use of Glycol Recovery Units (GRUs) in any area with deicing activity
in order to maximize the collection of high-concentration fluids, and to minimize the co-mingling and further contamination of precipitation with glycol from ADF.

Passive collection involves the use of dedicated glycol collection drainage systems for the deicing pad areas. These collection basins, piping, and pump stations allow the conveyance of spent ADF to on-site storage tanks for processing. GRUs are not used in the passive collection areas.

All spent ADF that is collected at PWM is treated at the on-site recycling facility. The glycol processing facility is owned and operated by a recycling subcontractor. This facility is located on the airport property but is outside the airside secured area.

Once the collected spent ADF, which has been comingled with precipitation (snow melt, rain, melted freezing rain), is transported to the recycling facility, it is held in local underground storage tanks until it is processed. The underground storage tank has two segmented sections in the tank. The combined storage capacity is 515,286 gallons, segmented into 343,524- and 171,762-gallon partitions. The partition of the underground storage tank allows for segmenting of the collected fluid by glycol percentage to further optimize processing efficiency. The fluid generated at PWM is segregated from a fluid that is transported there from other sources.

The recycling equipment includes three (3) Mechanical Vapor Recompression (MVR) units, an Ultrafiltration (UF) unit, a distillation system, and a chemical pre-treating settling tank.

All wastewater from the treatment process is discharged to the local municipal wastewater treatment facility (POTW). In addition, PWM is approved to receive fluids from other airports and serves as a regional recycling center.

