Navigating the Sea of Stormwater Practices

By Tara McDonough and Mark O. Liner

Setting sail

Stormwater management is an area of uncharted waters for many facilities. The passage through is ever changing and subject to the fickle winds of regulation. There are many courses that can be taken. Some are well known and widely practiced, while others hop into the market as the next best thing since the Panama Canal. Each has its benefits, each has its shortcomings. So, how does one chart a course towards a facility's optimum stormwater management goals? What has been proven to work?

A stormwater control system retards flow and allows infiltration at the Heritage Park Development in Minneapolis.

The regulatory winds

The stormwater permit is a regulatory instrument designed to protect the environment from man's compulsion for good drainage. Due to the water quality impacts of the first flush and damage associated with semi-frequent flooding, rainwater runoff now requires governmental regulation. Some local governments take the task more seriously than others, resulting in permits that stem from the national level down to the municipality.

In general, the National Pollution Discharge Elimination System (NPDES) Phase II regulations are the bare minimum that a facility must comply with; state and local regulations are often more stringent. Permits require the creation of a *Stormwater Pollution Prevention Plan* that identifies pollution mitigation as well as practices to reduce volume and discharge rates, and improve quality. If stormwater contamination is unavoidable and specific treatment is required, then a solution must be developed to treat this water. The variation of individual regulations has resulted in a wide spectrum of approaches that greatly vary in complexity and cost.

A gravel wetland was constructed at the UNH Stormwater Center. The photograph is courtesy of the UNH.

The new wave

Orlando, Fla., Burlington, Vt., Raleigh, N.C., and Minneapolis all have a stormwater utility fee. Stormwater discharges from these municipalities are NPDES permitted, and therefore require design, maintenance and administrative costs. These costs are passed on to property owners via a stormwater utility fee.

While a stormwater fee may mean greater expense to many industries and large commercial facilities, incentive to implement stormwater management also is in place. Through the reduction of impervious surfaces, the infiltration of stormwater and the treatment of stormwater contaminants, significant fee credits can be gained. For example, in Minneapolis, a 50-percent fee reduction can be received for practices that improve stormwater quality, and a 50- to 100-percent fee reduction can be achieved for reductions in stormwater quantity.

Retrofitting existing development with stormwater management practices can be quite a challenge. Fortunately, stormwater practices can be implemented in many locations along the runoff's path, which serves to reduce the quantity and improve the quality of discharged water. While simple practices do exist, according to Karl Westermeyer, administrator of the Minneapolis Stormwater Utility, out of 102,000 property owners in the city, just 160 have applied for and received credits toward the stormwater fee since the program began in March 2005.

Stormwater Practice	Result of Practice
Combined stormwater and sewer collection systems are constructed, water is conveyed to surface waters	Flooded streams and rivers, sever erosion from high velocity streams, surface water quality decrease
Wastewater treatment systems are constructed, combined sewers are routed to system, peak flows during storms are overflowed to surface waters	Surface water quality improvements, during storm events high flows to treatment systems
Separate Stormwater and Sewer Collection Systems	Increased capacity of wastewater treatment systems, decreased water quality resulting from direct stormwater discharge increase potential erosion
Rate control of stormwater discharge to surface waters by constructing detention ponds	Decrease peak event discharges, allows for partial treatment of water
Reduce Stormwater Quantity and Improve Quality by various BMP's and LID practices	Increase surface water quality and decreased potential for flooding and erosion

Table 1 – Evolution of Urban Stormwater Management

Charting a course

In order to determine the correct course, a brief evolution of stormwater history should be reviewed. **Table 1** summarizes the major milestones in urban stormwater management.

When designing stormwater control systems in the past, the quickest route to convey rain away was conceived. Eventually, this practice led to flooding, pollution and erosion. Over time, efforts were taken to restrict the rate at which stormwater was released. Thus, the stormwater retention basin was born. Today, there are two primary focuses of stormwater management: quantity reduction and quality improvement.

There are three primary locations that both stormwater quantity and quality can be managed. These include source or lot-level controls, conveyance system controls, and end-of-pipe systems. Many stormwater practices serve to improve quality and reduce quantity. Within each of these management locations are a variety of treatment options which can primarily be broken into two general categories: manufactured systems and engineered earthen systems. The control point and type of system depends on constraints such as available land, contamination type, maintenance level and cost.

