Chapter 4: Summary of Nonpoint Source Technology Analysis

4.1 Introduction

This chapter is an inventory of the information gathered on the nonpoint source best management practices (BMPs), or technologies, and provides information on each technology that passed the screening process described in Chapter 2, *Technology/Indicator Analysis*. The chapter also discusses the limitations of analyzing nonpoint source technologies on a watershed level. This information was used in the analysis of the screening alternatives and preliminary alternatives for both the Milwaukee Metropolitan Sewerage District (MMSD) 2020 Facilities Plan (2020 FP) and the Southeastern Wisconsin Regional Planning Commission (SEWRPC) Regional Water Quality Management Plan Update (RWQMPU), known collectively as the Water Quality Initiative (WQI).

4.2 Analysis Summary

Nonpoint source pollution originates from diffuse sources - not a specific physical location like point source pollution. Therefore, the technologies that can be used to reduce nonpoint source pollution and the analyses conducted to determine the most cost effective technologies was done differently than the point source technology analysis presented in Chapter 3, *Point Source Technologies*. There are many site-specific variables that can influence the effectiveness and cost of nonpoint source technologies, such as land use type, soil type, climate, drainage patterns, pollutant loads and build-up rates, obstacles to implementing the practice, land cost, compatibility with existing systems, and maintenance.(1) Thus, the assessment of the effectiveness of most nonpoint source technologies was not conducted using the direct production theory approach employed for the point source technologies.

The nonpoint technology analysis began by summarizing information from past and current local projects, U. S. Environmental Protection Agency (USEPA) documents, and technical papers. The information collected for each technology was organized into the following categories:

- Description
- Design Factors
- Experience
- Effectiveness
- Cost

Similar to the point source technology analysis, the nonpoint source technology information was used to analyze each technology so general comparisons between technologies could be made in terms of costs and performance. Then sets of technologies were selected for use in the screening alternatives and preliminary alternatives based on the information gathered. The performance of the technology sets was analyzed based on the results of the alternative runs.

Although only the literature values of the individual nonpoint technologies are presented in this chapter, the screening and preliminary alternatives took the analysis a step further. Selected nonpoint technologies were represented in the Loading Simulation Program in C++ (LSPC) model, generally assuming broad applications based on land use and soil infiltration characteristics in the greater Milwaukee watersheds (GMW). The LSPC model is a watershed model that applies a series of algorithms to watershed characteristics and meteorological data to simulate naturally occurring land-based processes, including hydrology and pollutant transport, over an extended period of time. Using the water quality results from the preliminary model runs, the technologies and the implementation assumptions were optimized on a subwatershed level to develop the components of the final recommended plan. The analyses performed on combinations of technologies are provided in Chapter 8, *Combinations of Technologies* of this report. The recommended plan is presented in Chapter 10, *Recommended 2020 Facilities Plan* of the *Facilities Plan Report* and Chapter X, *Recommended Water Quality Management Plan*, of SEWRPC *Planning Report No. 50, A Regional Water Quality Management Plan Update for the Greater Milwaukee Watersheds*.

4.3 Limitations of Analytical Methods

There are several limitations when analyzing nonpoint source technologies that require assumptions in order to compare them to point source technologies. Some of these limitations make it difficult to even compare nonpoint technologies to other nonpoint technologies. The limitations need to be understood in order to make effective decisions when choosing the most appropriate technology or group of technologies to improve water quality. The limitations are described below.

4.3.1 Annual versus Event Loads

Nonpoint source technologies are typically designed to reduce pollutant runoff loads on an annual basis, whereas point source technologies focus on event load reductions. For example, wet detention basins are designed to remove 80% of total suspended solids on an annual basis. They are designed to treat smaller events throughout the year, which account for about 80% of the annual runoff volume, and bypass larger events. Wastewater treatment plants, on the other hand, must continually meet their discharge permits and, therefore, are designed to treat all wastewater event loads.

4.3.2 Best Management Practices Function in Series

When analyzing the effectiveness of individual nonpoint technologies on a large scale, one must consider the fact that most technologies typically work in series. For example, wet detention basins receive runoff from streets that are swept by street sweepers and have catch basins that are cleaned periodically. The variability of sweeping frequency, catch basin cleaning and rainfall events continuously changes the wash-off loads and pollutant trapping, which ultimately changes the loads that reach the wet detention basin.

4.3.3 Watershed Basis

As explained above, the LSPC model was adjusted to represent broad applications of nonpoint source technologies and analyze an overall response of the system. Because most individual nonpoint technologies treat runoff from relatively small drainage areas, they must be applied on a massive scale in order to see a response on a watershed level. Modeling assumptions were made to evaluate the widespread application of individual technologies. Different assumptions or additional analyses may be required at a community level or individual site level because of the site-specific nature of nonpoint source controls. Therefore, an individual technology or set of technologies recommended in the 2020 FP or RWQMPU may need to be modified or replaced for a specific application based on a more detailed analysis during the preliminary engineering phase. This report can be used as a reference to determine alternative technologies that can be implemented to achieve the desired water quality improvement.

4.3.4 Impacts on Instream Water Quality

There are many variables and circumstances that must be considered when analyzing the benefits of nonpoint technologies to instream water quality. First, there are numerous site-specific variables that can influence the effectiveness of the technologies themselves, such as land use type, soil type, climate, drainage patterns, pollutant loads, build-up and wash-off rates, compatibility with existing systems, and maintenance.(2) The LSPC model uses the data provided to calculate the impacts of many of these variables, but there are a significant amount of engineering judgments that are made regarding the implementation and performance of the technologies. Second, the technologies can be far from a major tributary, which may allow the treated stormwater to contact additional pollution sources on the way to the receiving water. Third, the models also address instream processes, such as the die off rate of bacteria or the resuspension of solids. These instream processes can obscure the benefits of nonpoint technologies. Finally, the volume of water in the receiving water compared to the volume of water treated by a single nonpoint technology can mask the water quality improvements observed at the site level.

Point source controls, on the other hand, typically have a direct cause and effect on instream water quality because they have fewer uncontrolled variables that impact performance, they discharge directly to a stream or a lake, and they typically impact larger volumes of water. Therefore, fewer modeling assumptions are required.

4.3.5 Traditional Production Theory Not Easily Applied

In addition to the variables that impact effectiveness, the site-specific variables mentioned previously can influence the cost of nonpoint source technologies.(3) Applying nonpoint source technologies on a broad scale requires modifications to cost function and production function curves. Therefore, the traditional production theory analysis cannot be applied in most cases. However, there are some nonpoint BMPs, such as disinfection units, that can be analyzed using the traditional production theory.

4.4 Summary of Results

Table 4-1 provides a summary of the data collected for the nonpoint source technology analysis. The unit costs found for each technology are shown along with the typical land cover treated and the indicators that each technology addresses. As discussed above, because of the wide range of variables involved with nonpoint source pollution control, it may not be appropriate to directly compare the unit cost of one technology to another. However, this information can be used as a guide when determining technologies to reduce nonpoint pollution in the GMW.

Technologies	Cost			Typical Land Cover Treated		Indicator Addressed[1]								Comments
	Capital	Annual O&M	Unit[3]	Impervious	Pervious	Vol[2]	Debris[2]	TSS[2]	TN[2]	TP[2]	Coliform[2]	Metals[2]	Other[2,4]	Comments
Volume														
4.6.1 Bioretention	$16,150 - $37,000	$320 - $740	acre served	X		X	—	X	X	X	—	X	—	Effectiveness based on design and site conditions
4.6.2 Cistern	$500 - $6,200	$375	each	X	X	X	—	—	—	—	—	—	—	Based on MMSD analysis
4.6.3 Downspout Disconnection	$14 - $443	$0	each	X		X	—	—	—	—	—	—	—	Assumes redirecting to pervious areas or used in conjunction with rain barrels or rain gardens
4.6.4 Green Roofs	$5 - $25	$0.25 - $1.25	square foot	X		X	—	—	—	—	—	—	X	Aesthetic value, reduced energy cost and sustainability are added benefits
4.6.5 Parking Lot Stormwater Storage and Treatment (Green Parking Lots)	$455,000	$4,400	acre	X		X	X	X	X	X	—	X	—	Maintenance costs are similar to typical landscaping maintenance costs
4.6.6 Porous Pavement	$108,900 - $217,800	$400	acre	X		X	—	X	X	X	—	X	—	
4.6.7 Rain Barrels	$50 - $250	$2.50 - $12.50	each	X		X	—	—	—	—	—	—	—	
4.6.8 Rain Gardens	$25	$1.25	square foot	X	X	X	—	X	X	X	—	—	X	Can improve habitat and add aesthetic value
4.6.9 Stormwater Parks	$22,750	$700 - $1,100	acre served	X		X	X	X	X	X	—	X	X	Effectiveness based on design and site conditions. Stormwater parks can also have an aesthetic benefit
4.6.10 Stormwater Trees	$50	$2.50	tree	X	X	X	—	X	—	X	—	—	X	Can also provide aesthetic value, habitat improvement and temperature benefits
Total Suspended Solids (TSS)														
4.7.1 Agricultural Bench Terraces	$36 - $100	$3.60 - $10	acre served		X	—	—	X	X	X	—	—	—	
4.7.2 Agricultural Buffer Strips	$10,000 - $31,000	$150 - $900	acre		X	—	—	X	X	X	X	X	X	Can also reduce overspray of pesticides and herbicides that reaches waterways and improve habitat
4.7.3 Catch Basin Cleaning	$0	$16	catch basin	X	X	—	X	X	X	X	—	X	—	Assuming already installed
4.7.4 Catch Basin Filter	$160 - $2,400	$16 - $160	filter	X	X	—	X	X	—	—	—	—	—	Studies show little silt or clay particles removed
4.7.5 Conservation Crop Rotation	$0	$0	acre		X	—	—	X	X	X	—	—	X	Sustainability, higher crop yields and cost savings are other potential benefits
4.7.6 Constructed Wetland	$39,000 - $82,000	$780 - $1640	acre	X	X	X	—	X	X	X	—	X	X	Assumes wetland area is 1% to 5% of the drainage area. Can add aesthetic value and improve habitat
4.7.7 Fine Screens	$135,000 - $380,000	$4,050 - $19,000	screen	X		—	X	—	—	—	—	—	—	
4.7.8 Infiltration Basin	$21,700 - $108,300	$1,100 - $5,400	acre served	X	X	X	—	X	X	X	X	X	X	Can also reduce BOD up to 90%
4.7.9 Riparian Corridors/ Buffers - Rural	$210 - $3,000	$55 - $510	acre		X	—	—	X	X	X	—	—	X	See text Section 4.7.9 for multiple other benefits of Riparian Corridors
Riparian Corridors/ Buffers - Rural	up to $200,000	$0	acre	X	X	—	—	X	X	X	—	X	X	Additional benefits similar to ones listed above for rural areas
4.7.10 Stormwater Filtration Systems (Sand Filters)	$5,700 - $47,250	$290 - $2,700	acre served	X	X	—	—	X	X	X	X	X	X	Oil and grease removal estimated to be 40% to 80%
4.7.11 Street Sweeping	$1,000 - $2,500	$30 - $60	curb mile	X		—	X	X	—	X	X	X	—	Cost to contract weekly parking lot sweeping is about $2,500 - $3,700/ac/yr
4.7.12 Wet Detention Basin	$1,600 - $6,100	$50 - $305	acre served	X		X	X	X	X	X	X	X	X	Aesthetic value and habitat improvement are other benefits

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TABLE 4-1 SHEET 1 OF 2

SUMMARY OF NONPOINT SOURCE POLLUTION CONTROL TECHNOLOGIES

Technologies		Cost			Typical Land Cover Treated		Indicator Addressed[1]								Comments
		Capital	Annual O&M	Unit[3]	Impervious	Pervious	Vol[2]	Debris[2]	TSS[2]	TN[2]	TP[2]	Coliform[2]	Metals[2]	Other[2,4]	
Fecal Coliform															
4.8.1	Livestock Management	$2 - $3	$0.1 - $0.15	linear foot		X	—	—	—	—	—	X	—	—	Cost of fence only. Crossings are about $1,800 each
4.8.2	Manure Management	$150 - $1,500	$11 - $57	head of cattle		X	—	—	—	—	—	X	—	—	
4.8.3	Pet Litter Control	$0	$0	N/A		X	—	—	—	—	—	X	—	—	Self-sustaining through enforcement (fines)
4.8.4	Residential and On-Site Sewage Systems Management	$10,000 - $20,000	$40 - $60	system		X	—	—	—	—	—	X	—	—	
4.8.5	Stormwater Disinfection	$1.3 mil - $5.3 mil	$58,700 - $65,400	each	X	X	—	X	—	—	—	X	—	—	Debris is removed to improve disinfection
4.8.6	Waterfowl Control Measures	$190	$0	acre served	X	X	—	—	—	—	—	X	—	—	Cost for one application
Debris															
4.9.1	Debris / Trash Management (Litter Control)	$0	$5,170,000	MMSD planning area	X	X	—	X	—	—	—	—	—	—	Cost based on a California estimate to comply with their trash TMDL
4.9.2	End of Pipe Outfall Nets	$107,000 - $427,000	$37,700-$109,100	system	X	X	—	X	—	—	—	—	—	—	
4.9.3	End of Pipe Outfall Booms	$142,000 - $214,000	$1,200	each	X	X	—	X	—	—	—	—	—	X	Can also be used to remove oil and grease
4.9.4	End of Pipe Vortex Separators	$19,200	$1,050	each (3 cfs)[5]	X	X	—	X	X	X	X	—	X	—	
4.9.5	Skimmer Boat Operation	$420,000 - $1,000,000	$108,000	vessel	X	X	—	X	—	—	—	—	—	—	
Other															
4.10.1	Convert Land to Prairie (Habitat)	$860 - $210,300	$55 - $1,600	acre	X	X	—	—	X	X	X	—	—	X	Other potential benefits include aesthetics, habitat and sustainability
4.10.2	Convert Land to Wetlands (Habitat)	$4,000 - $230,000	$555 - $100,500	acre	X	X	X	—	X	X	X	—	—	X	Other potential benefits include aesthetics, habitat and sustainability
4.10.3	Fertilizer Management (Nutrients)	$0	$0	N/A	X		—	—	—	X	X	—	—	—	Program would pay for itself in fertilizer cost savings
4.10.4	LEED Development (Alternative Development Practices)	$2 - $3	($18) - ($25)	square foot	X	X	X	—	X	—	—	—	—	X	Negative annual O&M cost indicates a cost savings. Primary benefit is sustainability
4.10.5	Road Salt Management (Chloride Reduction)	$30 - $500	$90 - $1500	lane mile	X		—	—	—	—	—	—	—	X	Costs reflect estimated increases to salt only applications. Costs assume about 14 applications per lane mile per year and 25% of cost is capital and 75% is O&M. Reduces chlorides in receiving waters
4.10.6	Water Softener Salt Alternative (Chloride Reduction)	$0	$0	each	N/A	N/A	—	—	—	—	—	—	—	X	Reduces chlorides in receiving waters

1. Please see chapter text for more complete information on how well each technology addresses the indicators
2. "—" means technology does not address constituent
3. "acre" means footprint of the technology, "acre served" means area tributary to the technology
4. "OTHER" may include habitat, aesthetics, sustainability, temperature or toxicants
5. cfs = cubic feet per second

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TABLE 4-1 SHEET 2 OF 2

SUMMARY OF NONPOINT SOURCE POLLUTION CONTROL TECHNOLOGIES

2020 STATE OF THE ART REPORT

4.5 Chapter Outline

Most of the technologies included in this chapter passed through the screening process described in Chapter 2, *Technology / Indicator Analysis*. Some technologies were added as the planning effort proceeded because new information was discovered or a particular need for the technology was identified. These additional technologies did not go through the screening process described in Chapter 2. The technologies are organized as shown in the outline below.

TABLE 4-2
OUTLINE OF CHAPTER 4 TECHNOLOGIES

Section	Indicator	Subsection / Technologies
4.6	Volume	4.6.1 Bioretention
		4.6.2 Cistern
		4.6.3 Downspout Disconnection
		4.6.4 Green Roofs
		4.6.5 Parking Lot Stormwater Storage and Treatment (Green Parking Lots)
		4.6.6 Porous Pavement
		4.6.7 Rain Barrels
		4.6.8 Rain Gardens
		4.6.9 Stormwater Parks
		4.6.10 Stormwater Trees
4.7	Total Suspended Solids (TSS)	4.7.1 Agricultural Bench Terraces
		4.7.2 Agricultural Buffer Strips
		4.7.3 Catch Basin Cleaning
		4.7.4 Catch Basin Filter
		4.7.5 Conservation Crop Rotation
		4.7.6 Constructed Wetland
		4.7.7 Fine Screens
		4.7.8 Infiltration Basin
		4.7.9 Riparian Corridors/Buffers
		4.7.10 Stormwater Filtration Systems (Sand Filters)
		4.7.11 Street Sweeping
		4.7.12 Wet Detention Basin
4.8	Fecal Coliform	4.8.1 Livestock Management
		4.8.2 Manure Management
		4.8.3 Pet Litter Control
		4.8.4 Residential and On-Site Sewage Systems Management
		4.8.5 Stormwater Disinfection
		4.8.6 Waterfowl Control Measures
4.9	Debris	4.9.1 Debris / Trash Management (Litter Control)
		4.9.2 End of Pipe Outfall Nets
		4.9.3 End of Pipe Outfall Booms
		4.9.4 End of Pipe Vortex Separators
		4.9.5 Skimmer Boat Operation
4.10	Other Indicators	4.10.1 Convert Land to Prairie (Habitat)
		4.10.2 Convert Land to Wetlands (Habitat)
		4.10.3 Fertilizer Management (Nutrients)
		4.10.4 Leadership in Energy and Environmental Design (LEED) (Alternative Development Practices)
		4.10.5 Road Salt Management (Chloride Reduction)
		4.10.6 Water Softener Salt Alternative (Chloride Reduction)

4.6 Volume Indicator

For the purposes of this *State of the Art Report* (SOAR) analysis, the volume indicator refers to the reduction of separate sewer overflows (SSOs) and combined sewer overflows (CSOs). Nonpoint source technologies can help reduce SSO and CSO volume by reducing the volume of stormwater that will ultimately reach a separate or combined sewer system. Nonpoint source technologies that reduce the volume indicator by infiltrating stormwater should not be installed over sanitary sewer laterals due to the increased potential for infiltration into the sewer system. The volume indicator can also be effectively reduced by delaying runoff, which can reduce the peak volume.

