By James Higgins & Mark Liner, P.E.

ENGINEERING RUNOFF SOLUTIONS

As environmental regulations evolve, sub-surface flow wetlands are worth a look

Airport environmental managers know that the Environmental Protection Agency has been collecting data on the levels of deicing glycols and other contaminants in airport stormwater, and that mandatory stormwater management plans, and perhaps even prescriptive discharge limits, are on the horizon. The same managers also recognize that the airport is ultimately responsible for controlling discharge of pollutants to the environment. While airport stormwater runoff is particularly hard to treat using conventional means because it is cold, intermittent, and high-volume over short periods, an innovative approach using aerated gravel beds is proving to be an effective treatment for such contaminated stormwater.

These sub-surface flow (SSF) wetlands are insulated, aerated, and specifically engineered to remove glycol. In addition, they are easy to operate, requiring only minimal attention from airport staff, and their construction and operations and maintenance (O&M) costs are only a fraction of those of alternative conventional stormwater treatment facilities (less than 50 percent). A new facility of this sort is in its final design stages for Buffalo Niagara International Airport (BNIA).

Airports in cold weather areas use glycol-based aircraft deicing fluids (ADFs) for removing ice and snow from aircraft surfaces during winter and under frost conditions. Relatively concentrated, glycol-rich, spent ADFs (concentrate) may be collected from around the deicing pads; yet, significant parts of the spent ADFs at every airport end up in stormwater sewers and ditches, where they may be channeled into nearby streams.

The management of glycols varies from airport to airport. At some, sophisticated deicing pads and vacuum trucks are used to ensure the collection of up to as much as 65 percent of the glycols used. At others, little or none of the concentrate is recovered, and excess glycols and surface deicing chemicals are simply allowed to flow, drip, or blow into nearby sewers, ditches, and grassed areas.

FOCUSING ON THE PROBLEM

Early emphasis for airport glycol management focused on the concentrate stream and ignored that portion of the spent ADF that entered stormwater systems. There are options for the off-site management of the glycol-rich concentrate.

In some cases, that which is vacuumed up or otherwise collected at deicing pads is sent to local municipal wastewater treatment plants. However, this option can be expensive and may be risky, as increasingly municipalities local to airports are reducing or eliminating taking such materials.

> ***Federal regulations that establish baseline treatment for deicing liquids are scheduled for proposal in 2007, with the final rule scheduled for promulgation in 2009.***

Alternatively, on- or off-site recycling or treatment plants such as anaerobic digesters, reverse osmosis plants, and distillation units can be used to manage the concentrate if there is a market for the recovered material. However, these concentrate management options usually also produce byproduct streams (sludges, residual water, gases/odors) that must in turn be managed, and they require extensive and expensive operations and maintenance by airport or contract staff.

No matter how concentrate collection operations are carried out, much of the spent glycols will end up in the usually huge volumes of stormwater runoff at airports. For these streams, off-site disposal or treatment is often not an option.

Federal regulations that establish baseline treatment for deicing liquids are scheduled for proposal in 2007, with the final rule scheduled for promulgation in 2009. Even at airports that now treat their concentrate on-site, or send it to an off-site wastewater treatment plant, the on-site management of glycol-contaminated stormwater runoff will increasingly have to be considered as well.

Therein lies the rub. Stormwater runoff at airports is often dilute and cold, with inconsistent flows and contaminant loadings. This makes it extremely difficult to treat. In the early stages of a rainfall event, accumulated contaminants in the catchment area (spilt fuels & lubricants, chemicals from cleaning operations, sewage leaks, oils and greases), especially those on impervious surfaces such as roads, parking areas, runways, aprons, and other paved areas, are washed off early in the storm (the "first flush").

Generally, the first flush involves the first couple of inches of rainfall and carries off 90 percent of the pollution load and will have the highest concentrations of contaminants. Additionally, the low-flow-rate runoff in stormwater collection systems which flows between storm events can sometimes be more polluted than the more dilute streams flowing later during and after storms. Therefore, to achieve optimum contaminant removal from airport runoff, a stormwater treatment system must be able to deal year-round with these two flows (low rate flows and first flushes) as well as with the cold weather contamination by surface and aircraft deicing/anti-icing chemicals.

