Stormwater Runoff Water Quality Science/Engineering Newsletter Devoted to Urban Stormwater Runoff Water Quality Management Issues

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Preface to Volume 3, Number 2

Contents of this Newsletter

This newsletter is a follow up to the previous Newsletter (Vol 3-1) which provided an overview of urban area and highway stormwater runoff water quality impact evaluation and management. This Newsletter is primarily devoted to a review of the characteristics and associated costs of conventional BMPs that have been traditionally used to "treat" urban area and highway stormwater runoff. Mr. Scott Taylor of Robert Bein, William Frost Associates (RBF) Irvine, CA, has contributed an overview review of the characteristics of the conventional BMPs that are used for stormwater runoff water quality "management."

Mr. Taylor is Vice President of Water Resources at RBF. He also chairs the California Stormwater Quality Task Force on BMPs. His educational background is in civil engineering, with bachelors and masters degrees focusing on hydraulics and hydrology. He has extensive experience in urban area and highway hydrology, hydraulics and flood control design and in the design of stormwater pollution prevention plans. He is a part-time lecturer at the University of California at Irvine and California State University at Long Beach, teaching courses in hydrology and hydraulic design. He can be contacted regarding further information on his discussion of BMPs at staylor@rbf.com.

Overview of Conventional Stormwater Runoff Water Quality BMP Characteristics and Performance

Scott Taylor, PE
Vice President RBF

Introduction

The cost and effectiveness of structural or treatment control BMPs is becoming the subject of increased interest as storm water dischargers face permit requirements that include "BMP ratcheting down" clauses and TMDL waste load allocations. Stormwater's high volume, intermittent nature and variable quality make treatment a tremendous challenge. Conventional structural BMPs can be a useful element in the management of storm water quality but they are not a panacea to achieve water quality standards.

Structural BMPs should be used when it is determined that they will be 'cost effective'. A cost effective application is one that accomplishes the project goals for the least cost while also providing a benefit that exceeds the cost. Most current conventional structural BMPs will not remove the dissolved fraction of a constituent-potential pollutant. In most instances it is the dissolved form of the constituent that can be responsible for beneficial use impairment in downstream receiving waters. Consequently, the conventional structural BMP 'tool kit' available to the stormwater manager cannot independently achieve the goal of compliance with water quality standards.

Stormwater runoff water quality management programs must be a carefully crafted combination of non-structural and structural BMPs designed to address targeted constituents control requirements. Routine achievement of water quality standards will require more receiving water quality monitoring and evaluation to provide the basis for BMP development. Changes in urban planning and design will also be required to address peak flow and volume increases that occur with urbanization.

Structural BMPs

The primary structural BMPs currently in use in the southwest are:

Drain inlet inserts
Extended detention basins
Biofilters
Media filters
Infiltration

There are also other proprietary BMPs that use the principles of settling and filtration to remove chemical constituents and gross pollutants. Some of the benefits and pitfalls for each type of BMP are discussed below.

Drain Inlet Inserts

Drain inlet inserts are a proprietary BMP that is generally easily installed in a drain inlet or catchbasin to treat stormwater runoff. Three basic types of inlet inserts are available, the tray type, bag type and basket type. The tray type allows flow to pass through filter media residing in a tray located around the perimeter of the inlet. Runoff enters the tray and leaves via weir flow under design conditions. High flows pass over the tray and into the inlet unimpeded.

The bag type of insert is constructed from a fabric and is placed in the drain inlet around the perimeter of the grate. Stormwater runoff must pass through the ‘bag’ prior to discharging to the drain outlet pipe. Overflow holes are usually provided to pass larger flows without causing a backwater at the grate.

The basket type of inlet consists of a wire mesh that is placed around the perimeter of the inlet in an installation similar to the tray type device. The wire mesh operates similar to the bag type insert, screening larger materials from the runoff. Some basket type inserts also incorporate filter media similar to the tray type insert.

Drain inlet inserts have generally performed poorly in tests for several reasons. First, the detention or contact time with the insert ‘media’ is very short. Second, there is little storage area available for material that is removed from the flow. The device can act as temporary storage location, retaining solids as flow decreases, but then may allow resuspension when flow (and velocity) subsequently increases. Lastly, inserts require a high degree of maintenance and must be monitored closely during rain events to ensure that the unit is not clogged or bypassing flow. Such a level of maintenance is not practical for most installations.

Bag and basket type drain inlet inserts can be effective in removing gross pollutants (trash), but must be well maintained. For areas with a limited number of inlets where trash removal is the desired objective, inserts can be a useful BMP. Tray type inserts are generally not effective in trash or solids removal.