Management Type	Lot- Level, Source Control	Conveyance Control	End of Pipe Control
Quality	Roof Detention Green Roofs Zoned Management Operational Controls	Vegetated Swales Stone Swales	Oil Water Separators Constructed Wetlands Mechanical Systems Sand Filters Grit Chambers
Quantity	Reduced Impervious Areas Pervious Pavement Roof Detention Green Roofs	Vegetated Swales	Detention Ponds Infiltration Basins Rain Gardens Subsurface Infiltration

Table 2 - Stormwater Management Strategies

This stormwater control system is under construction at the Heritage Park Development in Minneapolis.

Quantity

Reducing stormwater quantity and discharge rates can be accomplished in a number of ways: reduce stormwater generated, store stormwater generated, convey generated stormwater in infiltrative swales or infiltrate collected water. Strategies such as green roofs and porous pavement reduce the volume of stormwater runoff. These strategies are most easily adopted during the design of a facility. Green roofs have been shown to reduce stormwater quantity by 70 to 90 percent in summer and 25 to 40 percent in winter. A sewage plant in Shakopee, Minn. recently installed a 30,000 square foot green roof.

Another option is the use of porous pavement that allows rainwater to percolate down. This pavement option is now being offered as a standard option by a number of paving companies.

A common stormwater storage practice is the detention pond. Ponds serve to reduce discharge rates and improve water quality through the storage and settling of particulate matter. In tight spaces, ponds are uneconomical from a land use perspective. As a result, an innovative option to retrofit and design building roofs for storage has been developed. If roofs can structurally handle the load of water, the roof edges can be raised and downspouts reconfigured to create a source control storage system. Roof storage systems also improve overall stormwater quality by reducing water velocities and subsequent particulate conveyance. A third location for storage is underground. From parking lots to football fields, storage systems can be constructed underground.

The use of swales in lieu of pipes also is proving to be a useful tool in stormwater management. Vegetated swales provide filtration and infiltration of stormwater. Using swales rather than pipes can reduce stormwater quantity when properly designed. The considerations needed for swales include limiting erosion though grading and techniques to reduce velocity.

The final system a facility can implement to reduce stormwater quantity is capture and infiltration of collected stormwater. Infiltration systems can be manufactured products or constructed on site. Manufactured subsurface infiltration systems are typically covered and unseen, and – similar to storage systems – can be located underground with other primary uses on top. Significant advances have been made in this area, and infiltration devices are available in plastic, concrete or fiberglass materials. On the other hand, earthen constructed systems for infiltration can require larger footprints.

Quality

A stormwater quality management system should be developed at a facility-wide level. Operational procedures to eliminate stormwater contamination, facility design to zone and separate areas of contamination, and end-of-pipe solutions to treat water all should be considered. The first consideration should be the elimination of contamination and creation of separate collection for contaminated zones, as this can serve to reduce the size and cost of end-of-pipe solutions.

Stormwater Practices

Operational procedures and zoned stormwater conveyance systems are largely dependant on individual facility designs. End-of-pipe solutions range in size and maintenance requirements. Some facilities route only contaminated stormwater to the existing mechanical system on site. This solution can impose operational difficulties due to the nature of stormwater to fluctuate in flow and load. On the other hand, natural treatment technologies, such as constructed wetland treatment systems, can be designed to handle a variety of flow and loading situations. Treatment wetlands also are operationally simpler than mechanical treatment systems.

Manufactured, passive systems typically provide treatment for common stormwater contaminants such as suspended solids and oil. Manufactured end-of-pipe solutions such as oil/water separators, baffled settling tanks and grit chambers are simple devices that provide a treatment solution to typical contaminants and have lower land requirements. **Table 2** summarizes some of the common quantity and quality stormwater management practices.

Keeping watch

The difficulty for engineers in implementing new stormwater management practices is largely based on a lack of performance data. Often, designers and planners are left to prescriptive design standards or must rely on manufacturer's claims. The University of New Hampshire sought to fill this gap through the development of a Stormwater Center dedicated to collecting and analyzing data from a variety of stormwater practices. A report published by the center in 2005 summarized the effectiveness of a variety of stormwater treatment and quantity reduction techniques.