Several of the nonpoint source technologies described in this section, including bioretention and porous pavement, can also be used to reduce other indicators, such as total suspended solids (TSS), phosphorus and metals. In addition, many of these technologies can be used to help meet runoff volume and TSS reduction requirements outside of the combined sewer service area.

4.6.1 Bioretention

Description

A bioretention area is an engineered system designed to use vegetation to filter and infiltrate stormwater runoff from an impervious area, such as a parking lot or roadway.(4,5) A bioretention system has water ponded for only a short period of time while the water infiltrates through a soil layer. Bioretention areas are applicable within the Milwaukee area and are generally accepted stormwater treatment practices.

A bioretention system typically consists of a grass buffer to reduce flow velocity and collect larger particulate, a sand bed to distribute the flow across the bioretention area, a ponding area for temporary stormwater storage typically depressed about six inches, an organic or mulch layer, and a planting soil area. The stormwater collects in the ponding area of the basin where it either evaporates or infiltrates into the mulch and planting soil layers and then into the underlying natural soils.(6) If the natural soils are impermeable, an underdrain layer or overflow system may be necessary.

Plant selection for a bioretention area focuses on native species that can withstand the varying wet and dry conditions and are tolerant to pollutant loadings.(7) The plantings should resemble a terrestrial forest community that includes trees, shrubs, and herbaceous groundcovers.

Design Factors

Bioretention areas are generally better suited for smaller sites.(8) Bioretention design factors include soil conditions for infiltration.(9) Subsoils in the Milwaukee area are generally clayey, which could reduce the infiltration outside of the planting soil bed and may require the use of a sand bed or underdrain system. Bioretention systems should typically not be sited in areas where the existing water table is within six feet of the surface or where the surface has a slope greater than 20%. Use of a clay or synthetic liner and an underdrain system may allow a bioretention system to be used in areas where the water table is within six feet of the surface. To avoid groundwater contamination, the botton of the bioretention should never intersect the groundwater table.(10) The size of the bioretention area should be 5-7% of the drainage area multiplied by the rational method runoff coefficient.

Bioretention maintenance includes inspection and maintenance of vegetation, removal of litter and debris, and mulch replacement.

Experience

At the Miller Brewing Company facility in Milwaukee, a rain garden and bioretention swale was constructed in 2004. This facility captures, slows and treats overland flow from a one-acre parking lot. Stormwater that runs off the lot ponds over engineered soil designed to promote infiltration, filter out pollutants, and store rainwater. The garden is designed to store approximately 60,000 gallons of stormwater.

The Milwaukee Department of Public Works constructed the first phase of a two-phased bioretention facility in the Menomonee Valley in 2006. Construction of the second phase will be completed as additional development occurs in the Valley. The entire facility will treat runoff from approximately 74 acres. It will be approximately 4.5 acres in size, 1.5 feet deep, and vegetated with wetland-type plants. The facility is designed to achieve a minimum 80% reduction in TSS from its tributary drainage area. Treated stormwater will be discharged to the Menomonee River.(11)

Effectiveness

Bioretention systems are considered to be a stormwater treatment and volume reduction practice.(12) They are most effective in capturing flow from smaller storms.(13). The systems can be designed to increase groundwater recharge potential. The following pollutant removal effectiveness percentages for filtering practices including bioretention have been achieved: (14)

- Total suspended solids: 86%
- Total nitrogen: 49%
- Total Phosphorus: 65%
- Total Lead: 88%
- Zinc: 95%
- Copper: 97%

Costs

Installation costs for bioretention areas range from $16,150 to $37,000 per acre drained. It is important to consider that the bioretention costs replace typical landscape costs for newly developed areas. Maintenance costs are expected to be about 2% of the construction cost per year, or $320 to $740, which is about equal to regular landscape costs.[1]

[1] Note: All costs presented in this chapter are escalated using the Engineering News Record Construction Cost Index (ENR-CCI), which was projected to be 10,000 in 2007, unless indicated otherwise.

4.6.2 Cistern

Description

A cistern is a large aboveground or underground tank that collects and stores stormwater runoff. Cisterns are typically used with gutters to collect stormwater from a roof area. Underground cisterns are also used to collect stormwater from additional surface areas. The water collected in the cistern may be used for landscape watering, household washing and mopping and agriculture and livestock uses. A cistern may also be used as a storage tank to reduce peak runoff rates during storm events. Cisterns can be retrofit into existing communities and require little space. Storing rainwater on-site for later use provides opportunities for water conservation and lower water utility costs.

The components of a cistern system typically include a catchment area (roof or ground) from which the stormwater runoff is collected.(15) The following components are also included: gutters, downspouts, and pipes to convey the water to the cistern; a purification/filter system such as leaf screens and roof washers (a length of pipe that stores the initial flush of water) to remove contaminants and debris such as leaves, dust, and bird droppings; the storage cistern or tank, which can be constructed out of wood, metal, or plastic; and a distribution system for delivery of the stored water either by gravity or pumps.(16)

Design Factors

Cisterns vary in size depending on the catchment area. They typically range in size from 200 gallons to 6,500 gallons, but can be as large as 10,000 gallons and can be used in combinations.(17) Underground cisterns can accommodate runoff from the ground surface because the site can be graded to drain to the cistern without pumping. However, underground installations cost almost twice as much as an aboveground installation.

The volume of stormwater that is stored in the system must be regulated to ensure capacity for future storms. The stored water must either be used or drained to a local storm sewer during non-peak flow times.

The cistern system should be inspected and maintained bi-annually to remove sediment accumulation and to check for system leaks.(18)

Local plumbing ordinances should be reviewed prior to installing underground cisterns or when planning to use the stored water as household gray water.

Experience

Cisterns have been used for centuries to collect stormwater runoff for household, landscape, livestock, and agricultural uses. The use of cisterns for runoff management is a relatively new concept. Cisterns were considered in the Vineyard Terrace Low Impact Development in Milwaukee. The Vineyard Terrace project also analyzed a cistern/rain garden combination system to increase storage capacity, provide infiltration and provide sediment removal.(19)

The newly constructed headquarters of the Chesapeake Bay Foundation in Annapolis, Maryland includes a cistern catchment system. The system captures rainwater for reuse in fire suppression, hand washing, mop sinks, the climate control system, and washing equipment.(20)

In Milwaukee, cisterns are planned to be used in conjunction with other stormwater management practices to manage stormwater at the Community Market Gardens at the Walnut Way

Conservation Corps. Two 500-gallon cisterns are scheduled to be installed in 2006 and will capture runoff from residential homes.

Effectiveness

A modeling analysis of cistern storage of residential rooftop runoff by MMSD found that a properly maintained 200-gallon cistern could capture 8,200 gallons per year.(21)

The Vineyard Terrace analysis found that the rain garden/cistern system was a viable option to meet MMSD Chapter 13 requirements; however, the developer did not implement the systems due to project schedule restraints.(22)

Costs

The installation costs for a cistern system range from $500 for a 200-gallon aboveground cistern to $6,200 for a 6,500-gallon underground cistern.

Operation and maintenance costs for a larger system are expected to be approximately $375 per year.

4.6.3 Downspout Disconnection

Description

This technology involves disconnecting roof downspouts from combined sewers, directing downspouts away from impervious areas such as driveways and roads that provide direct connections to a public stormwater system, and directing them to a storage facility or pervious area for infiltration. Downspouts can be directed to lawns or other vegetated areas, rain barrels or rain gardens. The most important issues to consider are contributing impervious area, soil permeability, slope of the receiving area, and proximity to buildings.(23) This nonpoint source technology is most applicable to residential areas where there is a sufficient pervious surface, but also has application in commercial and light industrial areas.(24)

Design Factors

In general, disconnecting downspouts may be viable for lot sizes of 6,000 square feet or larger. Downspout disconnection is most approprate for external downspouts; downspouts that are internally routed through a building will be more difficult to disconnect. The ground must slope away from the foundation of the building. The discharge must flow away from the building over a pervious surface, and not over sidewalks or driveways, nor onto an adjacent property. The discharge point must extend at least 5 to 10 feet from the foundation.

Experience

Downspout disconnection programs are being implemented in many cities across the United States and Canada, including: Toronto, Ontario; Vancouver, B.C.; Washington D.C.; Dearborn, Michigan; Fort Wayne, Indiana; Boston, Massachusetts; and Portland, Oregon. Shaker Heights, Ohio requires downspout disconnection as part of its stormwater ordinance.

In 2005 and 2006, hundreds of downspouts were disconnected in the combined sewer areas of Milwaukee and Shorewood. An analysis conducted by MMSD showed that a 12% to 38% reduction in runoff volume for each lot could be attained when disconnected downspouts were redirected to pervious areas and/or used in conjunction with rain gardens and rain barrels.(25)

Effectiveness

For every inch of rainfall that falls on a roof area of 1,500 square feet, approximately 935 gallons of stormwater runs off. Disconnecting downspouts that are directly connected to the sewer or redirecting downspouts from impervious surfaces to pervious areas provides an opportunity for this stormwater to infiltrate into the ground. A 1996 modeling analysis conducted for Detroit showed that a citywide implementation of residential downspout disconnection could potentially reduce wet weather runoff volume by 5,056 million gallons per year and may reduce the annual volume of CSO by about 2,000 million gallons. The reduction is based on a 40-44% reduction in directly connected impervious areas.(26)

Costs

The cost of downspout disconnection varies widely depending on the complexity of the disconnection. However, for a simple disconnection to a pervious area, costs for extensions, elbows, and splash pads usually run $14-28 per disconnection.(27) Detroit disconnected 577 downspouts at a cost of $387 to $443 per downspout.(28) In Shorewood, bids from private contractors to disconnect downspouts ranged from $38 to $169 per downspout.(29)

4.6.4 Green Roofs

Description

Vegetative roof covers or green roofs consist of soil and vegetation installed on top of a conventional, flat or slightly sloped roof.(30) There are two systems of green roofs – extensive (typically modular systems) and intensive (also referred to as built in place). They are both generally composed of the same system of layers, which includes the vegetation, growing medium, filter fabric, a drainage layer, a root barrier and a waterproof membrane. Extensive systems are lighter, typically have four inches or less of growing medium, use drought tolerant vegetation, and can structurally support limited uses, such as pedestrian traffic. Intensive systems are heavier, have a greater soil depth, can support a wider range of plants, and can support increased pedestrian traffic. Rainfall is intercepted by the vegetation, soaks into the growing medium and is absorbed by plant roots. Any remaining water filters through the growing medium and is drained away from the roof's surface by the drainage layer.(31)

Design Factors

Green roof systems can be incorporated into new building designs or installed on existing buildings. Installations for existing buildings require an appropriate structural analysis and may require additional structural support. Extensive (modular) systems, when saturated with water, can add 5 to 17 pounds per square foot.(32) Intensive (built in place) systems can add about 40 to 100 pounds per square foot.(33) A waterproofing layer is important for most installations as well, because typical roofs are not designed to withstand hydrostatic pressure.(34) Green roof systems may be modular, with drainage layers, filter fabric, growing medium and plants already prepared in movable, interlocking grids, which decreases installation time; or, each component of the system may be installed separately.(35) Vegetation should be well-adapted to the growing conditions of the area where it is installed. Maintenance includes a limited amount of irrigation and periodic fertilization and weeding.

Experience

Green roofs have been used extensively in Europe and there has been an increase in installations in the United States.(36) Some examples of local installations of green roofs are MMSD headquarters, the Great Lakes WATER Institute and the Karen Peck Katz Conservation Education Center at the Milwaukee County Zoo.

Effectiveness

Green roofs can be an effective technology to reduce and delay urban stormwater runoff by storing it on the building roofs and promoting evapotranspiration. An MMSD model simulation of green roofs showed it would be possible to reduce the average annual discharge volume contributed by a 5.9-acre commercial lot in the combined sewer service area (CSSA) by 22%, using historical meteorological data from 1995-2002.(37) The Low Impact Development (LID) Literature Review performed by the USEPA states that simple vegetated roof covers with approximately 3-inches of substrate can reduce annual runoff by more than 50% in temperate climates. Properly designed systems not only reduce runoff flows from new buildings, but also can be added to existing rooftops without additional reinforcement or structural design requirements. The value of green roofs for reducing runoff is directly linked to the design rainfall event considered. The green roof should be designed for storm events that most significantly contribute to CSOs, hydraulic overloads, and runoff problems for a given area.(38)

In addition to runoff reduction, green roofs contribute to overall sustainability by reducing building energy needs, minimizing urban heat island effects, and conserving land area that would typically be used for traditional stormwater management facilities.(39)

A study of runoff quality from two green roofs in North Carolina indicated that nitrogen and phosphorus can leach out of the organic matter present in the growing medium. This study points out that the receiving water limitations should be considered when selecting the soil media composition.(40)

Costs

The costs for a green roof vary considerably because of the variety of options and styles available. Typical costs range from about \$5 to \$25 per square foot.(41,42) Maintenance costs are assumed to be about 5% of the capital cost. Research in Germany shows that the 3-inch design offers the highest benefit to cost ratio.(43)

4.6.5 Parking Lot Stormwater Storage and Treatment (Green Parking Lots)

Description

Parking lot stormwater storage and treatment systems, also called green parking lots, are designed to reduce the impervious area and reduce the volume of stormwater runoff from the lot. Practices that may be used include the following:

- Reduce the size of the parking lot by reducing the number of parking spaces and/or minimizing the dimensions of the spaces
- Construct bioretention systems, grassed swales, or infilatration systems to treat the runoff
- Plant stormwater trees to treat runoff and provide shading and cooling

- Install porous pavements for low traffic or overflow parking areas
- Detain stormwater on the surface of the parking lot by using inlet restrictors and contouring the parking lot to temporarily pond stormwater
- Install underground storage vaults
- Encourage shared parking and provide economic incentives for multi-level parking structures

The practices can be applied to new development as well as redevelopment projects.(44)

Several of these practices (bioretention, stormwater trees and porous pavement) are discussed in detail in other sections of this chapter. Application of green parking lot practices are most common in commercial, industrial, and multifamily land uses, and are most successful in low traffic, light use lots.

The benefits of green parking lots include reduction of impervious cover, reduction of stormwater runoff and peak discharge, pollutant removal, improved aesthetics, and groundwater recharge.(45)

Design Factors

Design factors will vary depending on the system used and may include soil conditions, depth to groundwater, and traffic load.

The infiltration rate of the soil may limit the effectiveness of infiltration systems or require the use of a constructed infiltration/storage bed beneath porous pavements.

Surface storage areas should have a minimum slope of 0.5% toward the outlet to ensure complete drainage.

Parking lot surface storage should not be used in fire lanes or other emergency vehicle routes.

Maintenance is required for bioretention, porous pavement, and stormwater tree components of a green parking lot.

Experience

A “green parking” lot at the Oregon Museum of Science and Industry in Portland, Oregon was designed with seven bioswales to filter runoff from the parking lot before it enters the Williamette River. This project provides water quality treatment as well as runoff reduction, does not have problems with standing water, and saved $78,000 as compared with a conventional parking lot.(46)

The California cities of Sacramento, Davis and Los Angeles have implemented parking lot shading ordinances that require 50% of the total paved area to be shaded within 15 years of the issuance of development permits.(47)

Porous pavements have been used since the 1980s, and porous asphalt and concrete demonstration projects are underway in the Milwaukee area.(48) In 2004, MMSD installed an area of porous asphalt in its parking lot to study its effectiveness and to see how the pavement stands up to the freeze/thaw cycle of Wisconsin winters and snow plows. MMSD also installed a trench drain through a portion of the parking lot that leads to constructed wetlands.(49)

Effectiveness

Parking lot storage and treatment practices (green parking lots) can reduce imperviousness, runoff volume and peak flows depending on the practices selected.(50) Other pollutants, such as TSS, debris, nitrogen, phosphorous and metals can also be reduced by green parking lots.

Costs

Costs for bioretention, stormwater trees, and porous pavement are presented in other sections of this chapter. The Seattle Department of Planning and Development compared the costs of a conventional parking lot to the cost of a green parking lot incorporating porous pavement, pavers, rain gardens, and swales.(51) The design was for a 15-acre commercial parking lot. The costs are shown in Table 4-3:

TABLE 4-3
PARKING LOT COST COMPARISON

	Conventional Design	Green Parking Option Design
Total Capital Costs	$ 7,150,000	$ 6,820,000
Maintenance Costs ($/yr.) *(includes sweeping, landscaping, and water quality filters or swales)*	74,790	66,125

Note:
All costs are escalated using the Engineering News Record Construction Cost Index (ENR-CCI), which was projected to be 10,000 in 2007.

Source: City of Seattle Department of Planning & Development, DPD Client Assistance Memo # 515 - Green Parking Lots

4.6.6 Porous Pavement

Description

Porous pavement is a pavement surface that is permeable, allowing stormwater and snow melt to pass through and infiltrate into the ground surface below the pavement rather than running off the site. The pavement surface may be porous concrete or porous asphalt, or it may be a paver system consisting of paving blocks or paving grids. Porous pavement can reduce the volume of stormwater runoff from paved areas, provide filtering of pollutants, reduce the need and cost of curbing and storm sewer, improve road safety due to better skid resistance, and recharge local aquifers.

The concrete and asphalt pavement surfaces resemble traditional pavement except there are more void spaces to allow the water to pass. The void spaces can range from 14-25% of the total pavement mix volume.(52) Porous asphalt pavement consists of an open-graded course aggregate bonded together by asphalt cement. Pervious concrete consists of a special mix of Portland cement, open-graded coarse aggregate, and water.

There are three general types of pavers: grass, gravel, and concrete block. Grass pavers may consist of a plastic ring grid that is filled with sand and topsoil in which grass is grown. The grid prevents compaction while the vegetation area provides infiltration and filtration of the stormwater runoff. Similarly, gravel pavers may consist of a plastic grid structure filled with gravel. The gravel-filled grid provides greater support for heavier or more frequent loads. Interlocking concrete paving blocks are precast concrete blocks that fit together in a pattern that typically has about 10% open surface for drainage. The drainage areas are filled with permeable materials to allow for infiltration of stormwater runoff. Of these alternatives, the concrete paving blocks can support the greatest loads.

Porous pavement systems consist of a porous pavement layer underlain with a layer of highly permeable stone or gravel, which serves as a storage reservoir for the water until it can infiltrate into the natural soils. Filter fabric is placed below the stone layer. Some porous pavement systems may include perforated piping or other drainage systems to provide drainage for the stone reservoir.