Extended Detention

Extended detention basins are a relatively popular BMP since the design is well documented from flood control engineering, and extended detention may be incorporated as an element into flood control detention basins. Extended detention employs a relatively longer drain time than conventional detention used for peak flow control. An average hydrograph detention time of 24 hours is desired. This can be achieved by using a full basin drain time of at least 48 hours, with no more than 50 percent of the water quality volume draining in the first 24 hours (Barrett, 1999). Sedimentation in the basin is the primary removal mechanism.

Extended detention basins can be relatively effective in removing solids (including gross pollutants) but are relatively ineffective in removing dissolved constituents and bacteria. The application of extended detention must include a review of the downstream receiving channel to ensure that problems are not created by their use through increased erosion of the channel..

Careful consideration should be given when installing extended detention basins upstream of an alluvial channel. The stability of an alluvial channel depends in large part on the quantity of bed material load that is transported by the stream, as well as the frequency and duration of the bankfull discharge. Extended detention basins are effective in removing the bed material load from natural channels. Channel stability problems and channel scour can result from the misapplication of this BMP. Extended detention is a useful BMP where particulate removal is a desired objective for the downstream receiving water. Extended detention requires moderate maintenance as compared to other BMPs.

Biofilters

Biofilters consist of dense vegetation designed to 'filter' runoff as it passes through the BMP. The detention or 'residence' time is generally insufficient for a significant portion of the runoff volume to be infiltrated, however, infiltration can be significant for storms smaller than the design storm for biofilters in soils with good infiltration characteristics. Biofilters can be effective in removing particulates from runoff.

Biofilters are an attractive BMP in that they can be incorporated into many projects with relatively little site modification. Conveyance structures that are normally paved can sometimes be replaced with vegetation. Buffer 'strips' can be provided where sheet flow leaves paved areas. Biofilter swales are generally designed with a flow velocity of less than 1 foot per second and are installed in a location with enough length to provide a residence time of at least 5 minutes (the length of the swale divided by the average flow velocity) (WEF/ASCE, 1998). Biofilter strips treat sheet flow and their width is a function of the contributing drainage area, but the strips should be at least 12 feet wide (Barrett, 1999).

Swales and strips must be designed to withstand flow rates that exceed the water quality design velocity to ensure they are not damaged during high flows, or cause upstream flooding. Certain types of well-established vegetation can be sustained in flow velocities of up to about 8 feet per second with a more typical value being 4 to 5 feet per second. In the southwest, vegetation that does not require irrigation may be prudent to reduce water consumption. Biofilters can serve as a pretreatment device prior to infiltration or in situations where extended detention is desirable but insufficient area is available. Biofilters require a moderate maintenance schedule as compared to other BMPs.

Media Filters

There are a variety of media filters currently in use including sand, compost, sand peat and perlite/zeolite. Perlite/zeolite and compost filters are proprietary. The use of compost has declined since nutrients are released from this media. Sand filters enjoy the most widespread application.

Slow sand filtration is a relatively old technology largely abandoned by the US water industry several decades ago in favor of rapid sand filtration. Sand filters are generally limited to low turbidity waters and operate through a combination of straining and adsorption. Sand filters are among the most efficient conventional treatment devices achieving good removal of particulates and modest removals of bacteria and dissolved metals.

Sand filters are designed with a sedimentation chamber to store all or part of the water quality volume, followed by the sand bed. The purpose of the sedimentation chamber is to remove the settleable solids that could otherwise rapidly clog the filter. The sand bed is designed for a filtration rate of about 3.5 ft/day (Barrett, 1999) but generally operates at the rate limited by the release from the sedimentation chamber. Various configurations are available including the Austin design, the Delaware design and the Washington D.C. design. Sand filters require relatively higher maintenance as compared to other BMPs.

Infiltration

Infiltration of stormwater is a zero discharge solution infiltrating the entire design water quality volume to the surrounding soil. Infiltration is a popular BMP in areas that have relatively permeable soils. Significant questions remain as to the potential impacts on groundwater quality from the infiltration of stormwater (EPA NURP (1983) study concluded that most pollutants of importance in urban runoff are intercepted during the process of infiltration and quite effectively prevented from reaching the groundwater aquifers underlying recharge basins). Consequently, storm water infiltration devices should always include a groundwater monitoring element. Soils that are conducive to infiltration are also relatively poor in filtering and adsorbing contaminates that could otherwise enter an aquifer.