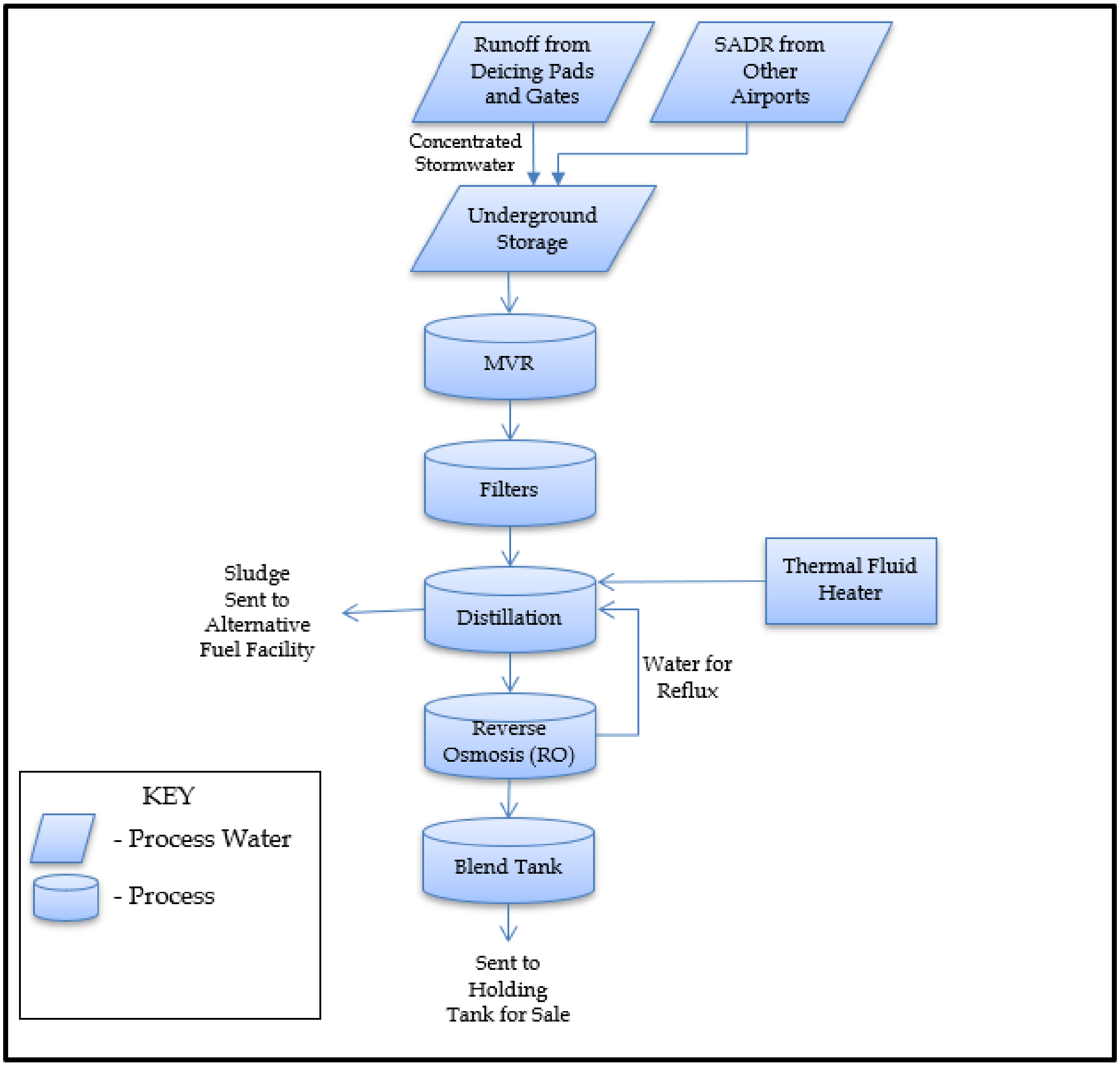

Figure 1. PWM deicer management system process flow diagram.

Deicer Treatment Technology Selection Considerations

Treatment technology selection was based on the ability to handle large fluctuations in glycol percentage, and the ability to capture and reuse the glycol. The objective of the Portland Jetport is to utilize technology with a favorable environmental impact as opposed to traditional destructive technological processes where the glycol is broken down and destroyed.

Utilizing the MVR, distillation, and support systems described here, the glycol is captured, recycled, and reused. The treatment equipment installed at PWM also has the ability and capacity to treat fluid collected and shipped from other airports.

Deicer Treatment Technology Description

MVR System

The PWM treatment system employs both the MVR and distillation treatment processes. Descriptions of the MVR and distillation treatment technologies can be found in the Treatment Technology Fact Sheet 106. The essence of the mechanical vapor recompression (MVR) process is glycol treatment and reuse. Glycol is not destroyed but rather purified by removing water and contaminants so that the glycol can regain commercial usage.

Weather, and deicing activity for a specific weather event, will drive large fluctuations in the percentage of glycol collected as a function of overall precipitation collected. The MVR technology is particularly well suited to handling large variations in the glycol percentage of the collected fluid. The MVR can accommodate infeed from 0.1% to 35+% glycol within its standard operation. Energy consumption and productivity vary with glycol percentage. The typical ideal efficiency is an infeed of >5%, but lower concentrations can be processed, just at a slower rate due to the volume of water that needs to be removed.

Equipment was sized with the ability to accommodate a treatment rate of approximately 300,000 gallons/ month to best optimize the volume of storage available at the airport and the capital costs of the equipment. The MVR equipment is modular in nature, and units can be incrementally added to keep pace with airport activity and growth over time.

Distillation System

PWM has a distillation process for further processing the concentrate product that is produced by the glycol concentrators on-site. The product from the concentrators has a glycol concentration of approximately 50% and is processed by the distillation process, which creates a 99.5% pure glycol product and a water distillate by-product. The water is purified to adequate purity levels for direct discharge to the local municipal wastewater treatment facility, the same as the water from the concentrator process.

The distillation process was custom designed for the purification of collected spent ADF in a multistep process that takes the 50% glycol feedstock and removes water and impurities. The resultant recycled glycol has comparable purity and quality characteristics to virgin glycol. This glycol is then blended into certified Type I ADF.

The distillation process utilizes a natural gas-fired thermal fluid heater as the energy/heat source for the process. The distillation columns are fed from a thermal fluid heater integrated with heat exchangers for transferring energy into the separation process. In addition, the system operates under a vacuum which improves efficiency.

The distillation equipment includes the distillation plant, feed pumps and filters, transfer pumps, fluid quality sampling and analyzing equipment, and processing and storage tanks.

The feed is filtered prior to introduction into the distillation column. As the feed is preheated, impurities in the form of dissolved solids come out of the solution and become suspended solids that are filtered out in filter canisters to reduce the fouling within the distillation columns and heat exchangers.

The processing equipment is made primarily from stainless steel materials to ensure the purity of the glycol is not negatively impacted. Stainless steel construction also provides long-term durability of the equipment.

The distillation process produces a compound made up of separated impurities and some sacrificial glycol. This compound is generically referred to as "sludge" and is disposed of by being trucked to an off-site alternative fuel facility. The compound has a relative volume of approximately 5% of the volume fed into the process.

The equipment is PLC-controlled, and the entire process can effectively be managed and operated by a single operator per shift. Typically, the system operates 24 hours a day, 7 days a week during the season, while feedstock exists to be processed.

PWM's distillate is treated with a Reverse Osmosis (RO) system to ensure its quality meets municipal discharge allowances. The purpose of the RO is to remove glycol from the distillate stream prior to release to sanitary. Distillate water is also recycled within the distillation process where it is used as reflux water for the distillation process. The reflux process utilizes water to strip glycol within the distillation tower, so utilizing the distillate water for reflux adds efficiency and reduces the post-processing of the distillate.