Design Factors

Porous pavement is ideally suited for low traffic areas and overflow parking areas.(53,54) It is generally not recommended for 1) high volume traffic areas because it is generally more susceptible to wear, 2) traffic surfaces with a slope greater than 5%, or 3) areas that will be sanded during winter months. Due to the water infiltration, porous pavement should not be used in areas where significant stormwater contamination could occur, such as at gas stations or chemical plants.(55) It should be located at least two to five feet above the seasonally high groundwater table, and at least 100 feet away from drinking water wells.(56)

Underlying soils should have a permeability rate between 0.5 and 3.0 inches per hour. A drainage system may be desired in less permeable soils. The subgrade should not be compacted. The bottom of the stone reservoir should be completely flat so that infiltrated runoff will be able to infiltrate through the entire surface. Perforated pipes along the bottom of the reservoir may be used to evenly distribute runoff over the entire bed bottom.

The size of the stone reservoir should be appropriate for the storm to be treated. The reservoirs are typically sized to handle the increased volume from a 2-year design storm, but it should be able to covey and mitigate the peak of less frequent, more intense storms. The reservoir should extend below the frost depth to reduce the effect of frost heave. A non-woven textile should be used to line the reservoir. Porous pavement systems should be designed with an overflow system.

Porous pavements can clog; therefore, upland areas should be stabilized prior to installation of the porous pavement and regular maintenance must be performed.(57) Maintenance should include quarterly vacuum sweeping followed by high pressure hosing to open voids in the top layer that may be clogged.(58) Regular inspections of the pavement area should be conducted after storm events to observe ponding, which indicates clogging. Monthly inspections should be conducted to ensure that the pavement is clean of debris and sediment.

Paver systems may require additional maintenance, including replacement of necessary aggregate on a quarterly basis, replacement of damaged pavers, and regular mowing and possible watering of grass pavers.(59) Snow removal can be conducted on the paved surfaces by raising the blade of the plow slightly to clear vegetation and paver corners. The use of salt, sand, and ash is not recommended for ice control on a paver system due to potential contamination and clogging.(60)

Some studies have indicated maintenance challenges in cold climate regions. However, other studies indicate the performance is not limited as long as appropriate maintenance measures are taken.

Experience

Porous pavement has been installed and studied across the United States. Locally, a half-acre pervious concrete parking lot was installed for a retail development in Oak Creek, Wisconsin. The lot was installed during the fall of 2003 as an alternative to conventional aboveground or underground stormwater detention. In addition, a 0.8 acre porous pavement parking lot was installed at the Milwaukee School of Engineering (MSOE). One-third of the MSOE lot is comprised of pervious concrete and two-thirds of the lot is comprised of pervious asphalt.(61)

With proper design features to reduce frost heave, porous pavement has been successfully used in cold climates.(62) The pavement has been used for over a decade in Norway, and studies suggest that snow melts faster on porous pavement.(63) Porous pavement in Sweden was found to be more resistent to freezing and frost heave than comparable impervious pavement.(64) During the winter, the pavement reduced snowmelt runoff, avoided excessive water on the road surface during the snowmelt period and recharged the groundwater. However, another study found that at the freezing point, the infiltration capacity of porous asphalt was about 50% of the infiltration capacity at 68°F (20°C).(65) Cahill & Associates has developed several dozen large, successful porous pavement installations; some installations are over 20 years old.(66)

Effectiveness

Porous pavement is an effective practice to provide groundwater recharge and stormwater pollutant removal. Pollutants are typically captured within the paver system or in the upper surface soils. Data suggest that 70-80% of annual rainfall will infiltrate. Pollutant removal data are limited, but suggest the following pollutant removal efficiency:

- Total suspended solids: 95%
- Total phosphorus: 65%
- Total nitrogen: 82%
- Metals: 98%

Costs

The cost of porous asphalt and concrete can fluctuate depending on the size of the application, but is expected to range between \$2.50 and \$5.00 per square foot (about \$108,900 and \$217,800 per acre). Plastic paver grid systems, filled with gravel, soil or grass, are estimated to cost \$4.00 per square foot (about \$174,300 per acre).(67) Concrete interlocking pavers are estimated to cost \$5 per square foot (about \$217,800). These costs are typically higher than conventional pavement surfaces, which are about \$2.50 per square foot (about \$108,900 per acre).(68,69) Maintenance costs vary depending on the type of pavement used. The annual cost for vacuum sweeping is about \$400 per acre, assuming quarterly sweeping.(70) However, the porous pavement can reduce or eliminate the need for traditional drainage and stormwater management facilities such as detention ponds, which can result in overall cost savings.

4.6.7 Rain Barrels

Description

A rain barrel is a container that collects and stores rainwater from a roof catchment area. The barrels typically hold 50 to 100 gallons and can be constructed from plastic or wood. The collected water can be used for lawn or garden watering or other outside water uses. The barrel is typically placed at a downspout location to capture water that would otherwise be directed to a storm or combined sewer.(71) The collected water can be used during dry weather, which allows for the water to infiltrate into the ground and reduce runoff into either the storm or combined sewer system.

The components of a rain barrel system include the roof catchment area and collection piping, gutters and downspouts, a collection barrel with a cover and screening for child protection and particulate and pest control, and piping for distribution of the water and overflow protection. To allow for greater capacity, barrels can be piped together.

The rain water collected is good for plant watering because it is not chlorinated and is mildly acidic, which helps plants take up important minerals from the soils. The use of the collected water reduces the cost of landscape watering.(72)

Design Factors

The barrel should be located in a stable area or on a flat stand to ensure stability when the barrel is being filled and used. The overflow should be directed away from building foundations.

Climate, algae and mosquito control, physical site suitability, and homeowner ability and willingness to operate the rain barrel effectively should be considered before employing this practice.

Rain barrels should be disconnected during winter months to avoid damage from freezing.

Experience

Rain barrels have been used for centuries to collect rainwater. Rain barrel programs are being implemented across the United States including Portland, Oregon; Dearborn, Michigan; Fort Wayne, Indiana; Seattle, Washington; and Boston, Massachusetts. Rain barrel programs are also being implemented in Southeastern Wisconsin.

In 2004, Milwaukee installed rain barrels at public housing residences. Over 100 downspouts were disconnected and nearly 200 rain barrels were installed.

Effectiveness

A rain barrel provides storage of 50 to 100 gallons of water.(73) An MMSD simulation that used meteorological data from 1995-2002 showed it would be possible to reduce the average annual discharge volume contributed by a 5-acre residential block in the CSSA by 14%. The similation assumed each residential property in the combined sewer service area had two 55-gallon rain barrels collecting rooftop runoff and were properly discharged to the lawns. The analysis also assumed all of the rain barrels overflowed onto lawns if their capacities were exceeded. It should be noted the analysis also showed rain barrels may actually increase CSO volumes during certain rainfall events due to the timing of peak rainfall and the attenuation and delay caused by overland flow, which can result in coincident runoff peaks from various areas.(74) This situation can occur as a result of any storage practice and is not unique to rain barrels.

A 1999 study for Toronto indicates that, although rain barrels are not likely to reduce CSOs, they can reduce volume and peak discharge from frequent storms.(75)

Costs

The cost for a rain barrel ranges between $50 and $250 for self-built and commercially available barrels, respectively.(76) Annual maintenance may involve minor repairs to fix leaks and is estimated to cost about 5% of the capital cost, or $2.50 to $12.50.

4.6.8 Rain Gardens

Description

A rain garden is a small, vegetated, recessed area designed to capture stormwater runoff and promote infiltration and evapotranspiration.(77) Rain gardens are typically smaller and less complex than bioretention facilities. The garden should be located where roof runoff and/or site runoff can be directed into it. The garden is typically vegetated with hardy native plants with extensive root systems that can take up large amounts of water. A rain garden can infiltrate up to 30% more water than a conventional lawn.(78) Rain gardens can easily be added to existing green spaces to improve the infiltration and reduce site stormwater runoff. Rain garden size is variable depending on the drainage area and underlying soils. The center of the garden area is typically recessed between four and eight inches. The stormwater will pond in the recessed area for a short period of time to allow for infiltration. A permanent pool of water will not be present in the rain garden. The rain garden can provide improved habitat for birds, butterflies, and other insects.

The components of a rain garden system include a drainage way into the garden area that can be piped by a downspout extension or channeled in a shallow swale, the garden infiltration area, a drainage layer if natural soils have low permeability and, if necessary, an overflow.

Rain gardens are best suited for well-drained soils. Placement of a drainage layer of well drained soils can aid in infiltration in soils with low permeability.

Design Factors

Rain gardens should be located a minimum of 10 feet away from a structure to prevent water damage.(79)

The size of the garden should be 10-35% of the drainage area, depending on the existing soil types. More permeable soils require less area to infiltrate the stormwater runoff. The ponding depth should be six inches or less. The ponding should not exceed 72 hours.

Rain garden maintenance includes cutting the plants back to a height of about six inches in the spring of each year. Regular weeding may be necessary during the first few years until the native plants are established.(80) The plants will likely require additional watering during the first year. Once the plantings are established, watering should not be necessary.

Experience

Rain garden programs are popular in Wisconsin, Minnesota, and Maryland. Prince Georges County in Maryland has experimented with rain gardens since 1990 and has worked with several communities to implement rain garden programs.

Edgewood College in Madison, Wisconsin initiated a program to design and construct rain gardens on the Edgewood campus as part of the Lake Wingra Watershed Management Program.

Rain gardens were installed at seven Automobile Recyclers Cooperation Compliance Program member sites in the Milwaukee area. Rain gardens were also installed at the Urban Ecology Center and at the Alterra Coffee Roasters Shop on North Lake Drive. Each rain garden was designed to receive runoff from the roof of an adjacent building.

In Shorewood, 48 rain gardens were constructed on residential properties in 2005. Two larger rain gardens were constructed at the Shorewood Library Village Center and at Atwater School.

Effectiveness

A rain garden can infiltrate 30% more water than a conventional lawn area. Pollutant removal effectiveness is expected to be similar to a bioretention system. The following removal rates are indicated for rain gardens in available literature: (81)

- Total suspended solids: 85%
- Total Phosphorus: 85%
- Nitrate: 30%

Costs

The cost for construction of the rain gardens installed for the Shorewood Wet Weather Flow Volume and Peak Management Project were $25 per square foot .(82) Annual maintenance costs are estimated to be about 5% of the construction cost, or about $1.25 per square foot.

4.6.9 Stormwater Parks

Description

Stormwater parks are an aesthetically pleasing means of providing detention and treatment for stormwater runoff through various chosen treatment elements. One such park has been developed to aid in the treatment of the Milwaukee Road Shops site (formerly CMC rail shops) in the Menomonee Valley. As stated, any variety of treatment methods can be used in a stormwater park; some of the elements used in the Shops stormwater park are: sedimentation basin forebays, treatment wetlands, natural vegetated infiltration areas, vegetated areas of detention, and swamp forests. These elements used in concert can provide greater than 80% TSS removal and can remove over half the phosphorus, nitrogen and hydrocarbons from the stormwater runoff captured. The elements can also capture debris that is carried away by stormwater runoff before it is deposited into a waterway.

The selected method(s) of treatment will determine the level of compliance with quantity and quality requirements. Stormwater parks can be designed to address site specific concerns and use native vegetative plantings. The size of the park is a site specific variable that should be considered when addressing site requirements.

Design Factors

The vegetation within the park needs to be maintained through grooming and continued monitoring of undesired species. Vegetation needs to be established prior to active use of the stormwater park to effectively provide the designed levels of treatment.

The soils under the stormwater park must be factored into the design. Groundwater levels and infiltration rates may play a deciding role in the treatment methods used and even the location of the park itself.

Experience

While the idea of combining treatment elements with impervious areas and native vegetation for an aesthetically pleasing method of controlling stormwater may be relatively new, the treatment elements within the park are common BMPs. The park is in essence using several well established BMPs in series to treat the stormwater runoff; this is also known as a treatment train. The concept of a treatment train has been widely used successfully as a method of stormwater treatment.

As mentioned above, there is a stormwater park in Milwaukee at the Milwaukee Road Shops site (formerly CMC rail shops) on the western edge of the Menomonee Valley. Milwaukee joined with the Sixteenth Street Community Health Center, Menomonee Valley Partners, the University of Wisconsin-Milwaukee, and MMSD to develop the facility, which was created to filter stormwater runoff from a 100-acre business park

Effectiveness

The effectiveness of a stormwater park depends on the implemented treatment elements. At this writing, the Shops stormwater park had not yet been completed, so effectiveness of pollutant reduction from this site was not available.

Costs

Stormwater parks can vary greatly to meet the needs of the area they treat. As a result, the capital and maintenance costs will vary greatly as well. The construction cost for the stormwater park in the Menomonee Valley is approximately $22,750 per acre served, which does not include the costs for several added amenities such as overlooks, soccer fields and special retaining walls.(83) Annual maintenance costs are estimated to be about 3% to 5% of the construction cost, or about $700 to $1,100 per acre served.

4.6.10 Stormwater Trees

Description

Stormwater trees are certain tree species that use large amounts of water. The trees are planted in urban areas to reduce the rate and quantity of stormwater runoff. The trees help to manage stormwater flow by intercepting the rainfall and slowing the rate at which it falls to and runs over the ground surface.(84) The slower flow rate allows for increased infiltration into the soil and reduced runoff. A 40% canopy cover is the goal identified by the USEPA. Individual trees may be planted using tree pits, tree box filters, or stormwater planters. These planters are specially designed to increase infiltration and promote healthy trees.

Runoff reduction from stormwater trees occurs in the following ways:

- Above the ground by interception of the rain, evaporation, and adsorption into the tree leaves and stems
- At the ground surface where leaf litter and organic matter hold precipitation, and roots and tree trunks create hollows for water to collect
- Below the ground where organic matter from the trees increases the infiltration and absorption ability of the soil; roots break up the soil, thereby improving infiltration and increasing percolation into deeper soils; and water is taken up by the roots

The majority of the reduction occurs below ground in the root uptake. The roots also filter pollutants such as nitrogen, phosphorus, and potassium.

This practice is most effective at reducing peak runoff rates in land uses with large amounts of open space or where stormwater can be directed to and contained near the roots of the trees.(85)

Design Factors

Trees have the greatest effects during the growing season and during smaller storm events.(86) Tree selection should consider the site conditions and use native species to improve establishment and survival of the tree. The minimum weekly water requirements of a tree are estimated at five gallons plus five gallons per caliper inch. In climates where the majority of the rainfall events occur during the summer, such as in southeastern Wisconsin, the use of deciduous trees would be expected to yield the greatest benefit. Trees planted in groves can also increase the amount of rainfall absorbed.

Examples of tree species that work well in southeastern Wisconsin as stormwater trees include White Oak, Red Maple, River Birch and Willow.(87) These trees thrive in southeastern Wisconsin and uptake large amounts of water.

It is important to consider the time it will take newly planted trees to develop the canopy and root system assumed in the design phase. Also, tree mortality issues and potential impacts must be addressed. Leaves should be collected and composted to prevent nutrient loading to waterways.

For siting and costing purposes, the average canopy of a stormwater tree is assumed to be 20 feet in diameter, or about 314 square feet.

When planning the location for stormwater trees, one must consider potential damage the roots may cause on nearby paved areas and sewers and the amount of debris each type of tree will produce. For example, river birch and willow are typically not prescribed for urban street settings because their roots can clog sewers and laterals. Also, willows generate a lot of debris throughout the year that can clog storm sewer inlets.

Maintenance of the trees includes pruning and debris pick-up.

Experience

Milwaukee is working towards "greening" the city. One of the ways they are accomplishing this is by promoting Greening Milwaukee Initiative, which is a non-profit organization dedicated to the development and preservation of trees. The goal of the organization is to increase the tree canopy in the city to 40%.(88) Lexington, Kentucky started a program in 1999 to reforest riparian areas and increase tree canopy. The program, called "Reforest the Bluegrass," is a cooperative effort between the Lexington-Fayette Urban County Government's Water Quality, Urban Forestry, and Parks & Recreation management programs. Through early 2006, the program, which relies heavily on volunteers and private funding, has planted over 130,000 tree seedlings.(89)

Effectiveness

The presence of trees in urban areas provides multiple benefits, including improving water quality and reducing runoff volumes. Scientists in Maryland estimated that a deciduous riparian forests took up 69 pounds of nitrogen per acre annually, but returned 55 pounds (80%) each year in the litter. They also reported the forest took up 8.8 pounds/acre/year phosphorus but returned 7 pounds/acre/year (80%) as litter.(90)

The presence of a canopy reduces the heating of urban surfaces and watercourses, reducing the thermal effects of storm events. It also reduces erosion by intercepting some of the energy of rain drops, reducing the energy with which they impact the soil surface. This can help reduce pollutant loads of TP and TSS which can be a function of erosion. The canopy also intercepts a portion of the initial storm rainfall, which reduces stormwater volume from nearly all events and may prevent runoff from smaller events. An analysis completed for MMSD in 2002 estimated that the current canopy cover intercepts 121 million gallons per year, saving $48,400 per year in treatment costs in the CSSA. The same report estimates that an additional annual savings of $145,000 could be gained if the percent canopy cover in the CSSA were increased to 40% from its current level of 10%.(91)

Other analyses reviewed for this report have suggested that the presence of trees would lead to much greater stormwater volume reductions, and include the following:

- In 1996, American Forests conducted an Urban Ecological Analysis for Milwaukee. This analysis indicated the current tree cover in the Milwaukee area, on average, reduces stormwater runoff volume by 5.5% and peak flow by 9.4%. The study also suggests that Milwaukee's urban trees reduce peak runoff flow by an average of 10% and found that in areas of the city with 40% tree cover, the flow was reduced by as much as 22%. (92)
- Another study estimates that a 3.86 acre residential lot with 8% canopy cover provides a 3% reduction in runoff and if the canopy cover is increased to 35%, the runoff reduction increases to almost 13%.(93)

Unfortunately, these analyses all rely on the assumption that the runoff generating characteristics of an area covered by tree canopy are similar to those found in an orchard or a tree farm. In actuality, runoff response, especially for moderate and large storm events, is largely dictated by the infiltration capacity of the land surface. Orchards and tree farms can be expected to have a significantly higher infiltration capacity because their soil is not compacted, they may have relatively deeply rooted grasses and forbs, their relatively undisturbed soil structure will develop pathways to increase inflow into the soil, as will the presence of holes due to animal activity and roots, and they may have an organic layer above the soil which soaks up a portion of the runoff. In contrast, a large portion of the area under the canopy cover in urban areas is impervious, which will not infiltrate stormwater at all, and the rest will tend to be areas of shallow-rooted grass atop compacted subsoils. Once the interception capacity of the canopy is exceeded, the rain will generally fall on urban surfaces that have much lower infiltration capacities than those found in orchards or tree farms. In other words, the assumption that an urban area with tree cover will respond to large storm events in the same way as an orchard or a tree farm will result in a significant underestimate of the stormwater generated. This suggests that the primary stormwater quantity benefit associated with stormwater trees is in the interception of initial rainfall.