Infiltration devices have a poor performance record due to clogging. Current guidelines call for minimum soil permeability rates of about 0.52in/hr (Schueler and Claytor, 1998) for infiltration to be considered feasible. Generous safety factors should be used (by increasing surface area) and the depth to the groundwater table, seasonally adjusted, must be well documented (10 feet separation to the invert of the infiltration device is recommended). If soil permeability does not allow the use of infiltration, retention and irrigation may be considered. The design water quality volume is stored and subsequently pumped through an irrigation system. Additional information on infiltration as a stormwater BMP has been provided by Lee et al. (1998) and Taylor and Lee (1998).

Conventional Structural BMP Performance

The volume of available performance data (constituent removal) for conventional structural BMPs is rapidly increasing. Removals of commonly monitored constituents can be estimated with good accuracy using tools such as ASCE's BMP database (ASCE, 2000). Table 1 provides estimated removals for selected categories of constituents for the BMPs discussed above. Note that the values are generalized and total (particulate and dissolved) for nutrients, pesticides and metals.

Table 1

Percentage Reduction in Storm water Load by BMP

Runoff Control	Solids	Nutrients	Pesticides	Metals	Bacteria
Drain Inlet Insert	10	5	5	5	5
Ext. Detention Basin	75	25	25	50	40
Vegetated Swales	70	30	30	50	0
Filter Strips	85	40	40	63	0
Media Filters	85	40	40	70	55

Source: Barrett, (1999)

Capital Cost

The capital cost of conventional BMP installation varies widely depending on site conditions. The primary factor is whether the BMP will be implemented as a part of new construction or is a retrofit project. Generalized costs for selected BMPs are provided in Table 2 for new construction and retrofit on a dollar per tributary acre basis assuming a 1-inch capture from the contributing watershed. Construction cost data is site specific, and the values given in Table 2 are based on one inch capture volume and should be considered valid for planning purposes only. Future versions of the ASCE BMP (2000) database will include cost data for various devices.

Table 2
Generalized Capital Cost for Conventional BMPs

Runoff Control	New Construction	Retrofit Construction
Drain inlet insert	1,000 $/ac	1,000 $/ac
Ext. Detention Basin	10,000 $/ac	25,000 $/ac
Vegetated Swales	10,000 $/ac	30,000 $/ac
Filter Strips	17,000 $/ac	37,000 $/ac
Infiltration Basin	20,000 $/ac	38,000 $/ac
Media Filters	27,000 $/ac	55,000 $/ac

Source: Barrett, (1999)

Operation and maintenance costs are also difficult to estimate on a general basis since variables such as maintenance access and constituent load are site specific. Table 3 gives general maintenance costs for conventional BMPs on an annual basis.

Table 3
Generalized Maintenance Cost for Conventional BMPs

Runoff Control	Maintenance Cost (per year)
Drain inlet insert	$ 500
Ext. Detention Basin	3% construction cost
Vegetated Swales	$ 5/foot
Filter Strips	$ 1/square foot
Infiltration Basin	3% construction cost
Media Filters	5% construction cost

Widespread Implementation

Structural Best Management Practices (BMPs) and non-structural BMPs are applied to various types of land uses according to their compatibility with the given land use, and the type of constituents of concern in the runoff. Numerous studies have been completed discussing siting criteria and constituent removal efficiencies for BMPs. There are fewer works assessing BMP effectiveness on a watershed basis, specifically in relationship to the ability of a conventional BMP system to achieve compliance with water quality standards. There is even less research defining the relationship between structural BMPs and receiving water quality. Currently, compliance with water quality standards is presumptive, given a “comprehensive” BMP installation program and adequate maintenance for the program.

Receiving Water Impacts

There is very little published evaluations of the benefits of conventional BMPs for receiving waters water quality-beneficial uses. Maxted and Shaver (1997) published a work entitled, *The Use of Retention Basins to Mitigate Stormwater Impacts on Aquatic Life*. In this paper, the authors reviewed eight watersheds, two of which had been retrofitted with 'stormwater' controls.

The study looked at watersheds with either detention or retention ponds. The facility generally had to control peak flows from storms with recurrance intervals of 2, 10 and 100-years, as well as provide detention or retention of the first inch of runoff from the watershed. Further, the BMPs had to be a least 2-years old to avoid construction-related stream impacts. Watersheds with at least 20% impervious cover were studied.

The results of the study indicate that the sites with the BMPs did not appear to improve the biological conditions in the receiving waters. The degree of urbanization did not appear to effect the biological conditions at the sites (Maxted and Shaver, 1997). The authors stress that complexity of the system under study could not be adequately understood using a single data set. The conclusions of the paper stress the need for additional monitoring of BMP sites to develop the information needed to improve BMP design. The authors also pointed to the need to focus on receiving water impacts rather than load reduction (of constituents) from the watershed. Aquatic life impacts are based on constituent concentration, rather than the average annual load of a constituent.