The 99% pure glycol that is produced in the distillation process is further treated utilizing a proprietary post-treatment process to further remove trace amounts of contaminants, for example, small traces of color dye and other microscopic contaminants, to ensure the recycled glycol has equal to or higher purity as compared to virgin glycol.

Type I ADF Blending Process System Description

Aircraft Deicing Fluid (ADF) blending takes place at the PWM facility. This is accomplished by blending the 99% pure glycol product produced in the distillation process with a certified chemical add pack according to an approved recipe. The ADF that is manufactured is a Type I ADF.

ADF manufacturing is accomplished by blending the ingredients in a blend tank. The process is a batch process, where the various ingredients are pumped into the blend tank according to a preestablished volume derived by the target blend volume, in accordance with the certified formula. The established volume of 99% pure glycol product is pumped into the blend tank with a set volume of the chemical add pack, also referred to as "slurry", and is blended with a set volume of water.

The ingredients are added to the blend tank, and the fluid is circulated according to an established SOP to achieve the target dispersion. After the mixing, the fluid is quality checked, and once confirmed to meet certification targets, is pumped into a holding tank and ready for sale.

The pH of the distilled glycol is checked throughout the process, including a final check of pH after blending. If needed, the pH can be adjusted to the desired pH level as an additional step of the blending process. The pH can be adjusted up or down as needed.

Description of Support Systems

The purpose of the chemical pre-treatment system, reverse osmosis unit, and ultrafiltration system is to remove contaminants and water from the collected glycol/water mixture. The water permeate from the RO system is of adequate purity for disposal and can also be used internally within the recycling process where clean water is required (e.g., ADF manufacturing). The purpose of the chemical pre-treating and the UF is to remove contamination from the fluid stream and to reduce the fouling of the RO membranes.

Treatment System Capacity and Performance Parameters

Component Capacities

Table 1. MVR system component capacities.

Component/Parameter	Size/Capacity of Treatment Units	Number of Treatment Units	Total Volume
Stormwater Storage Capacity			
Lower Percentage Collected <10%	343.524 gallons	1	343,524 gallons
Higher Percentage Collected >10%	171,762 gallons	1	171,762 gallons
Total Collected Storage	*515,286 gallons*		*515,286 gallons*
50% Concentrate Product Tank	20,500 gallons	5	102,500 gallons
Treatment Unit Dimensions			
MVR	20-ftLx6-ftWx8’2”H	3	
MVR with Scrubber	20-ftLx6-ftWx22’H		
Treatment Facility Footprint MVR Treatment Building	50’ x 60’ including offices, storage, etc.	1	3,000 sq. ft.

Table 2. Distillation system component capacities.

Parameter	Low End	Target/High End
Glycol Percentage of Feed	40% Glycol	48%–52% Glycol
Glycol Percentage of Final Product	98.0%	99.5%–99.9%
Input Feed Rate	1.5 gal/min	2.3–2.4 gal/min
Number of Effluent Streams	3 streams – Concentrate, distillate, waste sludge	3 streams – Concentrate, distillate, waste sludge
Product Output Rate	0.6 gal/min	0.7–0.8 gal/min
Distillate Effluent Flow Range	0.75 gal/min	1.07–1.36 gal/min
Distillate Effluent Water Quality	<600 COD in mg/L	<600 COD in mg/L
Sludge Rate	0.15 gal/min	0.23–0.24 gal/min
Product Output pH	5.0 pH	7.0–8.0 pH
Monthly Product Output	22,000 gal	30,000 gal

Treatment System Performance

MVR System

The MVR processing rate is approximately 300,000 gallons/month utilizing all three units. Processing throughput depends on the glycol percentage in the collected fluid, as well as the level of contamination in the fluid. The level of contamination influences the level of maintenance required, leading to scheduled cleaning of the equipment.

The MVR equipment is designed to have operational flexibility, in that it can be configured to process the collected fluid in either a single- or two-stage approach. The single-stage process takes the fluid from the collected state and creates a 50% glycol product in a single pass. A two-stage process takes the collected fluid and creates a 50% glycol product in two steps. The reason for the two stagings is, depending on the rate of collection during winter storm events, two stagings give the advantage of removing water volume faster than a single-stage process, thereby creating storage capacity faster to support airport collection and reducing the risk of storage constraints for the collected fluid. Depending on the specific level of activity, the MVRs can be seamlessly switched between single- and two-stage processing to optimize overall airport and recovery operations to balance the storage and processing rates at any given time.

Table 3. Stage 1 MVR processing performance.