Trees do have the potential to transfer water from their root zones to the atmosphere, and in this way they can augment other infiltration practices such as rain gardens. Other practices that provide this function are tree pits, tree box filters and stormwater planters. To be most effective, the trees have to be in an area where water infiltrates the soil, providing a source to transfer to the atmosphere, but is not inundated for periods long enough to cause physiological stress to the tree.

Costs

The cost of trees varies depending on the size, type and quantity of trees used. Greening Milwaukee estimates tree-planting costs for Milwaukee at $50 per tree, and estimates supplies, materials, and volunteer training at $3,100 for 500 trees.(94) Annual maintenance costs are estimated to be about 5% of the cost for each tree, or $2.50 per tree.

4.7 Total Suspended Solids Indicator

The total suspended solids (TSS) indicator relates to the reduction of sediment and other suspended solids contained in stormwater runoff that will ultimately reach a receiving water. Nonpoint source technologies that effectively reduce the total suspended solids indicator typically prevent or reduce erosion, promote sedimentation or capture sediment through filtering practices.

The nonpoint source technologies that could be used to reduce the TSS indicator are described in this section.

4.7.1 Agricultural Bench Terraces

Description

Bench terraces are level steps constructed to follow the contour of a hillside.(95) An earthen embankment separates the steps. The embankment makes a level step along the hillside, which breaks the slope into shorter segments and intercepts the flow of the stormwater runoff. The terrace slows the velocity of the runoff and reduces the potential for erosion. Terracing is best used in areas with a moderate (at least 6%) uniform slope. Terraces can also be designed to temporarily store water allowing for infiltration.(96) Crops are grown on the level steps and the embankments are vegetated with grass.(97)

A bench terrace system consists of the flat, or nearly flat, terrace that is used for cropland; a small vegetated berm that directs the stormwater runoff to a stable drainage way; and an embankment or backslope vegetated for stability. The embankment vegetation also may provide habitat for birds and other animals.

Construction of the terraces is expensive. However, they are considered practical on high-yield land where other erosion control measures have failed. Phasing of terrace construction may be necessary to prioritize construction on the most productive portions of land. Terracing the fields that are dedicated for high-return row crops will allow the maximum erosion protection. Careful scheduling will allow for construction of the terraces that coincides with crop rotation.

Design Factors

The terrace/cropland portion should have a slope of 1:8 or less. The width of the farm equipment, crop type, steepness of the slope, soil type, and rainfall amount should be considered when determining the width of the terrace.

The distance between terraces should be minimized to the extent possible to reduce the potential for erosion. The embankment slope should be approximately 1:2 for clay soils and 1:3 in sandy soils. The embankment length should be based on soil types and terrace loads.

The berm should be designed to control runoff from a 10-year, 24-hour storm.(98) Reserve capacity should be included to account for a loss in volume due to tillage operations. Additional practices may be necessary to prevent sedimentation in the drainage channels.

Regular maintenance of the bench terrace system includes removal of accumulated sediment from drainage channels and around piping. Regular inspections should be conducted to check the embankments for channeling, settling, loss of vegetation, and other signs of erosion.(99)

Experience

Bench terracing is not commonly used in the United States due to the availability of level land for farming operations. Bench terracing is commonly used in other countries where the land availability requires farming on sloped areas.

Effectiveness

The USEPA estimates that a terrace system will reduce phosphorus loadings by 70%, nitrogen by 20%, and sediment by 85%.

Costs

Construction of bench terraces is estimated to be about $5 to $22 per foot, or $36 to $100 per acre served.(100) The Chesapeake Bay project estimated the cost of construction and maintenance of terraces at about $174 per acre per year calculated over a 10-year life span.(101)

4.7.2 Agricultural Buffer Strips

Description

Agricultural buffer strips are narrow strips of perennial herbaceous vegetative cover established across a slope and alternated down the slope with cropped strips.(102) Buffer strips adjacent to waterways, ditches, wetlands, or other environmentally sensitive areas are typically called riparian buffers (riparian corridors/buffers are discussed in more detail in Section 4.7.9 below).

Stormwater flow across and through the buffer area is slowed and evenly distributed by the buffer vegetation.(103) The buffer strips trap sediment, nutrients, and pesticides.(104) They also provide habitat for plants and animals and can help support aquatic communities when adjacent to waterways. Buffer strips located within cropland usually consist of a mixture of grasses and legumes, while riparian buffers consist of trees, shrubs, and grasses.

The health and variety of buffer strip vegetation contributes to the buffer strip effectiveness. Vegetation should have dense top-growth along with a fibrous root system and provide uniform soil coverage throughout the filter area. The buffer should be relatively flat to effectively slow the velocity of the runoff. The buffer will be most effective in pollutant removal if the flow is shallow and uniform rather than in small channels or gullies. In Wisconsin, the filter width generally ranges between 30 and 60 feet and should not be less than 15 feet. In most cases, increasing filter width will result in greater pollutant removal. Buffer strips commonly make up 20-30% of the area of the slope.

For the purposes of this report, buffer strips were considered to be engineered treatment areas maintained to prevent the formation of small channels and gullies as opposed to natural, set-aside areas.

Design Factors

Optimum flow velocity is achieved at less than 3 feet per second and desired depth of flow is 0.5 inches across the surface area. Buffers are not recommended for areas with a slope greater than 10% because the quantity and velocity of the water may overwhelm the buffer area. The state of Wisconsin Conservation Reserve Enhancement Program (CREP) requires that the vegetated buffer have a width between 30 and 150 feet measured from the ordinary high water mark.

Grass should be selected for ease of establishment, ability to create a dense mat, erosion resistance, and water tolerance. Reed canary grass (Phalaris arundinacea), Kentucky bluegrass (Poa pratensis), creeping red fescue (Festuca rubra), chewing red fescue (Restuca rubra ssp. Falax), and other invasive plants should be avoided. Trees should also be avoided in areas adjacent to cropland as they will shade crops and limit their growth. Legumes may be seeded along the grasses to improve soil fertility, but they are not as effective in filtering sediment. If removal of dissolved nitrogen is desired, the minimum buffer width should be 70 feet and the buffer should include 50% deep-rooted vegetation.

Maintenance should include inspections two to three times per year. Weed removal, fertilizer application, and repair of rills and channels should be performed as necessary. The buffer area should be mowed between August 1 and September 1 each year. Cut vegetation should be removed to encourage dense upright growth and to remove nutrients contained in the plant tissue.

The land owner retains ownership of the vegetated buffer and selects the vegetation cover type, within acceptable Natural Resources Conservation Service (NRCS) Conservation Practice Standards.

The vegetated buffers are not used to prevent livestock access to watercourse areas. Fencing should be added to address livestock issues (see Section 4.8.1, *Livestock Management*).(105)

Experience

Buffer strips within crops and along riparian areas have been used throughout Wisconsin.

Effectiveness

Properly installed and maintained buffers can remove 50% or more of the nutrients and pesticides, 60% or more of certain pathogens, 75% or more of the sediment, and up to 95% of the zinc from the area served.(106)

Costs

Installation of an engineered agricultural buffer strip in southeastern Wisconsin, including land rental and incentives, is estimated to cost between $10,000 and $31,000 per acre. Annual maintenance of buffer strips is estimated to be between $150 and $900 per acre.(107,108) Financial assistance for the development of agricultural buffers may be available through various state and federal programs such as CREP.

4.7.3 Catch Basin Cleaning

Description

A catch basin is an inlet to the sewer system constructed with a sump, or a depression. The sump captures sediment and debris before it enters the sewer drainage way. Catch basin cleaning is the removal of the sediment and debris from the sump.(109) Catch basin cleaning is typically conducted with a vacuum truck, although manual cleaning can also be conducted

Catch basins can effectively capture sediment and debris transported in stormwater runoff. However, regular cleaning of the sump is necessary to prevent re-suspension of the sediment.(110) The frequency of the cleaning relates to the effectiveness of this practice. One study concluded that catch basins will capture sediments until about 60% of the sump capacity is reached.(111) Catch basins with sediment levels greater than 60% discharge the additional sediment and debris into the storm sewer flow. Large storm events may flush out accumulated sediment below the 60% capacity level. Catch basin cleaning is generally recommended when the sediment accumulation level is one-third of the sump capacity.

The sediment and debris removed from catch basins is typically disposed of in conventional landfills. Testing may be required to accurately determine if the materials are considered hazardous waste.(112)

Design Factors

Catch basins should be monitored to determine the rate at which sediment accumulates. This will aid in the development of an appropriate and effective cleaning schedule.

An inspection of the overall condition of the catch basin can be included with the cleaning operation.

Catch basins may be difficult to clean in areas with poor accessibility, high traffic levels, and in parking areas.(113) Cleaning might also be difficult during the winter due to snow and ice accumulation.

Catch basins should not be flushed out without having means to remove sediments and other pollutants that are deposited in the storm drain system.

Monthly catch basin cleaning was found to remove the maximum annual sediment volume. However the removal increase must be evaluated against the cost of conducting the more frequent cleaning.

Experience

Many public works departments conduct catch basin cleaning on at least an annual basis.

Effectiveness

Catch basin cleaning effectiveness varies depending on the frequency of the cleaning operations.(114) A typical catch basin can retain up to 57% of coarse solids and 17% of equivalent biological oxygen demand.(115) One study found that monthly cleanouts can remove 90 to 170 pounds of sediment per year while annual cleaning will remove 30 to 75 pounds of sediment per year depending on the land use of the contributing area.(116)

The following pollutant removal efficiencies have been estimated:(117)

- Total suspended solids: 35%
- Total nitrogen: 15%
- Total phosphorus: 15%
- Metals: 15% (estimated to be similar to nutrients)

Appliation of the Watershed Treatment Model (WTM) to the Milwaukee area indicated that monthly cleaning of catch basins could remove 25% of the incoming TSS load and 15% of the incoming nutrient load.(118)

Costs

A cleaning cost of $16 (2007) per catch basin was estimated for communities with vacuum capabilities.(119)

4.7.4 Catch Basin Filter

Description

A catch basin filter is used in or around sewer inlets to prevent sediment and debris contained in stormwater runoff from entering the sewer system.(120) The filters may be external around the perimeter of the inlet or internal placed in the inlet opening. Catch basin filters reduce the velocity of the runoff flow and capture the sediment by settling and filtering.

External filters may consist of concrete block wrapped in geotextile filter fabric, filter fabric covered with stone, silt fencing, sand bags, or straw bales placed around the inlet opening or directly over the inlet opening.(121) Internal filters may consist of filter fabric placed directly under the inlet grate and across the curb opening or a bag type filter installed below the inlet grate. Many different kinds of catch basin filters are commercially available. These filters contain screens to trap organic debris, trash, and gravel; filtration elements; and absorbents to collect oils. All inlet filters should have an emergency spillway or overflow to safely pass water if the filter becomes clogged. Catch basin filters are typically installed at construction areas, unpaved roadways, unpaved parking lots, and industrial sites where sedimentation potential is high. They are not suitable for removal of fine particulate such as metals, nutrients, silts, or clays. The catch basin filters can collect the courser grained particles as well as debris.(122)

Design Factors

Catch basin inlet filters should not cause ponding that will create a safety hazard, cause property damage, or interfere with traffic.

The drainage area to a catch basin inlet filter should not be greater than one acre to prevent overloading of the filter. Catch basin inlet filters will be most effective when included in an overall erosion control plan consisting of several BMPs.

Regular cleaning and maintenance of the inlet filters is required to maintain effectiveness and prevent clogging. Maintenance includes regular inspections and removal of sediment deposits.(123)

Catch basin filters should be used in conjunction with other BMPs if removal of fine particles and associated pollutants is desired.

Experience

Catch basin inlet filters have been used throughout southeastern Wisconsin for several years. Inlet filters are a required part of construction erosion control plans on most MMSD construction projects.

Effectiveness

King County, Washington evaluated six different catch basin filters. The study indicated that the catch basin filters did not remove significant amounts of pollutants associated with silt- or clay-sized particles; however, the filters were capable of trapping and removing the coarser materials and debris related to unpaved areas.(124) Inserts designed to remove petroleum hydrocarbons were found to reduce oil and grease concentrations by 30%.

Costs

The cost for inlet filters can range from $160 to $2,400 depending on the size of the insert, the filtering medium and design, and construction materials.(125)

Maintenance costs range from $16 to $160 per filter assuming monthly replacement of the filter media.(126)

4.7.5 Conservation Crop Rotation

Description

Conservation crop rotation is the process of changing the crops grown in a field, usually in a planned sequence, to include at least one resource-conserving crop in order to reduce erosion and improve soil fertility. Wisconsin crop rotations typically include corn, legumes (e.g., alfalfa), and small grains.

The vegetative cover on a field is directly related to the potential for erosion.(127) Crops in rows or with low residue will have more erosion than a crop of grass or legumes with increased surface cover and residue. Rotations to diversify the crop characteristics will reduce the potential for erosion.

Crop rotation results in fewer problems related to weeds, insects, and diseases when compared to monocultures.(128) Crop rotation adds diversity to the farming operations and has been shown to increase crop yields.(129)

Small grains and alfalfa can significantly reduce soil erosion.(130) Alfalfa and other legumes can replace nitrogen lost during corn and other grain seasons. Deep rooted crops, such as alfalfa, safflower, and sunflowers, can improve filtration and reduce soil compaction. Alternating grass with broadleaf crops is the best practice. A high residue crop followed by a low residue crop will help to maintain sufficient residue cover on the field.

Design Factors

The crops chosen must be suitable for the soil conditions and overall environment. Legume crops should precede a high nitrogen demand crop.(131) The crop residue should be evaluated when determining the crop rotation as well as root depth.(132)

Crops should be alternated every year to decrease weed, insect, and diseases. Crop selection can also reduce wind erosion.(133,134)

Experience

Conservation crop rotation is a practice that has been recommended and used for many years throughout Wisconsin and the United States.

Effectiveness

Studies have shown that a fourth year corn crop has 125 times more erosion than a grass-legume sod.(135)

Qualitative data on crop rotation effectiveness is not readily available because crop rotation is used as part of a larger conservation management plan that involves many other BMPs.

Costs

In many cases, there is no additional cost for crop rotation. Potentially higher crop yields, reduced nitrogen application and reduced pesticide use may result in cost savings.

4.7.6 Constructed Wetland

Description

A constructed wetland is an engineered system designed to use vegetation to filter and infiltrate stormwater runoff from an impervious area.(136,137) A constructed wetland maintains a shallow wet pool and the water is filtered by wetland plants.(138) Constructed wetlands are applicable within the Milwaukee area and are generally accepted stormwater treatment practices.

The components of a constructed wetland include a forebay to allow larger particulates to settle, low and high marsh areas and/or a storage/drainage pathway, a micropool, and an outlet. The constructed wetland is vegetated with wetland plants selected for tolerance of the site conditions and ability to filter pollutants. The wetland design maintains a shallow pool of water. Pollutants are filtered from the stormwater by the wetland vegetation. The biodiversity in a constructed wetland is less than that of a natural wetland area.

Design Factors

Constructed wetlands are generally better suited for larger sites than bioretention areas.(139) The drainage area for a constructed wetland must be sufficient to maintain a shallow permanent pool; this may be greater than 25 acres. The surface area of the wetland should be at least 1% of the drainage area and can range up to 5% of the drainage area. The wetland length-to-width ratio should be at least 1.5:1 to reduce the potential for stormwater short circuiting the practice. Flood control wetland design must include storage above the wetland surface.

Constructed wetland maintenance includes vegetation inspection and removal of invasive species, inspection and maintenance of embankments and inlet and outlet structures, sediment removal in the forebay area, and sediment removal in other pool areas.(140, 141)

Experience

There are a couple constructed wetlands that have been installed in southeastern Wisconsin, including a small wetland at MMSD headquarters and one near Trinity Creek in Mequon.

Effectiveness

Constructed wetlands are effective in reducing the peak flow and flood hazards associated with large storm events.(142) Constructed wetlands are also very effective for pollutant removal. The following pollutant removal effectiveness percentages for stormwater wetlands have been achieved:(143)

- Total suspended solids: 76%
- Total nitrogen: 30%
- Total phosphorus: 49%
- Zinc: 44%
- Copper: 40%

Costs

Installation of an emergent wetland with a sediment forebay can cost between $39,000 and $82,000 per acre of wetland. Maintenance costs are expected to be about 2% of the construction cost per year.(144)

4.7.7 Fine Screens

Description

Fine screens on a combined sewer overflow, sanitary sewer overflow, or storm sewer outfall can reduce the amount of screenable solids and floatables that are released to a stream during a storm event.(145) A system developed by Parkson Corp., called a ROMAG screen, generally includes the installation of a fixed bar screen with 0.157 inch (4 mm) openings on an overflow weir. The sewer discharge passes through the screen as water levels rise. Solids are trapped on the screen and cleaned off manually or by automatic means.(146)

Design Factors

Flow through the outfall, size of the outfall, and head loss through the screen are all factors in the design.

Experience

Fine screens in CSO/SSO and stormwater outfalls have been more prevalent in Europe, since stormwater issues have historically been a higher priority in Europe than in North America. The ROMAG screen was developed in Switzerland in 1990. There are over 250 screens installed across Europe (as of 1999 European Patent Convention (EPC) document). The first ROMAG screen installation in the U.S. was in Rahway, NJ in 1997. According to literature from Parkson, over 800 ROMAG screens have been sold worldwide.

Effectiveness

Debris removal ranges from 80-95%, with removal of most particles with a diameter greater than 0.157 inches (4 mm). Effectiveness will depend on the water quality coming into the screen. Removal of TSS by use of fine screens is not significant**.**

Costs

The cost of the screens varies greatly depending on the size, materials, flow rate and method of cleaning. Equipment costs can range from $85,000 to $270,000 per outfall, with construction costs ranging from $50,000 to $110,000 depending on flow rates through the screen.(147) Annual operation and maintenance costs are estimated to be about 5% of the total cost (equipment plus construction).