Advanced Treatment

Advanced treatment controls for stormwater are becoming a source of greater interest with the advent of water quality-based effluent limits (WQBELs). Advanced treatment controls may include ion-exchange, reverse osmosis, disinfection, or ultrafiltration. None of these technologies has been tested on a prototype scale for stormwater and their cost and effectiveness is unknown with respect to application to urban area stormwater runoff treatment. Ozone and UV disinfection systems have been developed for stormwater runoff applications but limited data on their effectiveness has been published.

Advanced treatment may be a last resort option in existing urban areas faced with Total Maximum Daily Load (TMDL) waste load allocations (WLAs), as well as when compliance with water quality standards in the stormwater runoff is required. Further study will need to be done to determine the capital and operation and maintenance cost for these devices, as well as the impacts to downstream receiving waters as a result of their operation. Many advanced treatment processes, such as reverse osmosis and ion exchange result in a brine that must be disposed of to the sanitary sewer or other location. Flow equalization and pretreatment would also be a necessity for these processes.

Additional Comments by G. Fred Lee

Mr. Taylor's discussion of the characteristics/efficacy and costs of conventional BMPs provides information that is pertinent to appropriate selection of BMPs in accord with current regulatory requirements. It is clear that the conventional BMPs discussed by Mr. Taylor were not selected based on demonstrated or even expected performance for protection/ enhancement of the water quality-beneficial uses of the receiving waters for the stormwater runoff BMP-treated waters. Except for possible control of suspended solids arising from erosion within the watershed, conventional BMPs are largely consmetic in addressing real, significant water quality issues. This situation has arisen from a lack of understanding/ application of existing knowledge of water quality issues by those responsible for BMP development, deployment, and evaluation. Current conventional BMPs are based largely on hydraulic considerations with little or no regard to true water quality issues. These issues are not new; they have been well known in the water quality management field since the late 1960s-early 1970s. As discussed by Jones- Lee and Lee (1998) current conventional BMPs can best be characterized as "snake oil" BMPs with respect to managing constituents in urban area and highway stormwater runoff that have the potential to cause significant adverse impacts to the beneficial uses of the receiving waters for the runoff.

The current US EPA BMP ratcheting down process that is in place in California and is expected to spread nationally within a few years, where finding a water quality standard violation in the NPDES-permitted stormwater runoff requires that the permit holder work with the regulatory agency in applying ever more effective BMPs to eliminate the water quality standard violation, will result in massive public expenditures on the order of one to three dollars per person per day in the permitted communities contributing to stormwater runoff, for the retrofit installation and operation of conventional BMPs. The current US EPA regulatory approach, involving a BMP ratcheting down process is obviously fundamentally flawed, in which large amounts of public funds could be spent developing and operating conventional BMPs that will, when full compliance with water quality standards is required, have to be replaced by advanced water and wastewater treatment processes. The projected national cost of full compliance with water quality standards at the point of discharge for urban stormwater runoff is on the order of several hundred billion dollars. This translates to about five to ten dollars per person per day for the acquisition of property and construction and operation of the advanced treatment works needed to comply with existing water quality standards.

As discussed in previous Newsletters, the current regulatory approach, which focuses on mechanically complying with water quality standards at the point of stormwater discharge, fails to recognize that the US EPA water quality criteria, which serve as the basis for state water quality standards, tend to over-regulate heavy metals and many other constituents in urban area stormwater runoff and may fail to regulate deleterious constituents present in urban runoff for which there are no criteria/standards. While the US EPA in 1998, as part of promulgating the then-proposed Phase II regulations governing the application of the NPDES permit system to urban areas with a population of less than 100,000, claimed that six nonstructural BMPs would enable the Phase II communities to comply with water quality standards, it was obvious that the US EPA did not understand the characteristics of urban area runoff relative to the ability of the six nonstructural BMPs to control the concentrations of potential pollutants that are normally present in urban area stormwater runoff at concentrations that will cause violations of water quality standards at the point of runoff.

Thus far, the US EPA has refused, even though repeatedly urged to do so, to provide the US public with information on the cost of compliance with water quality standards in urban area and highway stormwater runoff. While the date of full compliance with water quality standards has not yet been established, based on recent discussions regarding the implementation of the California Toxics Rule, it could be within five years. When these costs are known, the public will likely work with their legislators at the federal and state level to cause the US EPA to develop an urban area and highway stormwater runoff water quality management program that focuses on controlling real, significant water quality use impairments without unnecessary expenditures for chemical constituent control.

Future Newsletters will continue to address these issues. The next Newsletter will focus on infiltration as a BMP for urban area and highway stormwater runoff water quality management.

Contributions to this Newsletter on these issues are encouraged.

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