Glycol Percentage	Min Removal Rate per Month (3 – Concentrators Stage 1)	Max Removal Rate per Month (3 – Concentrators Stage 1)
<10% and Lower	285,000 gallons	300,000 gallons

Table 4. Stage 2 MVR processing performance.

Glycol Percentage	Min Removal Rate per Month (1 – Concentrators Stage 2)	Max Removal Rate per Month (2 – Concentrators Stage 2)
<10% and Higher	95,000 gallons	260,000 gallons

Table 5. Overall MVR processing performance.

Parameters	Single Stage Production	Two Stage Production	
		Stage 1	Stage 2
Influent Flow Rate Range (gallons per hour)	150 to 200	170 to 230	130 to170
Influent Glycol Concentration Range (% glycol)	4 to 27	1 to 4	13 to 27
Influent Temperature Range (F or C)	Ambient	Ambient	Ambient
Number of Effluent Streams Produced	2 streams – Distillate (water) & Concentrate	2 streams – Distillate (water) & Concentrate	2 streams – Distillate (water) & Concentrate
Distillate Effluent Flow Rate Range (gallons per hour)	60 to 184	136 to 219	52 to 126
Distillate Effluent Water Quality (COD range in mg/L)	<50 to 1,000	<50 to 1,000	<50 to 1,000
Distillate Effluent Water Quality (pH range)	3 to 8	3 to 8	3 to 8
Concentrate effluent flow rate range (gallons per hour)	12 to 120	8.5 to 61	33 to 102
Concentrate effluent flow rate range (% glycol range)	48 to 52	15 to 20	48 to 55

Distillation System

The processing rate of the distillation system was designed to produce approximately up to 30,000 gallons of 99% pure glycol product per month from a feedstock of a 50/50 glycol-water fluid.

Table 6. Key Treatment system sizing parameters – distillation.

Component/Parameter	Size/Capacity of Treatment Units	Number of Treatment Units	Total Volume
Distillation Feed Tank	20,500 gallons	5	102,500 gallons
Intermediate Processing Tank	6,600 gallons	1	6,600 gallons
Intermediate Holding Tank (PGD)	20,500 gallons	2	40,100 gallons
Final Product Holding Tank (PGP)	20,500 gallons	2	40,100 gallons
Sludge Tank	20,500 gallons	1	20,500 gallons
Distillation Space Claim	40-ftLx40-ftWx50-ft H	1	
Distillation Process Facility Footprint (including offices and ADF manufacturing)	65’ L x 62’ W	1	4,030 sq. ft.
ADF Type 1 Storage Tank (on-site)	20,500 gallons	3	61,500 gallons

Lessons Learned from PWM for Airports Considering Selection of MVR, Distillation, and/or ADF Blending

The following lessons learned are applicable to those considering these technologies at other airports.

- Claim space for future growth. Often SADF treatment starts with a smaller-scale pilot program for 1 or 2 years. Upon demonstration of success, it often grows into a more permanent and expanded operation, requiring more footprint and greater infrastructure. This is the case at PWM, where the original site where SADF was treated has expanded to provide greater and greater value to the airport, but the site is heavily constrained on footprint and trucking access.
- Airside versus groundside recycling operations. Having the SADF/glycol recycling operations groundside has many advantages versus being airside. PWM has demonstrated the value of having the operations ground side.
- PWM has enjoyed benefits from their support and willingness to accept fluids from other airports at their facility for processing. One critical benefit is reduced operating costs over time due to the acceptance of fluids from other locations, lowering the Airport’s operational costs. The airport management realized that environmental sustainability is important to the traveling public and therefore marketable.
- Partnering with a service provider who is innovative and flexible will be beneficial as airport conditions, environmental regulations, and other influences change. A service provider with in-house technology can help with continuous improvements needed over time.

Lessons Learned from PWM for Airports Operating MVR, Distillation, and ADF Blending

The following lessons learned are applicable to those operating these technologies at other airports.

- Planning for future growth was a key lesson learned as an operator. With fluid acceptance from other airports, planning for feedstock storage and Type I storage for supplying to other airports was important.
- Sludge disposal. Distillation produces a sludge by-product that needs to be disposed of. Finding a suitable outlet for this sludge can be challenging.
- Logistics of bringing fluid from other airports and supplying Type I ADF to other airports ended up being an important operational factor at PWM. Having in-house transportation proved to be more advantageous as compared to reliance on a 3rd party.
- The ability to leverage in-house corporate technical support has allowed the local operator to continuously improve operations by optimizing the operation and upgrading the equipment and processes to be increasingly more effective.
- Having MVRs, distillation, ADF blending operations, and distribution under one operator has enabled cross cross-utilization of resources to be more efficient as compared to the services being executed/managed separately.