4.7.8 Infiltration Basin

Description

Infiltration systems provide runoff volume and peak flow control because they detain runoff and slowly release the stormwater to the groundwater. An infiltration basin is a shallow depression over permeable soil that allows stormwater to infiltrate. Infiltration basins are typically vegetated.

Design Factors

Infiltration basins should be designed to minimize the level of pollutants infiltrating to groundwater. Pretreatment of stormwater runoff prior to infiltration is required for parking lots and new commercial, industrial and institutional roadway areas by Wisconsin Administrative Code Natural Resources (NR) 151. Infiltration is not appropriate in areas where the soils are not suitable for infiltration, areas with a potential for stormwater contamination, and areas near drinking water supplies. Typical depths are 3 to 12 feet.

Washington Department of Ecology Guidelines for Infiltration Basin Design (1992) are as follows:

- Minimum infiltration capacity of 0.5 inch/hr.

- Maximum clay content of 30%.
- Maximum silt-clay content of 40%.
- Minimum depth to bedrock and high water table of three feet.
- Maximum ponding time of 24 hours.
- Pretreatment required (forebay, biofilter, or sedimentation chamber).
- Measured infiltration rate reduced by factor of two for design.
- Basins control 6-month, 2-year and 10-year, 24-hour rainfall events. If the infiltration capacity is greater than 2 inches/hr, stormwater must be treated to protect groundwater.

Maintaining the designed infiltration capacity can be difficult. Most infiltration basins constructed in the 1970s and 1980s in Wisconsin failed within two years.(148) Design standards and construction techniques have improved; however, there are not many existing infiltration basins in southeastern Wisconsin that have been operating for an extended period of time, so the life span or success of infiltration basins that were designed and constructed with the improved standards and techniques is not known.(149)

Experience

A local example of an infiltration basin is the Pabst Farms development in Oconomowoc. This multi-phase, mixed-use development is located about 30 miles west of Milwaukee. The site consists of pervious subsoils and is incorporating several infiltration basins.(150)

Effectiveness

Specific volumes of stormwater runoff are identified for infiltration based on the type of development and soil infiltration properties. Wis. Admin. Code NR 151 requires residential developments where the infiltration rate of the soil is at least 0.6 inches per hour to infiltrate at least 90% of the pre-development infiltration volume, based on an average annual rainfall, but no more than 1% of the project site is required as an effective infiltration area. New commercial, industrial and institutional developments where the infiltration rate of the soil is at least 0.6 inches per hour are required to infiltrate at least 60% of the pre-development infiltration volume from rooftop and parking lot areas, based on an average annual rainfall, but no more than 2% of the project site is required as an effective infiltration area.

Typical pollutant removal rates for infiltration basins and trenches have been identified as follows:(151)

- Sediment: 99%
- Total phosphorus: 65-75%
- Total nitrogen: 60-70%
- Trace metals: 95-99%
- BOD: 90%
- Bacteria: 98%

Volume reductions from infiltration practices can be increased if desired.

Costs

Infiltration basins for residential developments cost about $21,700 per acre served to install and about $1,100 per acre served for annual operation and maintenance. Practices for commercial, industrial and institutional developments cost about $108,300 per acre served to install and about $5,400 per acre served for annual operation and maintenance.

4.7.9 Riparian Corridors/Buffers

Description

Riparian corridors are vegetated buffers and natural areas along streams, wetlands and lakeshores. They consist of trees, shrubs, and grasses that can intercept contaminants from surface water runoff before they reach the waterbody and reduce the loads of pollutants entering the system. Riparian corridors can be formed by establishing or restoring natural areas along waterways and by preserving and protecting existing natural areas along waterways.

Riparian buffers are an important best management practice to protect water from contamination by nonpoint source pollutants because habitat and riparian corridor conditions are strongly influenced by the width and nature of the buffers adjacent to a waterbody.

There are many different kinds of buffers. While these buffers may be applied to a variety of situations and called different names, their functions are much the same - improve and protect surface water and groundwater; reduce erosion on cropland, streambanks, lakes, and wetlands; and provide protection and cover for plants, insects, fish, birds, amphibians and reptiles, and mammals.(152)

Experience

Southeastern Wisconsin has a long history of protecting natural areas and green space along watercourses. For decades, the Southeastern Wisconsin Regional Planning Commission (SEWRPC) has recommended the protection of primary and secondary environmental corridors throughout the seven-county Southeastern Wisconsin region.(153) Local units of government within the region have adopted SEWRPC's plans.

The Milwaukee County Park System includes over 140 parks and parkways totaling nearly 15,000 acres.(154) Most of these parks line the watercourses or Lake Michigan, and therefore act as outstanding riparian corridors.

Greenseams, which is one element of MMSD's flood management program, is another program that aims to preserve floodplains and land along streams through land acquisition or conservation easements. MMSD retained The Conservation Fund to operate Greenseams.

Design Factors

Although the essential dimensions and composition of riparian corridors are dependent on the slope, soil, and current condition of a corridor, researchers have found that a minimum buffer width of 50 to 100 feet is necessary to protect wetlands and streams and support wildlife.(155,156) Under SEWRPC's guidelines, a corridor must be at least 200 feet wide in order to be classified as a primary environmental corridor.(157)

For the WQI analysis, riparian corridors are assumed to be "set-aside" areas that will be left as natural areas and will not require grading, planting or maintenance, unlike the agricultural buffer strips. Trees allowed to grow will provide watercourse shading for fisheries habitat; however, if they are allowed to grow along agricultural fields, they will also shade and limit crop growth. Plant and animal species within a riparian corridor may consist of native species representative of pre-European settlement times, or other appropriate biological communities suitable for the site conditions.

Effectiveness

Riparian corridors may provide the following benefits:

1) Reduce pollutant runoff into lakes and streams
2) Reduce overspray of pesticides and herbicides that reaches waterways
3) Reduce erosion of nearshore areas and shorelines
4) Provide protection and cover for plants and animals, increase species diversity, and support sustainable communities
5) Reduce water temperatures during the summer by increasing shade
6) Protect valuable wetlands, forests, and habitat areas
7) Help prevent flooding
8) Support the movement of wildlife and the dispersal of seeds along waterways
9) Enhance the aesthetic, educational, and recreational value of the corridor
10) Reduce air pollution

Although the pollutant removal effectiveness of a riparian corridor will vary depending on site conditions and corridor width, vegetation can effectively slow stormwater runoff, filter and settle pollutants, and increase infiltration. The following average pollutant removals have been observed:(158)

- Total suspended solids: 65-73%
- Total nitrogen: 48-80%
- Total phosphorus: 48-75%

Costs

The cost of establishing or preserving riparian corridors/buffers includes land acquisition and conservation easements and is estimated to cost between $210 and $3,000 per acre in agricultural areas and up to $200,000 per acre for urbanized residential areas. Annual rental and incentive payments to farmers to preserve and/or establish riparian corridors/buffers are estimated to range between $55 and $510 per acre. Because this land is assumed to be "set-aside," no additional maintenance costs are included.(159,160)

4.7.10 Stormwater Filtration Systems (Sand Filters)

Description

Stormwater filtration systems use sand, sand/peat combinations, or compost filter media to remove fine-grained suspended solids. Although there are many configurations, the basic design includes a sediment chamber to capture large particles and a filtration chamber that captures smaller particles and other pollutants. Filtration systems can be located either at or below grade and can be designed to operate as either on-line or off-line facilities depending on the application. They are typically concrete structures, but surface filter systems can be constructed out of earthen walls.(161)

There are several common types of stormwater filtration systems, including Austin filters, Washington D.C. (D.C.) filters, Delaware filters and multi-chamber treatment trains (MCTTs).

- The Austin filter is a surface sand filter that uses a sedimentation basin and a filtration basin.(162)
- The D.C. filter is an underground vault sand filter designed to treat stormwater flowing through a storm sewer and consists of a sedimentation chamber, a filtration chamber and a discharge chamber.
- The Delaware filter is a shallow, double trench sand filter designed to collect and treat stormwater directly from an impervious area.(163)
- The MCTT is an underground vault system that consists of a series of treatment elements that mimic the process found in a wastewater treatment facility.(164) As flow enters, it passes through packed column aerators that permit preliminary settling of the large diameter particles. Flow is then transferred into the main settling chamber where most of the settled particles are captured. Floatables and oils are captured in the main settling chamber using absorbent media. Finally, the flow is passed through the filtering chamber, which contains a sand/peat filter.(165)

Table 4-4 summarizes the differences between these four types of sand filters.

TABLE 4-4
SAND FILTER COMPARISONS

Feature	Type of Filter: Austin	D.C.	Delaware	MCTT
Size of Typical Drainage Area	Up to 50 acres[a]	Under 1 acre[a]	Under 5 acres[a]	0.25 – 2.5 acres[b]
Expected Cost per Impervious Acre	$5,700 - $27,100[c]	$21,800[c]	$21,800[c]	$47,250[d]
Typical Annual Maintenance Cost	$290 - $1,400 per acre[c]	$2,100 per practice[c]	$2,100 per practice[c]	$2,700 per practice[d]

Sources:
a) United States Environmental Protection Agency, *Storm Water Technology Fact Sheet Sand Filters,* (EPA 832-F-99-007, EPA, Office of Water: Washington, DC, September 1999), http://www.epa.gov/owm/mtb/sandfltr.pdf
b) United States Department of Transportation Federal Highway Administration, Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, *Fact Sheet - Underground Sand Filters* [Internet], (no date), http://www.fhwa.dot.gov/environment/ultraurb/3fs7.htm
c) United States Department of Transportation Federal Highway Administration, Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, *Fact Sheet - Surface Sand Filters* [Internet], (no date), http://www.fhwa.dot.gov/environment/ultraurb/3fs8.htm
d) Roger Bannerman, *A Procedure for Selection of Stormwater Treatment Practices in Established Areas* (Madison, Wisconsin Department of Natural Resources, no date)

Design Factors

The design factors are very site specific. Most filtration systems are designed to capture the first 0.5 inches of runoff, or the first flush, because it is typically the most polluted, but they can be designed to handle large storms. Proper sizing and maintenance of the system is critical to prevent clogging of the sand filter. It is important to consider average annual runoff volume, event mean concentration of TSS for the runoff to be treated, and the maintenance cycle.(166) Most filtration systems are combined with another technology, such as street sweeping or catch basins to pretreat the stormwater and remove larger sediments.(167)

The type of unit selected depends on whether an above ground or below ground unit is preferred, the drainage area to be treated, and whether the application is for new construction or a retrofit for an existing area. Austin filters are typically designed to treat drainage areas up to 50 acres; however, there are some installations in Austin, TX that treat up to 100 acres.(168,169) The surface area required for installation is generally between 2-7% of the tributary area.(170) Because the Austin filter is constructed at or near the ground surface, it is susceptible to freezing in colder climates and may not be as effective in these areas.(171)

Delaware filters are typically designed to treat drainage areas of 5 acres or less. At roughly 30 inches deep, they are relatively shallow structures, which reduces construction and maintenance costs.(172) However, as with the Austin filter, freezing issues need to be considered because of the shallow construction.

D.C. filters typically service areas under one acre and can be used in retrofit applications.(173,174) Because it is an underground system requiring only access manholes for maintenance, the surface area required is minimal.

MCTT systems typically service areas between 0.25 and 2.5 acres in size. Their design depends highly on rainfall frequency and intensity/duration relationships. Providing a sufficient equalization capacity is important to provide uniform flow into the filtration bed. Because of the site specificity of the units and whether they are drained by gravity or pumped dry, there can be a 300% variation in the size of the filtration systems. The surface area required for installation is typically 0.5-1.5% of the tributary area.(175)

Because of their costly installation and high maintenance requirements, stormwater filtration systems are usually used in small areas with high concentrations of pollutants, such as gas stations, loading docks, and parking lots.(176) Additional pretreatment measures, such as grassed swales or vegetated filter strips, should be used in areas where sand filters will be subjected to high loads of oil and grease.(177)

Experience

Stormwater filtration systems are becoming a widely used BMP throughout the United States. There are a number of installations in Delaware, Maryland, Florida, Virginia, Texas and Washington, D.C.(178,179) The there are two known installations of MCTTs in Wisconsin – one in Milwaukee and one in Minocqua.(180)

Effectiveness

Stormwater filtration units are proven technologies that effectively remove pollutants such as TSS, metals, nutrients and fecal coliforms.(181) A monitoring study done on an MCTT system installed at a municipal garage and parking lot during 13 storms determined the removal of 83% of TSS, 100% of lead, and 91% of zinc.(182) A study performed by the WDNR on the Lake Wingra watershed in Madison, Wisconsin assumed 80% pollutant removal rates for TSS, 70% for phosphorus, and 73% for recoverable zinc. The authors of the WDNR study point out that although the MCTT systems can achieve suspended solids removal efficiencies of 98%, MCTT's usually bypass high flows, so a maximum annual load reduction of 80% is more realistic.(183) Austin, D.C. and Delaware filters all have similar removal efficiencies and typically provide removals of approximately 85% for TSS, 35% for total nitrogen, 55% for phosphorus, 35-90% for metals, 55-84% for oil and grease and 40-80% for fecal coliform.(184)

As a result of the aerobic processes, the filtration systems may increase nitrate levels as ammonia undergoes nitrification. However, it is also possible that ammonia levels can increase due to anaerobic conditions in the accumulated sediments. Also, filtration systems that use peat in the filtration bed tend to discharge water that is tinted and off color.

Costs

Stormwater filtration units are considered to be a high-cost BMP.(185) Costs can vary widely due to site-specific factors such as real estate costs, utility conflicts and whether pumping is required. Because Austin filters can serve a wide range of drainage areas compared to the other sand filters discussed in this report, the costs can vary due to the economies of scale as well. Unit capital costs for Austin filters can range between about $5,700 per impervious acre (for facilities serving areas greater than five acres) to $27,100 per impervious acre (for facilities serving less than two acres).(186) The annual maintenance for Austin filters is assumed to be about 5% of the capital cost, or $290 to $1,400 per impervious acre.(187)

Unit capital costs for a Delaware filter used in the WDNR's Lake Wingra analysis were found to be about $21,800 per acre of connected imperviousness, with an annual maintenance cost of $2,100 per practice. Costs for a D.C. filter are similar to the Deleware filter.(188)

The Lake Wingra analysis found the cost for an MCTT system to be about $47,250 per acre of connected imperviousness, with an annual maintenance cost of $2,700 per practice.(189) A retrofit application of an MCTT system for an existing storm sewer that drained a 2.5 acre area had an installation cost of $95,000 ($38,000 per acre).(190) Some information puts construction costs at $10,000 to $20,000 per quarter acre of drainage area when using prefabricated units.

4.7.11 Street Sweeping

Description

Street sweeping is a common best management practice employed by municipalities to collect sediment and debris from roadways and other paved areas. Mechanical sweepers use one of three basic technologies: a traditional mechanical sweeper uses rotary brushes that sweep the material onto a conveyer belt, a vacuum-assisted sweeper uses rotary brushes and a high-powered vacuum, and a regenerative air sweeper uses compressed air and a vacuum. Water is sometimes used in the mechanical and vacuum-assisted sweepers for dust control. Tandem sweeping, using two machines to sweep and vacuum is another option.(191,192) Street sweeping can be a very effective practice to reduce sediment because parking lots and roadways are a leading source of sediment.(193,194,195)

Mechanical sweepers are the most common sweepers used in the United States. They are designed to remove standard road debris. The vacuum-assisted sweeper and regenerative air sweepers are newer technologies designed to loosen and pick-up smaller particulates.(196) Some vacuum-assisted sweepers may also work well under frozen or wet conditions.

A computer model simulation in Portland, Oregon indicates that sweeping frequencies of once per week or more will result in the highest sediment load reduction.(197) Vacuum-assisted sweeper sediment reductions increase from 50% for a monthly program to 60% for bi-weekly to 77% for weekly and 79% for greater than weekly sweeping frequencies. Reduction in fecal coliform bacteria loading was evaluated by the United States Geological Survey. The study modeled street sweeping with a vacuum-assisted sweeper in a single-family residential land use area. The study indicated a reduction in fecal coliform ranging from 1-17%.(198)

Street sweeping will not reduce pollutant loadings in stormwater run-on (stormwater that flows into roadways from adjacent land areas during a storm event).(199)

Design Factors

There are many factors that need to be considered when choosing a street sweeper and developing an effective sweeping program. These include:

- Sweeper type – this is important for removal efficiencies, but there are other factors to consider, including:
    - The maximum travel speed varies among sweeper types and models. Sweepers used for highway sweeping may require trailering to the sweeping site if their maximum travel speed precludes them from driving on roads with high speed limits or if they need to travel far distances from the municipal garage.(200)

  - A sweeper may require a trailing vehicle or "blocker" on high speed roadways for protection.
  - A dry vacuum sweeper will be more effective but typically will move slower than a mechanical or regenerative air sweeper.
  - Sweepers requiring water are less efficient because they require more frequent stops to fill the water tank and to dispose of sediment.
- Target roads - pollutant loads generated by roads can vary depending on type (e.g., local, collector, arterial) and location. Roads that generate higher pollutant loads should be a priority and targeted for more frequent sweeping.
- Pavement conditions - the effectiveness of a sweeping program may be hindered by wet pavement and pavement in disrepair.(201)
- Parking restrictions - parked vehicles along the roadside reduce access to the curb line where the majority of the pollutants are located.(202) Restricted parking during scheduled sweeping should be considered.
- Seasonal impacts – early spring sweeping can capture sand that was applied to streets and other pollutants that accumulated over the winter months.(203)
- Sweeper maintenance - regardless of sweeper type, the sweeper must be properly maintained to ensure peak performance.(204)

Experience

Mechanical street sweeping is widely employed across MMSD's service area and in many countries across the world.

Effectiveness

The effectiveness of street sweeping in pollutant removal varies based on the type of sweeper, the frequency of the sweeping program, the condition of the roadway, the level of maintenance provided for the sweeper, and the ability of the sweeper to reach the curb line.(205) Studies have been performed to determine how effectively sweepers remove sediment or total suspended solids, phosphorus, and metals.(206) A comparison of sweeper effectiveness in TSS removal from a street surface is presented in Table 4-5.