RECENT HISTORY: SSF WETLANDS

Sub-surface flow wetlands are typically used where the wastewater being treated is noxious or odorous; where a higher degree of freeze protection is desired; where the attraction of wildlife (especially waterfowl) may be undesirable (e.g., at airports); and/or where ample, economic supplies of suitable substrate material are readily available.

These wetlands consist of submerged gravel beds constructed below ground level. To the untrained eye, they are difficult to discern from open fields. Technically, they are wetlands because wetland plants can grow in them, though there is no open water. Their water surfaces are typically 12 inches below their mulch and unsaturated gravel surfaces.

They can be operated either with the wastewater flowing horizontally through the bed or with the water percolating down vertically through the gravel. Bacteria attached to the gravel are responsible for pollutant removal. For high-strength deicing liquids, aeration of the bed is required to assist the bacteria in metabolizing the glycol.

Although there have been several smaller, pilot-scale wetland systems, there are currently only three large, existing SSF constructed wetlands now operating that treat glycol-contaminated stormwater at airports: at Edmonton International Airport in Alberta; at Heathrow International Airport in London; and, at Air Express Airport in Wilmington, OH. The first two are horizontal flow SSF wetlands, while the third is a reciprocating (tidal) flow, vertical SSF wetland. All three are associated with surge ponds in front of their multiple wetland basins ("cells").

• The wetland at Edmonton treats stormwater contaminated with ethylene glycol; at Heathrow, a variety of glycol types; and, at Wilmington, propylene glycol.

• The Edmonton wetland operates only part of the year, being frozen in the coldest weather. The Heathrow wetland can operate year-round. The Wilmington wetland attempts to operate most of the year, but tends to impound water in the very coldest periods.

• The Edmonton wetland is vegetated with transplanted cattails; the Heathrow wetland is planted with reeds; and the Air Express wetland is not vegetated.

• At Edmonton and Wilmington, influent contaminated runoff flow rate is keyed to water temperatures with lower throughputs occurring when the water is colder. None of the wetlands is insulated.

In the laboratory: sub-surface flow (SSF) wetlands are insulated, aerated, and specifically engineered to remove glycol.

• All three wetlands use gravel as their substrates: it is 2.3 feet thick at Edmonton, 2.1 feet thick at Heathrow; and, seven feet thick at Wilmington.

The horizontal sub-surface flow wetland at Edmonton, which commenced operation in 2001, consists of 12 square, gravel-filled cells with sides

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measuring 156 feet each, arranged in six trains of two cells each. Wetland gravel surface area is seven acres and its "footprint" is eleven acres. Design conditions for the wetland were for the treatment of stormwater runoff contaminated with up to 1,350 milligrams (mg) of ethylene glycol per litre at flows of up to 330,000 gallons per day (gpd). The wetland system there includes the wetland cells; a lift station; associated ponds and ditching; piping between existing and new ponds and the wetland; an outlet weir system; mandated continuous sampling facilities; and, fencing and diversion facilities that allow less contaminated water to bypass the wetland into a normally dry, very large stormwater detention pond.

Operating and maintenance costs for the wetland system are quite low, and it's designed for unattended operation, except for periodic monitoring. The sub-surface flow wetland at Edmonton International Airport continues to operate successfully with minimal operator attention, meeting effluent targets.

A SOLUTION: ENGINEERED WETLANDS

Nevertheless, there still are problems with the use of these ordinary constructed wetlands for treating glycol-contaminated stormwater runoff at airports. They all tend to be relatively large.

Although it continues to run well, the SSF wetland at Edmonton only operates outside of frozen conditions and must impound water/collect contaminated snow in winter. The horizontal SSF wetland at Heathrow has been experiencing plugging problems in the shallow gravel of its primary cells. During very cold weather, cold air drawn into the beds of the wetland cells at Wilmington freezes the bacteria used for contaminant removal and water must be impounded during these periods.