The Stormwater Center constructed and analyzed the performance of 12 stormwater practices for water quality and volume reduction. The water quality parameters evaluated included: total suspended solids (TSS), total petroleum hydrocarbons-diesel (TPH-D), nitrate (NO_3-N) and total zinc (Zn). The report also provided ranges of maintenance sensitivity, required inspections and sediment removal.

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The report provided a range of options for consideration, but no silver bullet. The retention pond had low maintenance requirements and correspondingly lower sediment capabilities. The systems with the highest capabilities for hydrocarbon removal were the sand filter (94 percent), bio-retention basin (99 percent) and subsurface gravel wetland (99 percent). Nitrate removal capabilities were highest in the bioretenton system (44 percent) retention pond (64 percent) and gravel wetland (99 percent). Zinc removal capabilities were highest in the subsurface infiltration unit (99 percent), bioretention system (99 percent), constructed wetland (99 percent) and retention pond (94 percent).

Of the 12 stormwater systems, five were capable of peak flow reduction and were evaluated for percent reduction. These systems included: the manufactured subsurface infiltration unit, surface sand filter, retention pond, bioretention system and the gravel wetland. The research results found that the retention pond, bioretention system and the gravel wetland were all capable of 85-percent average peak flow reduction, the subsurface infiltration unit was capable of 83 percent reduction, and the surface sand filter was capable of 50-percent reduction.[1]

The roof at the Green Institute in Minneapolis collects and filters rainwater on its roof.

Innovative implementations

A solution to unavoidable pollution currently is being developed at the Buffalo Niagara International Airport in New York. The airport uses glycol-based aircraft de-icing fluids (ADFs) for removing ice and snow from aircraft surfaces during winter or frost conditions. To treat the glycol contaminated stormwater, the airport planned to install an aerated subsurface-flow wetland (SSFW) treatment system. The system was designed at grade with no aboveground structures that present an airside hazard. More importantly, the subsurface nature of the wetland avoided open water areas that might present bird strike hazards. Stormwater discharge from the airport currently is regulated by the New York DEQ, which limits the amount of biochemical oxygen demand in the runoff.

The stormwater system was designed to manage both the quantity of rainwater collected and treat the stormwater to meet the limits in the permit. A key to this design was the use of aeration in the wetland gravel bed, which facilitated the biological oxidation of glycol and other pollutants in the wastewater.

In another example, the Jay Peak Ski Resort has been expanding rapidly, with condominiums constructed adjacent to ski trails on slopes of 15 percent and greater. Resort developers wanted to minimize the amount disturbed area on the hillside in an effort to preserve the mountain landscape, while protecting the environment at the same time. A conventional stormwater design would have called for large ponds with permanent pools of standing water. This was not a desirable approach because of safety concerns, as well as the amount of down slope fill that would be required to reach existing grade.

Subsurface flow constructed wetlands were designed by Engineered Solutions Inc., Burlington, Vt., to treat the stormwater runoff for the water quality volume, with dry detention ponds for temporary storage of extreme storm events. The subsurface flow constructed wetland was lined with an impermeable membrane to maintain a permanent water level below a stone media. The wetland was filled with 2- to 4-inch stone and topped off with pea stone for planting.

Infiltration chambers are used to redistribute flow within the wetland, and water is collected at the bottom of the outlet end to ensure that all of the water entering the wetland passes through the stone media. The safety concerns with the ponds are mitigated by the wetlands because there is no standing water. The wetlands are not more than 4 feet deep, and the side slopes can be nearly vertical. This allows the wetland to be cut into the hillside and drastically reduces the amount of down slope fill required.

Anchoring down

Once the goals of stormwater management have been defined, the course to appropriate solutions can be charted. From facility-wide planning to post development retrofits, there are stormwater practices that can be implemented at each of these levels. These stormwater practices range in quantity reduction and quality improvement capabilities, as well as size and maintenance requirements. Charting the course of stormwater management must begin with a clear definition of project goals and should begin upstream at the source of stormwater creation. **PE**

Resources

1.The University of New Hampshire Stormwater Center: www.unh.edu/civil-engineering/research/erg/cstev/index.htm

2. EPA NPDES Program: http://cfpub.epa.gov/npdes/

3. Minnesota Stormwater Manual: www.pca.state.mn.us/water/stormwater/stormwater-manual.html

4. National Low Impact Development Clearinghouse: www.lid-stormwater.net/clearinghouse/

5. International Stormwater Best Management Practices Database: www.bmpdatabase.org/

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