TABLE 4-5
COMPARISON OF SWEEPER TECHNOLOGY AND TSS REMOVAL FROM STREET SURFACE ON MAJOR ROADWAYS

Sweeper Technology	Percent Removal of Total Suspended Solids
Mechanical	15[a]
Vacuum-Assisted	79[b]
Regenerative Air	22[c]

Sources:

a) Bannerman, Roger, Wisconsin Department of Natural Resources, personal communication with T. Deibert, January 20, 2005

b) Street Sweeping for Pollutant Removal (Montgomery County Department of Environmental Protection, Montgomery County, Maryland, February 2002)

c) Based on studies performed by the Center for Watershed Protection (Watershed Treatment Model, 2001)

Costs

Street sweeping costs include the capital, maintenance, and operation costs plus the cost for disposal of the material collected. Street sweeper costs are quite variable depending on the type of machine. Mechanical sweepers cost about $100,000 for a new machine and about $60 per curb mile to operate. Vacuum sweepers cost about $250,000 per machine and only about $30 per curb mile to operate. Approximately one sweeper is needed for every 100 curb miles assuming weekly sweeping.(207,208,209,210,211) To hire a contractor to sweep a parking lot every week for eight months during the year using a vacuum sweeper, the cost is about $2,500 to $3,700 per acre of parking lot per year.(212)

4.7.12 Wet Detention Basins

Description

A wet detention basin is a constructed pond that has a permanent pool of water.(213) It is designed to collect, detain, treat, and discharge stormwater runoff during and after storm events.(214) A wet basin treats the stormwater runoff through settling and through nutrient uptake by plants and other aquatic organisms. A wet detention basin can also reduce peak runoff rates. Wet detention basins are one of the most commonly used and cost-effective stormwater treatment practices.

A wet detention basin can be constructed for a single property or as a regional practice for a large drainage area. The size of the basin is primarily dependant on the size and land use of the area draining to the basin. A low-density residential area will have less runoff than a paved commercial area and therefore would require a smaller area to store and treat the runoff.(215)

Design Factors

A wet detention basin design should include the following components: a pretreatment forebay to collect larger sediment particles from the runoff and reduce maintenance needs for the pond; a treatment pool that is the permanent pool area, which may be enlarged to increase the pollutant removal effectiveness; conveyance mechanisms to and from the pond designed and stabilized to minimize the potential for erosion, including an emergency spillway to pass storms that are larger than the basin design storm(216); maintenance reduction features such as a non-clogging pond outlet and access points for maintenance; and landscaping to enhance habitat and aesthetic benefits as well as control erosion and provide pollutant uptake.(217)

The drainage area to the wet detention basin must be sufficient to maintain a permanent pool level. A basin can intersect the groundwater level to provide the permanent pool if the drainage area is not highly contaminated. Only a slight reduction in pollutant removal may occur if groundwater is the primary source of the permanent pool.(218) Soil permeability will affect the pond's retention of water in the pool area. Soil permeability between 10^{-5} and 10^{-6} cm/sec is adequate to maintain a permanent pool. The sediment forebay should be included to remove larger particles. The forebay should comprise about 10% of the volume of the permanent pool.

The volume of the permanent pool affects the pollutant removal effectiveness. A larger volume will increase the detention time of the water in the pool, allowing for increased filtering and treatment. The basin length to width ratio should be at least 1.5:1 to prevent water from short circuiting the system.

Freezing weather, as well as salt and sand loadings during winter months, may require modification in pond operation and maintenance and vegetation selection.

Land availability may limit the possibility for a wet basin installation.

Maintenance is a key element in the effectiveness of the wet detention basin. Maintenance for a wet detention basin includes an annual inspection to identify damage, measure sediment accumulation, monitor signs of hydrocarbon build-up, and examine the inlet and outlets. Debris should be removed from the inlet and outlets and side slope vegetation should be maintained on a monthly basis. Sediment removal from the forebay is typically necessary every five to seven years. Pond sediment should be removed when the volume has been reduced or when the pond becomes eutrophic, typically in 20 to 50 years.

Experience

Wet detention basins have been widely used throughout the United States to remove pollutants for urban stormwater runoff.(219) Extensive evaluation and design information has been developed.

Effectiveness

Pollutant removal effectiveness of a properly designed and maintained wet detention basin is as follows:(220)

- TSS: 80%
- Nutrients 30-50%
- Metals 30-70%
- Bacteria up to 70%

Costs

Costs for a wet detention basin can range between $1,600 and $6,100 per acre served. The cost includes permitting, design and construction, and maintenance. Annual maintenance costs are typically 3-5% of the construction costs.(221,222,223)

4.8 Coliform Indicator

The coliform indicator relates to the amount of bacteria in the stormwater that will ultimately reach a watercourse. Nonpoint source technologies that effectively reduce bacteria typically reduce or eliminate the exposure of bacteria sources to stormwater discharges.

The nonpoint source technologies that will effectively reduce the coliform indicator are described in this section.

4.8.1 Livestock Management

Description

For purposes of this study, livestock management is defined as preventing livestock from directly accessing streams in order to prevent the direct deposition of manure into the waterways. This also provides streambank and shoreline protection by reducing livestock damage due to bank erosion and overgrazing bank vegetation.

Design Factors

Livestock exclusion from waterways can be accomplished with fencing. If livestock need to cross the waterway, a crossing should be constructed. An alternative water source may be necessary for livestock that are excluded from the waterway.

Experience

Two successful projects that implemented livestock exclusion fencing in Wisconsin were conducted along Otter Creek (a tributary to the Sheboygan River) and Spring Creek (tributary to the Yahara River).(224,225)

The Lake Champlain Basin Watershed Project in Vermont implemented and evaluated the effectiveness of grazing management, livestock exclusion, and streambank protection as tools for controlling nonpoint source pollution in small agricultural watersheds.(226)

Effectiveness

The Lake Champlain Basin Watershed Project in Vermont showed that reducing cattle access to streams reduced fecal coliforms by about 38%.(227)

The Otter Creek project's monitoring data indicated the BMPs implemented, including barnyard runoff and manure management, nutrient management, reduced tillage and shoreline and streambank stabilization (using streambank fencing) reduced fecal coliforms by 84%.(228)

Costs

Exclusion fencing for livestock is expected to cost approximately $2.00 to $3.00 per linear foot, assuming the fence is installed in a cleared area and is relatively straight.(229) Stream crossings for livestock are estimated to cost about $1,800 each.(230) Annual maintenance costs are assumed to be 5% of the construction cost and include fixing and replacing the fence and clearing debris from stream crossings.

4.8.2 Manure Management

Description

Manure management incorporates structural and non-structural practices to address manure application, manure storage and animal lot runoff. Manure application should be conducted in accordance with a nutrient management plan to maximize the nutrient value while eliminating over application, which can result in excess manure in stormwater runoff. Manure storage from confined livestock areas allows the manure to be safely stockpiled until conditions are environmentally favorable for spreading. In Wisconsin, common manure storage includes walled enclosures, earthen ponds, above-ground tanks, and under-floor storage. Animal lot runoff control includes diversion of stormwater runoff from the confined area along with a capture or filter technology for runoff from the area.(231)

Design Factors

Manure application should be in accordance with a site specific nutrient management plan that includes soil testing, manure testing, and a spreading plan. The type of manure spreader used should be evaluated.

The cost, space requirement, manure transfer, odors, and state and local regulations should be evaluated when selecting manure storage. Rain gutters and downspouts should be used to prevent roof runoff from flowing through confined animal areas.

Diversion, either by a berm or channel, should be constructed to prevent run-on into a confined animal area. Traffic patterns should be evaluated when designing the diversion.

Treatment of stormwater runoff from the confined animal area may include a settling basin or a filter strip. Regular maintenance is required for these treatment options.

Experience

Based on the feedback from county agricultural agents and WDNR staff, it appears that about 30-35% of livestock operations in southeastern Wisconsin have manure storage facilities that meet NR 151 standards. Information on barnyard runoff controls indicates the degree of implementation to be less than that of storage. Racine County reported only about 5% compliance with NR 151 while Sheboygan County reported about 20%.(232)

Effectiveness

When used in conjunction with livestock management, manure management is assumed to reduce fecal coliforms from agricultural land by about 50%.

Costs

Manure storage costs range from $150 per cow for earthen ponds to $1,500 per cow for above ground tanks.(233) Annual repairs and maintenance costs for a liquid manure pit system and equipment are approximately 3% of the initial investment cost. The annual cost of an agitation pump tractor ranges from $6.20 to $12.40 per cow.(234)

4.8.3 Pet Litter Control

Description

Although there are existing pet litter control regulations, this technology was evaluated during the alternative analysis and is, therefore, included in this chapter.

Municipalities may use an ordinance for pet waste removal and proper disposal provisions. The ordinances often incorporate fines for failure to comply.

Design Factors

The public education program may include provisions for signs, pick-up bags and receptacles in key areas, and inclusion of pet litter control in overall public water quality informational brochures and newsletters.

Experience

Proper management of pet waste is required to be included in a public information and education program under both Wis. Admin. Code NR 151 and NR 216.

Effectiveness

The effectiveness is dependent on the implementation and enforcement of the pet litter program. For the purposes of the SOAR, pet litter control contributed to a 50% reduction in fecal coliform for urban areas.

Costs

A pet litter control program is assumed to be self-sustaining as a result of enforcement citations.

4.8.4 Residential and On-Site Sewage Systems Management

Description

Although there are existing on-site sewage system management standards, this technology was evaluated during the alternative analysis and is, therefore, included in this chapter. Private on-site wastewater treatment systems are regulated by Wis. Admin. Code Comm 83. This regulation establishes standards and criteria for the design, installation, inspection, and management of private on-site wastewater treatment systems to ensure that the systems are safe and will protect the public health and the waters of the state. Plans of new and replacement systems must be reviewed and approved by the Department of Commerce. Local regulations for design, approval, inspection, and testing may also apply. Inspection and testing of the system may be conducted by the state or local regulating unit. Regulary inspection of septic systems installed prior to 1980 may not be covered under most inspection programs.

Septic system failures can result in untreated wastewater and sewage entering the groundwater and/or nearby waterway. Regular maintenance and inspection is required to ensure proper operation of a septic system.(235) A septic system inspection program reduces the possibility of septic failures and overflow. Improperly functioning septic systems result in high levels of pollutants, including bacteria and nutrients, entering local water sources. A failure may be caused by improper siting, inadequate installation, system operation failures, or lapse in regular inspection and maintenance.(236)

An outreach program to educate homeowners on the proper operation and maintenance of their septic systems may compliment the inspection program.(237)

Design Factors

Septic systems should be inspected annually to certify that the system is in proper operating condition and that the septic tank is less than 1/3 full of sludge or scum. Septic tanks that were installed after 1980 are covered under existing inspection programs per Wisconsin Statutes Chapter 145, *Plumbing and Fire Protection Systems and Swimming Pool Plan Review* in areas where governmental units have adopted a maintenance program.

Experience

Examples of septic system management programs that include inspections are:

- Villas County, Wisconsin - The program requires inspections of new or reconstructed systems every three years by licensed personnel or government employees or their designee. It also requires an inspection when a dwelling unit served by a septic system adds at least 150 square feet. In addition, all developed properties not already participating in the maintenance program must begin participating when a property is sold. (238)
- Georgetown Divide Public Utilities in California - The program includes comprehensive site evaluation, septic system designs, system layout, and construction and post construction inspections. Homeowners pay $12.50 per month.(239)
- Bellevue, Washington - Program includes biannual septic system inspections at no charge, unless remedial actions are necessary.(240)

Effectiveness

A failing septic system can have major impacts on nearby groundwater wells or the nearshore area of an adjacent lake. Failing systems along rivers and streams not only impact nearby areas, but they can also impact downstream waterways. Failing septic systems within 300 feet of waterways may contribute 10,000 colony-forming units per 100 milliliters (cfu/100 ml) to receiving waters, and direct discharges of septic system sewage can contribute up to 12 million cfu/100 ml.(241,242,243)

Costs

Septic system inspections cost about $40-$60 per system, depending on the density of the houses.(244) Each system is assumed to have a lifespan of 20 years, with a replacement cost of $10,000 to $20,000 per system.

4.8.5 Stormwater Disinfection

Description

Stormwater disinfection inactivates or destroys disease-causing organisms (pathogens) found in stormwater runoff, such as bacteria and viruses, by exposing them to powerful oxidizers or radiation. Chlorination/dechlorination is the predominant technology in use; however, because of health risks associated with chlorine, alternative disinfection methods have also been developed.(245) Alternative methods include ultraviolet radiation (UV), ozonation, peracetic acid, chlorine dioxide, bromine and electron beam irradiation.(246) The two methods analyzed in this report are chlorination/dechlorination and UV.

A typical chlorination/dechlorination system includes a chemical feed system for chlorination, an area where thorough mixing occurs and a chemical feed system for dechlorination. Depending on the specific application, solids removal (i.e., screen or grit chamber) may be required at the front end of the system.(247)

UV systems expose the stormwater to lamps that emit the spectrum of light between 40 and 400 nanometers. The light waves penetrate the cell walls of pathogens and structurally alter their DNA, which prevents the cells from functioning and replicating. No hazardous chemicals are produced or released as a result of UV disinfection. There are two basic configurations for UV systems – contact or non-contact. The contact systems use submerged lamps that are encased in quartz sleeves. Non-contact systems use suspended lamps. The configuration used depends on the application and whether an open channel or closed channel is preferred.(248)

Design Factors

When designing a disinfection system, the following issues need to be considered:

- Types of organisms targeted
- Number of organisms
- Nature of the stormwater
- Temperature
- Intensity and nature of physical agent (UV)
- Concentration and type of chemical agent (chlorine)
- Contact time
- Residual standards
- Operation and maintenance (249,250)

Contact time is critical for both UV and chlorination/dechlorination systems. One of the most challenging components of maximizing contact time is controlling solids. Solids may hinder disinfection in both chlorination/dechlorination and UV systems because they can protect or shield pathogens from the chlorine or UV radiation.

For chlorination/dechlorination, effective mixing is also critical to ensure proper contact between the chlorine and the pathogens. Mixing can be accomplished by using mechanical mixing (e.g., pumps, mixers, spargers) or by using the energy provided by the stormwater gradient and hydraulic jumps, flumes or high velocity segements. Determining a method for proper dosing of chlorine and sodium bisulfate (commonly used for dechlorination) can be a challenge because of the variability in flow and chemical and physical properties of the stormwater. Safety is an important consideration with the storage and handling of chlorine because of its corrosive nature. Also, disinfection residuals and by-products created during the disinfection process need to be monitored and addressed, if needed.(251)

UV systems do not produce any residuals or by-products; however, there is a risk for regrowth. Important design factors include flow rate, flow depth, suspended solids concentration, number of lamps in operation, average lamp output, and average transmissibility of the transmitting surface, which is a function of the clarity or cleanliness of the protective sleeve around the lamp.(252)

Experience

Chlorine disinfection has been used to control water-borne diseases for drinking water since the early twentieth century. Chlorination is proven to be an effective and reletively inexpensive method; consequently, it is the most widely-used. Over the last two decades it has become more widely used for wastewater applications and is now being used for stormwater.(253) UV disinfection has also been used to disinfect drinking water since the early twentieth century in the United States and is being more widely implemented for both drinking water and wastewater disinfection.(254)

Effectiveness

In a pilot test conducted in Onondaga County, New York, chlorine disinfection was found to have average log reductions of 3.3 for fecal coliform, 2.3 for *E. coli* and 3.1 for *Enterococcus* spp. In the same pilot test, UV disinfection was found to have average log reductions of 3.0 for fecal coliform, 2.1 for *E. coli* and 2.9 for *Enterococcus* spp.(255)

Costs

The cost to design and install a stormwater disinfection unit that can treat a peak flow rate of about five million gallons per day (MGD) is about $5,300,000 per unit for a chlorination/dechlorination unit and about $1,300,000 for a UV unit. Neither of these capital costs includes contingency or engineering costs during construction. Annual operation and maintenance costs are estimated to be about $65,400 for a chlorination/dechlorination unit and $58,700 for a UV unit.(256,257)

4.8.6 Waterfowl Control Measures

Description

Waterfowl control measures are various methods that can be used to reduce the waterfowl population around waterways.(258) The measures include chemical repellent; planting buffer strips of tall grasses, plants, or shrubs; and erecting a barrier, possibly a stone wall, hedge, or plastic fencing along the shoreline. Electric fencing can also be used as a barrier.

Large numbers of gulls roost on beaches and are known to contribute high amounts of coliforms to the sand.(259) Prime geese habitat in urban areas is the perimeter of lakes and ponds, which are typically surrounded by flat areas of mowed grass. The problems encountered with increasing urban populations of geese include droppings in parks, golf courses, beaches, and other public areas.(260) Waterfowl droppings are believed to be a major contributor to coliform in waterways.(261)

Canada geese prefer to see around themselves at all times to watch for predators. Therefore, the geese can be deterred by planting taller vegetation or by erecting a barrier that would make it difficult for the geese to come ashore.(262)

A combination of techniques for controlling waterfowl could maximize effectiveness. Additional, more direct, measures that can be used in conjunction with the buffer or barrier include implementation of a no feeding ordinance, scare techniques using loud sounds or Mylar® balloons with eyespots, goose repellent, trained dogs, relocation, egg tampering, hunting, sterilization or slaughter.

Design Factors

Studies recommend a minimum shoreline buffer ranging from 20 to 100 feet of vegetation with a minimum height of three feet. The vegetation should consist of native vegetation to reduce maintenance costs and improve success of the plantings. The vegetated buffer may also provide improved water quality by filtering runoff, flow attenuation, and biological uptake of pollutants.

The choice of methods depends on the size of the area to be protected, stakeholder preferences, and local restrictions that could limit the use of some techniques.

Management measures should be implemented in the early spring before waterfowl nest and become established in a location.

Experience

Vegetative barriers have been largely accepted in many communities. Some communities have used various direct measures.

Effectiveness

The effectiveness of the control measures is based on timing. Measures should be implemented prior to a goose population becoming established in an area. Geese that have become established will often defend their territory or resist any management measures.

Costs

Natural vegetative buffers are not expected to have additional costs. The cost for chemical repellent is about $190 per acre treated.(263)

4.9 Debris

Nonpoint source technologies that effectively reduce debris and floatables are described in this section. Debris and floatables can be removed at outfalls, from receiving water bodies, or from source areas on land prior to entering the stormwater drainage system or watercourses.