> ***With engineered wetlands, higher levels of contaminant removals are possible at higher throughputs and with much shorter residence times.***

What was needed was a wetlands technology that could overcome such limitations. The answer lies with engineered wetlands.

Engineered wetlands are new types of semi-passive constructed wetlands designed so that operating and process conditions can be modified, manipulated, and/or controlled, in contrast to the more passive operation of ordinary constructed wetlands.

With engineered wetlands, higher levels of contaminant removals are possible at higher throughputs and with much shorter residence times. Constructed wetland systems can be "engineered" in many ways to greatly improve performance.

An aerated vertical SSF engineered wetland is one kind in which air (supplied by blowers) is introduced under thicker gravel substrate (4–12 feet thick). Aeration air flows up through the gravel from a buried fine bubble diffusion system, countercurrent to downward percolating wastewater. The vegetated gravel surfaces of engineered wetlands are insulated with layers of mulch or compost to prevent freezing problems, and the systems are designed to operate throughout northern winters — whatever the ambient air temperatures.

The aerated sub-surface flow engineered wetlands technology is demonstrated and proven. Dozens of smaller wetlands of this sort are already in operation for sewage treatment in northern U.S. areas, and have operated successfully during summer and winter for many years. As well, several very large systems for flow rates of up to 4.5 mgd and contaminant concentrations of up to several thousand mg/L now have been designed and are under construction for treating a variety of wastewaters.

THE BUFFALO EXAMPLE

A large new aerated vertical subsurface flow engineered wetland system is now in the final stages of design at Buffalo Niagara International Airport. Previously, concentrate from around the deicing pads had been collected for disposal at a local wastewater treatment plant. This facility has given notice that it wishes the airport to find an alternative disposal option. Also, the large fraction of the glycol that still ends up in the airport's stormwater sewers can exceed the airport's NPDES permit, which mandates a 30 mg BOD_5/L limit.

The airport's owner, the Niagara Frontier Transportation Authority, decided to proceed with the design and engineering of a sub-surface flow engineered wetland to treat both the concentrate (the spent deicing fluids from the deicing pads) and stormwater together prior to discharge. The objective of the project is to ensure that no water leaving the airport exceeds regulatory requirements.

The project already has involved the successful off-site treatability testing of propylene glycol-spiked stormwater from the airport at high (70ºF) and low (40ºF) design basis temperatures at off-site pilot-scale wetland test facilities to determine kinetics and other scale-up parameters for subsequent full-scale facilities. The results of the pilot-scale testing determined that a 12-acre aerated vertical SSF engineered wetland would do the job. It demonstrated very good treatment (96-97 percent removal of target pollutants) at both the high and low design basis temperatures.

The new engineered wetland for BNIA will treat glycol-contaminated stormwater runoff and other wastewaters during the deicing season, and stormwater sewers' base flow and rainfall event first flush runoff year round. The wetland will consist of ten earthern-bermed, rectilinear wetland cells excavated from an existing open area near the airport's main runway. At ground level, only a field of wetland grasses will be visible, growing from a "dry" mulch surface.

Design is based on treating up to 0.2 mgd of concentrate from the deicing pads generated by up to 300,000 gallons of pure propylene glycol use annually during the average 190-day deicing season, and an average stormwater flow rate of 1 mgd year-round. The design allows for the treatment of a mix containing up to 2,150 mg BOD/L during the deicing season and uses existing underground glycol and stormwater tanks for flow equalization.

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Airport managers are ultimately responsible for the activities that take place at their airports. Keeping aircraft safe from the effects of cold weather is a primary concern for airports in northern climates. Due to regulations soon to be imposed by the EPA, managers will also be responsible for safeguarding the local environment from deicing activities. Every airport will develop a unique plan depending on the particularities and constraints of their site. Aerated sub-surface flow wetlands are proving to be an effective component of these plans because they are capable of handling the strength and variability of spent deicing liquids.

About the Authors

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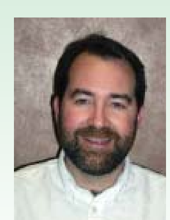

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