4.9.1 Debris/Trash Management (Litter Control)

Description

Debris/trash management involves the cleanup of litter in parks, streets, and along beaches. Debris and trash that is not picked up and properly disposed of is often washed into Lake Michigan, area watercourses, and stormwater drainage systems. An effective debris/trash management program may include placement and maintenance of additional trash receptacles; daily collection of debris from beaches, drainage ways, and storm drain inlets; preparation and posting of signs regarding proper trash disposal; fines for littering; and organization of outreach "Clean-up Days."

There are several organizations that organize cleanup and litter prevention programs, including Keep America Beautiful and its local affiliate, Keep Greater Milwaukee Beautiful (KGMB). KGMB works with its communities to address neighborhood cleanup and beautification; waste reduction, reuse, and recycling; environmental education for children; environmental forums; renewable and efficient energy use; and resource conservation. KGMB facilitated over 500 different cleanup events involving over 50,000 participants in southeast Wisconsin in 2005.

Keep America Beautiful suggests a five-step attitude change process, which includes: (264)

1) Getting the facts about the littering problem
2) Involving people with influence over the issue and involve volunteers
3) Plan systematically
4) Focus on the results
5) Provide positive reinforcement

One study found that 18% of all littered items end up in our streams and waterways. Debris/litter management is a preventive practice to reduce the litter within watercourses and within stormwater drainage systems.(265)

Design Factors

The effectiveness of the program is linked to the frequency of regular trash pickup, the number and location of trash recepticles, and the frequency of emptying the trash receptacles.

Successful implementation of the debris/trash management program is no litter in the watercourses, on the beaches or at the treatment plants.

Some trash and debris may be collected by other technologies, such as skimmer boats and street sweepers.(266)

Experience

KGMB was established in 1983 and has won over 24 national, state, and local awards. Over 50,000 people participated in cleanup programs in the greater Milwaukee area in 2004.

The MMSD and Milwaukee County Parks Department conducted a one-year demonstration project from May through September in 2005 to clean and groom Bradford Beach. The cleanup included both trash and cladophora removal.(267)

Adopt-a-Highway programs are in place across the United States to facilitate clean-up of litter and debris along highways.

Trash/debris management programs are included as a good housekeeping activity in the Tennessee BMP Manual and to some degree is part of most municipal operations.(268)

The California Regional Water Quality Control Board, the Los Angeles Region, and the State Water Resources Control Board (Water Boards) have adopted a trash Total Maximum Daily Load (TMDL) for the Los Angeles River. The USEPA defines a TMDL as a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards.(269) The ultimate goal of the TMDL is to achieve a 100% reduction in trash discharges to the Los Angeles River by 2015.(270,271)

Effectiveness

KGMB picked up over 5 million pounds (about 2,500 tons) of litter and trash and cleaned over 300 miles of rivers and lakes, and over 6,000 acres of parks in the Milwaukee area in 2004.(272)

The MMSD Bradford Beach cleanup project removed approximately 20 cubic yards of trash, debris and cladophora from May through September in 2005.(273) It is estimated that 80 to 90%

of the material collected was cladophora. The beach grooming also helped reduce bacteria levels in the sand.(274)

The Great American Clean-up 2005 collected 104,000 tons of litter and debris across the United States.

Costs

The cost for a trash receptacle is estimated to be $175.(275) Litterbug.org estimates that litter cleanup costs are about nine times more than the costs to collect trash from public and private trash receptacles.(276)

The Bradford Beach cleanup project conducted by MMSD and the Milwaukee County Parks Department employed a potato picker machine to groom the sand and remove trash, debris and cladophora from May 10, 2005 to September 30, 2005 at a cost of $54,000, or about $1,100 per acre per month. (277,278) The disposal service for the collected material is estimated to have cost about $8,000 for the five-month period, or $160 per acre per month.(279) Bradford Beach is about one mile long and covers just under 10 acres.

Using a cost estimate developed to determine the cost of complying with the trash TMDL in California, adjusting for the winter months and the fact that Milwaukee beaches are open only five months per year, the annual cost to implement a litter prevention and cleanup program within the MMSD's planning area would be about $5,170,000. (280) This includes costs for beach clean up, enhanced street sweeping, litter law enforcement, various end of pipe trash capture devices and landfill disposal.(281)

Landfill disposal costs for litter, including a dumpster, transportation of material to landfill, and tipping fee, are estimated to be $70 per ton.

4.9.2 End of Pipe Outfall Nets

Description

End of pipe outfall nets are typically a floatable control technology used on CSO outfalls designed to reduce the amount of visible solids at outfall locations. They can also be configured to catch nonfloatables if desired, and can be used to control floatables at storm sewer outfalls. There are two parts to this system: the end of pipe chamber where the nets are housed, and the nets themselves. Typically, two nets are used per outfall chamber, but more can be added to accommodate larger outfalls. The entire system is designed to have a minimum life span of 20 years, while the nets need to be replaced at least once a month or as required after storm events (depending on the volume captured). The nets and their contents are disposed of by the municipality. The nets can be used effectively during freezing conditions. Floatables are transported under the ice and into the nets, and when the ice thaws, the nets are replaced. There are also nets designed to be used at high velocity outfalls. These specialized nets are used where discharge velocities exceed 7ft/sec, and are more expensive than the standard netting.(282)

Design Factors

Location of the netting is critical for maintenance and proper implementation.(283) The area needs to be accessible by a road to accommodate not only maintenance crews and their vehicles, but also cranes for the initial placement of the prefabricated structures. For the netting to function properly, they should be protected from extreme currents and be located where they will not interfere with heavily navigated waterways.

Experience

Initial pilot tests were completed at three locations in New York and New Jersey. Due to the success of these pilot tests, the use of netting has expanded at all three locations and beyond.(284)

Effectiveness

The three demonstration projects in New York and New Jersey found the removal efficiency ranged from 90-97%. This efficiency percentage was determined by using a secondary boom and curtain to capture missed floatables.

Costs

The planning and construction of the netting system can range from $107,000 to $427,000, depending on the site conditions. The capital cost of a typical two-net system, which handles 500 lbs of damp weight per net with a 15ft span of an outfall is approximately $178,000. The fabrication and installation can take three to six months. The estimated capital cost of the disposal associated with the netting system can range from $35,600 to $107,000, with an additional operation and maintenance cost of $2,100 per month. Each net costs approximately $140.(285)

4.9.3 End of Pipe Outfall Booms

Description

End of pipe outfall booms, or containment booms, are floating structures with suspended curtains used to capture floatables from sanitary or combined sewer overflows or storm sewer outfalls. The suspended curtains can also be designed to capture oils and grease. The booms are typically anchored to the shoreline and fitted with anchors to the boom out in the water.(286) The structure can be used downstream of one or multiple outfalls. The material that is captured in the curtains is removed after a storm event by means of a vacuum truck or skimmer vessel, or manually. This removal should occur regularly and as soon as possible after an event, due to the high visibility of the captured material in the curtain. Due to this maintenance requirement, the use of booms may not be desired near waterfront development. There is also some National Pollutant Discharge Elimination System (NPDES) permitting authorities that may not approve the use of containment booms because they are constructions within the natural boundaries of the waterway.

Design Factors

The booms are sized based on an anticipated volume of floatables during a set design-storm. They can not be used if the water body is frozen, has high river velocities, or where high winds are common as booms may become dislodged.

Experience

A two-year pilot study of a four-boom system was tested in the Jamaica Bay of New York City. The study produced an average efficiency of 75%. Skimmer vessels removed 40 tons of material from the curtain during the two-year study. (287)

Effectiveness

Efficiency of the booms can range from 60-90% of floatables.

Costs

The installation costs for a boom can range from $142,000 to $214,000. Capital costs for the pilot study were $342,000 for the four-boom system, with operation and maintenance costs of $7,100 over eighteen months. The expense of removing the floatables from the curtain and then disposing them also needs to be addressed. These costs will very depending on the method of removal and the method of disposal.(288)

4.9.4 End of Pipe Vortex Separators

Description

A vortex separator is a circular chamber used in a storm sewer or combined sewer system to remove sediment and other solids from stormwater. Water enters the circular chamber and flows in a centrifugal manner. Due to the circular motion, sediment and other suspended solids settle out more quickly than they would in a straight line flow. Sediments settle out to the floor of the unit. Floating solids are trapped by a surface weir or screen.(289)

A vortex separator is installed below the ground surface, and it discharges to a storm or combined sewer. The size of the unit is based on the tributary drainage area. The units come in a variety of sizes and are manufactured by several different companies. The vortex separators do not have moving parts and do not require a power supply. The units are typically prefabricated, which allows for relatively quick installation. The vortex separators can be installed in areas where surface space is limited.(290)

Components of a vortex system include piping for water inflow and outflow, a circular chamber where the water flows to separate out solids and floatables, and possibly a baffle-type chamber to further separate floatables.(291)

Design Factors

The size of the unit is based on the tributary drainage area and associated flow rates.

Maintenance includes regular inspection and removal of collected materials. There are no filters or other replaceable parts that require regular maintenance.(292)

Experience

Vortex separator technology was developed in the 1970s. They are widely used across the United States, including Wisconsin.

Vortex systems are more effective in removing larger particles such as sand than fine sediments such as silt.(293)

A Vortechs® system installed at the Riverwalk site in Milwaukee to treat runoff collected from a 0.25-acre portion of Interstate 794 was used by the USEPA as part of The Environmental Technology Verification Program.(294)

Effectiveness

Verification testing conducted by the USEPA indicated that the reduction in the sand fraction was 94% while the reduction in the silt fraction was 21%.(295)

The effectiveness of vortex separators varies depending on the manufacturer and flow conditions. The following pollutant removal rates have been indicated: (296)

- Total suspended solids: 25%
- Total phosphorus: 19%
- Nitrate and nitrite nitrogen: 6%
- Copper: 30%
- Zinc: 21%

Similar pollutant removal rates have been noted for a Vortechs® unit installation in Milwaukee: (297)

- Total suspended solids: 35%
- Total phosphorus: 61%
- Copper: 33%
- Zinc: 24%

Costs

The cost for a 3 cubic feet per second capacity unit from CDS Technologies is $19,200. Maintenance costs are estimated at $1,050 per unit based on three cleanouts per year.(298)

4.9.5 Skimmer Boat Operation

Description

A skimmer boat is designed to collect floating debris and trash from the water surface.(299) Skimmer boats typically use a conveyor belt system to collect the floatables. The boats may be equipped with articulated arms or booms. The primary source of floatables in the waterways is trash from roadways that enters the storm drain system.(300)

Control of floatable material is an important component of USEPA's CSO Control Policy.(301) The use of skimmer boats is one method to reduce or eliminate the visible solid waste that often results from CSO discharges and other sources.(302)

The operators may also be able to monitor waterways for other signs of pollution such as illicit discharges, fish kills, and sheens. The skimmer boat operations almost always require companion equipment, including a shore conveyor for offloading, a truck for disposal, and a trailer for land transport.

Design Factors

The size and features of the boat should reflect the area of operation, including width, height, maneuverability, capacity, and depth.

The U.S. Coast Guard does not require a specific license to operate a skimmer boat. However, considerable skill and a crew of two are typically required to operate these vessels. Skimmer boats typically do not perform well in high winds, in the wakes of other vessels, in strong currents, or in the presence of ice.

Experience

The MMSD operated the Harbor Mate Skimmer Barge from 1991 through 1994. A new skimmer was purchased in 1998. Currently, a Milwaukee real estate company manages the operation of the vessel with the contributions from a group of local businesses and the MMSD.(303) The vessel is used every spring and after every CSO event.(304) The skimmer operation is currently confined to the estuary area.

Many coastal cities employ skimmer boats to maintain clean harbors and ports.

Effectiveness

New York City estimates a 90% reduction of floatable trash in the harbor due to its operation of a fleet of skimmer boats.(305)

In Milwaukee, the Harbor Mate Skimmer Barge annually collected approximately 700 cubic yards of floatables (399 tons) when the skimmer boat was in full operation. It was assumed that 90% of all debris in the estuary was collected during each outing because of access limitations, overlooked items, and other conditions.(306)

A skimmer operated on the Buffalo Bayou in Harris County, Texas collected more that 2,500 cubic yards of litter in two years of service.(307)

Costs

MMSD's average annual cost when they operated the Harbor Mate between 1991 and 1994 was $108,000 including field labor, repair labor, repair costs, and material disposal. Approximately $40,600 of the total was maintenance and repair costs. The annual costs are based on an average frequency of 46 outings per year and six hours per outing. The cost for disposal of the collected materials is estimated to be $70/ton. A new skimmer costs approximately $420,000 to $1,000,000.(308,309) Currently, MMSD contributes $4,500 every time the vessel is deployed.(310)

4.10 Other Indicators

Nonpoint source technologies that reduce or enhance other indicators associated with stormwater runoff are described in this section. The technologies described address chloride reduction, habitat improvement, land use, alternative development practices and nutrient management.

4.10.1 Convert Land to Prairie

Description

Prairies are open, herbaceous plant communities dominated by native grasses, wildflowers, and forbs.(311) Prior to European settlement, vast expanses of prairie existed in southern Wisconsin. Periodic burning helped maintain the prairies. Due to agricultural development and fire suppression, more than 99% of the prairies in Wisconsin were destroyed.

Small remnants of prairies still exist, and there is renewed interest in restoring prairies. Benefits of prairies include reduced stormwater runoff, natural filtering and cleansing of stormwater, natural aesthetics, bird and wildlife habitat, increased diversity of native plant species and organisms, protection of rare and endangered species, and conservation of topsoil.(312) Some researchers also believe that prairies can influence carbon and nitrogen cycling in both natural and human managed ecosystems, which could impact the global climate system.(313,314,315)

Prairies may be considered in areas where pre-settlement prairies were established. An appropriate site should have full sun exposure, suitable soils and drainage conditions, and access for maintenance. Once the plant communities are established, prairies need periodic burning to prevent the encroachment of woody plant species. During each burn, non-native plants are destroyed, allowing prairie plants more nutrients and space to grow. Prairie species are able to survive the fires due to their deep root system.

Design Factors

Undertaking a prairie restorative project involves:

1) Selecting a site
    - Full exposure to the sun
    - Suitable soils
    - Suitable drainage and groundwater conditions
    - Appropriate adjacent land use
    - Protection from human disturbance
    - Access for maintenance and prescriptive burning
2) Planning
    - Construction and maintenance procedures
    - Appropriate season for beginning the restoration
    - Selection of species and seed supplier
3) Seedbed Preparation
    - Till the soil
    - Destroy existing vegetation
    - Add soil amendments, such as organic material, if necessary
4) Obtaining and Preparing Seed
    - Select plant community species
    - Consider seedlings and plugs
    - Purchase plants and seeds from native plant supplier
    - Prepare seed (stratification and scarification if needed). Stratification prevents seed from germinating in late fall and winter and allows the seeds to germinate the following spring. Scarification is the mechanical scratching or cutting of the outside covering of the seeds.(316)
5) Planting
    - Broadcast and rake seeds

- Plant plugs (unpotted growing plants)
- Plant species

  --grasses

  --forbs

  --wildflowers

Experience

Nationwide, nearly 35 million acres of degraded agricultural land have been taken out of production and connected to native vegetation.(317) Prairie restorations are being undertaken by governmental agencies, private and non-profit organizations, universities, and private landowners.

The Comprehensive Plan for the Des Plaines Watershed published by SEWRPC in 2003 recommends restoring 20% of the potential prairie areas in the watershed, which is six square miles.(318)

Effectiveness

In the mid-1980s, the federal Conservation Reserve Program (CRP) was established, in part to oversee widespread initiatives to restore native vegetation communities. Researchers are studying whether prairie restorations are meeting the ultimate goal of ecological restoration, which is to establish a sustainable community that mimics the structure and function of a natural undisturbed ecosystem.

Like natural communities, restored prairies are not static. These communities change and respond to fire, climate conditions, seed viability, soil and groundwater changes, and species succession.

Specific objectives of the ongoing research are to:

1) Compare carbon cycling elements
2) Quantify plant phenology (leaf area), biomass, and carbon and nitrogen content
3) Compare root biomass, rooting depth profile
4) Evaluate microbial communities
5) Study soil conditions (319)

These types of studies will help define the expected long term impacts of restored prairie communities.

Costs

Restored native plant communities can be installed for costs that are similar to traditional turf grass plantings. Costs reported by Prairie Restorations, Inc., a Minnesota-based landscape firm, are as follows: (320)

Installation:	$650 to $10,300 per acre
Annual Maintenance:	$540 to $1,100 per acre

The installation costs include site preparation, materials, seeding, and planting. Installation costs increase with the more diverse seed mixtures (number of wildflower and grass types) and the number of seedlings planted. The maintenance costs include biennial prescriptive burning or mowing and occasional spot spraying or cutting.

The cost of acquiring land and conservation easements is estimated to be between $210 and $3,000 per acre in agricultural areas and up to $200,000 per acre or more in urban areas. Annual rental and incentive payments to farmers is estimated to range between $55 and $510 per acre.(321)

4.10.2 Convert Land to Wetlands

Introduction

Converting land to wetlands can be accomplished by restoration or creation. Restoration of wetlands changes the current site conditions in order to return prior converted wetlands back to wetland. Activities such as ditching, installation of drain tile, stream channelization have been used to covert wetland areas to agricultural or other land uses. Wetland characteristics, such as hydric soils and some plant or seedbeds typically remain in place in the prior converted areas. Restoration of the wetland may include breaking of drain tile, excavation, water level control, and replanting.

Creation of wetlands changes current site conditions to create a new wetland area where there is not a historical wetland area. Artificial wetlands are created by impounding water or excavating depressions for water to pond. New wetlands require proper design and construction. Stormwater treatment wetlands are typically created wetlands.

Design Factors

The key to wetland restoration is reestablishing the area’s original hydrology and topography, and restoring natural process including the original native plant cover.(322)

Factors to consider when evaluating a potential wetland site include hydrology, topography and geology, soils, biotics, land ownership, and agency requirements.(323)

Wetland restoration projects may require local, state, and federal permitting. There is funding available for many types of projects. The primary applicable regulations include Wis. Admin. Code NR 353 administered by the WDNR and federal rules adopted under Section 404 of the Clean Water Act and administered by the Army Corps of Engineers.(324)

Maintenance, monitoring, and long term management of the wetland should be included in the project to maintain the integrity of the wetland community. Invasive species, structure, plants, and incoming pollutants will require monitoring, maintenance, and management for a successful project.(325)

Experience

The Wetland Reserve Program is a voluntary program through the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service that offers landowners financial incentives and technical advice to protect, restore, and enhance wetlands on their property. WDNR staff help facilitate implementation of this wetland program, which resulted in over 13,000 acres of wetland restoration in two years (2003-2004).(326)

The Comprehensive Plan for the Des Plaines Watershed released by SEWRPC in 2003 recommends restoring all potential wetland areas within floodlands, particularly those that are currently agricultural lands or open uses, which is about 3.1 square miles.(327)

Service organizations, such as Ducks Unlimited, are also involved with numerous wetland restoration projects across the state.

Effectiveness

Diverse habitats are successfully developed in restored wetlands. A stable biological community and good annual and perennial vegetation can be established in the first year. A diverse plant and animal community can be established within three years.(328) Wetland restoration also improves water quality and helps to mitigate flooding issues.

Pollutant removals for constructed wetlands are highly variable. Monitoring results from a project conducted in the Washington, D.C. area showed that 25 wetlands averaged 75% removal of total suspended solids. Removal efficiency of total phosphorus was 45%, but some investigators have reported removal efficiencies of only 9%. In West Bloomfield, Michigan unpublished data from an NPS wetland system showed a total phosphorous removal efficiency of 85% during the growing season. Removal efficiencies of total nitrogen have been reported to be between 5-60%. The study in Washington, D.C. reported an average of 25% removal.(329)

Costs

Wetland restoration costs average between $3,800 and $15,000 per acre, including design and construction but can cost up to $20,000 or $30,000 per acre. (330,331) The cost of acquiring land and conservation easements is estimated to be between $210 and $3,000 per acre in agricultural areas and up to $200,000 per acre or more in urban areas. Annual rental and incentive payments to farmers is estimated to range between $55 and $510 per acre.(332) Annual maintenance and monitoring costs can vary considerably from about $500 to $100,000, but are typically between $7,500 and $15,000 per year.(333)

4.10.3 Fertilizer Management

Description

Fertilizer management involves controlled and accurate fertilizer application to meet the needs of the vegetation as determined by soil testing. Fertilizers can contribute to surface and groundwater pollution. Therefore, limiting their application to only what is needed can reduce their impacts to surface and groundwater pollution.

Design Factors

Although there are existing fertilizer management standards, this technology was evaluated during the alternative analysis and is, therefore, included in this chapter. NR 151 identifies fertilizer management standards for municipally controlled properties and non-municipal property with over 5 acres of pervious surface to which fertilizer is applied. The standards must be met by March 10, 2008. NR 151 requires agricultural operations to apply fertilizers in accordance with a nutrient management plan. Where applicable, existing croplands were required to comply with the standards by January 2005 and new croplands were required to comply by October 1, 2003.

Fertilizer application in developed urban areas on municipally-owned property must be in accordance with a nutrient application schedule based on appropriate soil test. Non-municipal property owners who apply fertilizer to more than five acres of pervious surface must do so in accordance with an application schedule based on soil tests. Nutrient application should be designed for the optimum health of the lawn or vegetated area.

Experience

Fertilizer management for certain types of properties is required under NR 151. Some communities in Wisconsin, such as Pewaukee and Dane County, have strictly regulated the use of fertilizers containing phosphorus in order to try to reduce the phosphorus loads to area lakes and waterways.

Effectiveness

Based on input provided by several technical experts to the Dane County Lakes and Watershed Commission, the effectiveness of restricting the use of fertilizer containing phosphorus is still uncertain. However, it appears that contributions from lawn fertilizers would be a relatively small amount of the total load – perhaps 0% to 5%.(334)

Costs

It is assumed that fertilizer management programs would pay for themselves with savings on fertilizer purchases.

4.10.4 Leadership in Energy and Environmental Design

Description

The LEED (Leadership in Energy and Environmental Design) Green Building Rating System® is a voluntary, consensus-based national standard for developing high-performance, sustainable buildings. LEED standards include:(335)

- LEED-NC: New commercial construction and major renovation projects
- LEED-EB: Existing building operations
- LEED-CI: Commercial interiors projects
- LEED-CS: Core and shell projects
- LEED-H: Homes
- LEED-ND: Neighborhood development

LEED provides a complete framework for assessing building performance and meeting sustainability goals. Based on well-founded scientific standards, LEED emphasizes state-of-the-art strategies for sustainable site development, water savings, energy efficiency, materials selection, and indoor environmental quality. LEED recognizes achievements and promotes expertise in green building through a comprehensive system offering project certification, professional accreditation, training, and practical resources.(336)

LEED was created to:

- Define “green building” by establishing a common standard of measurement
- Promote integrated, whole-building design practices
- Recognize environmental leadership in the building industry
- Stimulate green competition
- Raise consumer awareness of green building benefits
- Transform the building market (337)

The LEED criteria define a “green” building as being highly energy efficient, having high indoor environmental quality, being resource efficient, and being sensitive to its impacts on the surrounding environment.

Design Factors

LEED “points” are awarded for meeting specified LEED standards. Depending on the number of points achieved, a building can attain Platinum, Gold, Silver, or LEED certification status. While many of the standards relate to building design, energy conservation, material reuse and recycling, and indoor environmental quality, a number of standards are stormwater-related.(338)

The following LEED standards could affect the quantity and quality of stormwater runoff:

- Erosion and sediment control
- Reduced site disturbance
- Stormwater management
- Water efficient landscaping

For example, for commercial construction, peak discharge rate and volume during the one- and two-year 24-hour design storms should not exceed predevelopment rates (if existing impervious area is less than 50%) or provide a 25% reduction in the two-year 24-hour storm runoff volume (if existing impervious area is greater than 50%). For residential construction, the LEED standard requires that pervious surfaces cover at least 65% of the lot.

To manage water quality, BMPs should treat the runoff associated with 90% of the average annual rainfall (which is equivalent to treating all runoff from storm events up to about 1”). In addition, the BMPs should achieve at least an 80% reduction in post-development total suspended solids loadings.

New standards are currently under development for LEED-Neighborhood Development (ND). The U.S. Green Building Council, the Congress for the New Urbanism, and the Natural Resources Defense Council -- three organizations that represent the nation’s leaders among progressive design professionals, builders, planners, developers, and the environmental community -- are formulating these ND standards. This new rating system will integrate the principles of smart growth, urbanism, and green building into the first national standard for neighborhood design.(339) Whereas other LEED products focus primarily on green building practices, LEED-ND will emphasize smart growth aspects and neighborhood design of development while still incorporating a selection of the most important green building practices. Guided by the Smart Growth Network's ten principles of smart growth and the Charter of New Urbanism, it will include compact design, proximity to transit, mixed use, mixed housing type, and pedestrian- and bicycle-friendly design. Leed H discourages home building that would impact environmentally sensitive sites and farmland.(340)

It is anticipated that the LEED-ND system will be launched in 2008.

Experience

While more than 30,000 designers, builders, and other professionals have attended programs to learn about LEED programs, the program is relatively new. LEED was created in 1998 and the pilot version of the guidelines was introduced in 2000. Revised versions of the program were released in 2000, 2002, and 2005.

Since 2000, over 2,000 building projects have registered for LEED nationwide, and over 45 million square feet of building space has been LEED certified.

Effectiveness

Benefits of LEED certification include the following:

- Enhanced occupant well-being and comfort
- Reduced operating costs
- Reduced environmental impact
- Increased building valuation and return on investment
- Marketing advantage
- Reduced absenteeism and employee turnover
- Increased retail sales

The aggregate total return of publicly held companies affiliated with LEED outperformed the Dow Jones Industrial Average by over 18% from 2000 to 2004.(341) This may indicate well-managed, progressive companies are looking to build and operate green buildings as an opportunity to differentiate themselves as leaders in the marketplace.

Costs

The Natural Resources Defense Council reported that completing a LEED-certified green building project typically increases the upfront cost by 2%, compared to a conventional building. A study of 61 buildings conducted by Davis Langdon Adamson found that LEED certification had little or no budgetary impacts.(342)

In 2004, the U.S. General Services Administration commissioned a study of the cost of achieving Certified, Silver, and Gold LEED ratings for two building types: a courthouse and a mid-rise office building. The study concluded that achieving LEED certification would increase the building cost by about 2.1% or less. Achieving a Silver rating would increase costs by 4.4% or less, and a Gold rating would increase costs by up to 8.1%.(343)

The LEED approach is also useful for evaluating life cycle costs: over the life of a building, significant cost savings can be expected. A cost analysis in Portland, Oregon revealed that green roofs were the preferred option for two of three buildings being studied. The largest economic benefit of green roofs came from eliminating the need to replace conventional roof materials as often as every 12 years. Green roofs also lowered energy consumption of the building, reduced stormwater runoff, added aesthetic benefits, and reduced heat island effects. Other economic benefits resulted from lower water consumption and the use of recycled materials. The life cycle cost savings amounted to 13 to 16% of the building construction costs.(344)

The study conducted in California was based on 33 LEED certified buildings. In comparison to conventional building design, the average premium for these green buildings is slightly less than 2% or $3-5 per square foot. The majority of the cost is due to the increased architectural and engineering design time necessary to integrate sustainable building practices into projects. The benefits of green buildings are over ten times the average initial investment required to design and construct a green building.

TABLE 4-6
FINANCIAL BENEFITS OF GREEN BUILDINGS
(PER SQUARE FOOT)

Category	20-year NPV[1]
Energy Value	$5.79
Emissions Value	$1.18
Water Value	$0.51
Waste Value (construction only)	$0.03
Commissioning O&M Value	$8.47
Productivity and Health Value (Certified and Silver)	$36.89
Productivity and Health Value (Gold and Platinum)	$55.33
Less Green Cost Premium	($4.00)
Total 20-year NPV (Certified and Silver)	**$48.87**
Total 20-year NPV (Gold and Platinum)	**$67.31**

Note:

1) NPV – Net Present Value

Source: Kats, Greg, et. al, The Costs and Financial Benefits of Green Building – A Report to California's Sustainable Building Task Force, October 2003;
http://www.usgbc.org/Docs/Resources/CA_report_GBbenefits.pdf

4.10.5 Road Salt Management (Chloride Reduction)

Description

Road salt management involves determining the type of de-icing or anti-icing agents used, the protocol for application and quantity used, and the storage of the chemical agents. De-icing is the practice of destroying the bond between snow and ice and the pavement after it has been formed, whereas anti-icing prevents the bonding of snow and ice to pavement. Typically, the chemicals used for de-icing are the same ones used for anti-icing.(345)

Road de-icing is a widely used practice in Wisconsin to prevent snow accumulation and to melt snow and ice on road surfaces. Sodium chloride, also known as road salt, is the primary de-icer, which is used because it is readily available and has a relatively low cost. Maintenance of clear and safe roadways is essential. However, traditional de-icing has raised concerns about environmental degradation, ineffectiveness at low temperatures, and corrosion of vehicles and road structures.(346)

The environmental impacts linked to roadway de-icing include vegetation stress or die off, groundwater and surface water impacts, and aquatic life stress. Due to the potential impacts of road salt usage, alternative de-icing and anti-icing methods have been developed. Common alternative de-icing agents include: (347)

- Other chloride salts such as potassium chloride, calcium chloride, and magnesium chloride, which appear to have similar impacts as the sodium chloride.
- Calcium magnesium acetate (CMA), which is biodegradable in soil, has little adverse affect on vegetation, but may cause oxygen depletion in receiving waters and increased soil permeability. CMA materials are typically needed in larger quantities for effective de-icing and are estimated to exceed road salt cost by a factor of 10 to 20.(348)
- Sand, which is not a de-icing agent but an abrasive that can provide additional friction for vehicle tires, is chemically inert but can accumulate and bury vegetation and instream habitat.

Technology improvements for the application of de-icing and anti-icing agents include road weather information systems (RWIS) that use a geographic information system along with sensors to determine the amount of ice and snow on roadways, pre-wetting solid chemicals or use of liquid agents to provide quicker melting times and more controlled spreading and application, mechanical de-icing such as pavement heating and improved plow blade design, and calibration devices for spreaders to assist in proper application rates.

Winter maintenance pollution prevention practices to mitigate usage of de-icing and anti-icing chemicals include:

- Education of road maintenance staff to reduce the quantities of salt used and to prevent the unnecessary use of salt
- Use of snow fences
- Limiting salt application to specific areas most in need, such as steep inclines, bus routes, and main thoroughfares
- Establishment of buffer zones and filter strips on the sides of roadways to prevent direct spray and runoff from reaching sensitive surface waters and vegetation
- Development of programs that promote recycling, minimize salt usage, and protect salt/sand storage
- Construction of drain systems that direct salt-laden runoff away from sensitive areas

- Use of alternative chemicals, increase efficiency of use, increase reliance of abrasives, and change to the road surface in salt sensitive areas

Design Factors

Depth of snow should be considered. Small predicted accumulations can be easier to handle by spreading salt in advance to induce melting rather than needing to plow.

To be acceptable, an alternative de-icing chemical must be effective, readily available, and cost-effective. The environmental impacts of the alternative chemical de-icer should be sufficiently understood. Environmental impacts vary with each chemical de-icer; they include increased biological oxygen demand, ionic impacts to watercourses, soils, and plants; and contamination of drinking water sources. Environmental impacts associated with using abrasives such as sand and cinders include sedimentation, increased erosion, and impacts to soil structure.

Alterations to operational practices should be inexpensive to implement and reduce the amount of chemicals required to maintain roads. The information provided by the RWIS unit needs to be integrated and communicated to managers. Chemical pretreatment programs require proper implementation to successfully reduce maintenance costs. Mechanical approaches must be effective, easily and inexpensively maintained, and not lead to additional problems such as reducing vehicle traction in non-snow conditions.

Experience

Calcium chloride and calcium magnesium acetate are popular chemical deicing alternatives. Agricultural byproducts have also been used as a chemical deicing alternative. Abrasives such as sand and cinders have been widely used on roadways.

The Federal Highway Administration reports that Idaho reduced crashes by 83%, labor hours by 62% and material costs by 83% by using road weather sensors to manage the application of anti-icing treatments.(349)

Marquette University conducted a study between 1990 and 1991 and found that 88.3% of all injury accidents during snow storms could be avoided by deicing the roadways.(350)

Driving conditions on roads treated with all-salt mixture could be improved with sand, especially on hills and at intersections. On the other hand, snow melts considerably slower on roads that are treated with a 2:1 mixture of sand/salt, relative to roads treated with salt only.(351)

Effectiveness

Nearly all winter maintenance strategies are effective in some conditions. The manager needs to consider potential environmental impacts and the actual weather conditions to determine the most appropriate maintenance strategy.

The effectiveness of chemical de-icers varies. De-icing chemicals are evaluated with a wide range of criteria, including thermodynamic factors, physiochemical characteristics, and materials compatibility. The effectiveness of some chemical de-icers diminishes at very low temperatures.

Abrasives, such as sand and cinders, are effective at all temperatures. Normally, sand is mixed with salt to keep the sand thawed.(352)

An RWIS is an effective tool that facilities winter maintenance. This system leads to safer roads, more efficient use of de-icing materials, and lower costs.

Snow fences have been shown to make winter roadways safer and reduce maintenance costs by reducing the amount of snow on roadways.(353)

Costs

It is estimated that approximately $240 million worth of sodium chloride is used annually in the U.S. Alternative chemical de-icers are typically more expensive than sodium chloride. For example, the cost of calcium magnesium acetate is 10-20 times more expensive than sodium chloride. So, the cost per lane mile per application would jump from a range of about $2 to $7.50 up to a range of about $20 to $150. If an alternative chemical de-icer was used in the study area for the WQI project instead of sodium chloride, the additional cost would be about $28 million per year.

The cost-benefit ratios for using straight salt on two-lane highways and divided highways were 12:1 and 3:1, respectively. In contrast, the cost-benefit ratio for use of abrasives and abrasives/salt mixture on two-lane highways and freeways were 0.8:1 and 2.8:1, respectively. The greater cost of sand was due primarily to greater number of applications.(354)

The use of an RWIS reduces cost by allowing agencies to more effectively manage their resources. The Minnesota Department of Transportation (MnDOT) estimates that they have realized a 200% to 1,300% return on their investment. Maryland DOT estimates that a $4.5 million RWIS would pay for itself within 5-7 years.(355)

Prior to updating their *Snow and Ice Control Policy and Procedures* manual, Brookfield, WI typically applied 2 parts sand to 1 part salt to 290 residential lane miles and applied only salt to the remaining 162 residential lane miles. Currently, Brookfield applies a mixture of 1 part sand to 1 part salt to all 452 residential lane miles. After 12 years, Brookfield will have completed the replacement of all patrol trucks; the new trucks will be outfitted with $CaCl_2$ pre-wetting tanks. The tanks will increase the cost of each truck by $4,900. After 12 years, the additional annual cost, primarily through the use of the $CaCl_2$ pre-wetting agent, will be $52,250. This results in an additional cost of about $116 per lane mile per year. Through the use of the pre-wetting agent and the 1:1 mixture of sand to salt, Brookfield was able to reduce their annual application of salt by 600 tons per year.(356)

Mechanical means of keeping snow from accumulating on roadways reduces costs. MnDOT indicates that new fences made of plastic mesh mounted on wood frames cost approximately $9.50 per square foot. The $6,775 spent to install 720 feet of snow fence is offset by reduced snow removal costs.(357)

4.10.6 Water Softener Salt Alternative (Chloride Reduction)

Description

Water softeners typically use a negatively-charged medium and a sodium chloride solution, or brine, to remove calcium and magnesium from hard water. The system is periodically regenerated by flushing the medium with the brine. This solution is then discharged to the sewer. Because chloride is not used up during the exchange process, eventually all of the chloride added to the water softener (as salt) will end up being discharged to the sewer as spent brine. Alternative technologies that do not use a chloride solution in the ion exchange process are available and should be considered. These include catalytic treatment, magnetic treatment, electronic treatment, carbon filtrations, membrane technology, and off-site regeneration (exchange tank system).(358)

Design Factors

There are numerous alternatives available for typical residential uses. Some are maintenance free, while others require varying degrees of maintenance.

Experience

Since March 2003, it has been illegal to install automatic water softeners in Santa Clarita Valley, CA.(359)

Effectiveness

Chloride-free water softener alternatives reduce the chloride load from water softeners by 100%.

Costs

Some chloride-free water softener alternatives, such as electronic water conditioners or reverse osmosis systems, cost about the same as conventional water softeners. Others that use salt-free filtration media can cost several times more.(360)

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