APPENDIX E
TECHNICAL MEMORANDUM NO. 3

Potential Best Management Practices for Stormwater

TO: BRUCE MOSER, PROJECT MANAGER, CITY OF CORVALLIS

FROM: JAMES HANSEN, PROJECT MANAGER

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PREPARED BY: DAVE FELSTUL, BROWN AND CALDWELL

REVIEWED BY: JAMES HANSEN, BROWN AND CALDWELL

SUBJECT: POTENTIAL BEST MANAGEMENT PRACTICES FOR STORMWATER

PROJECT: CORVALLIS STORMWATER MASTER PLAN

CONTENTS

Purpose

The purpose of this technical memorandum is to identify and briefly describe Best Management Practices (BMPs) that can be used in the Corvallis area to reduce the volume or improve the quality of stormwater runoff. The BMPs are grouped according to their position in the watershed: upstream, inline (middle), or downstream. Each section contains a summary table that lists the type of BMP, its effect on peak flows, its effect on water quality, and comments on usage.

A summary table containing details of estimated pollutant removal effectiveness and costs is included as Table TM3-4. This table includes an estimate of cost per mass of pollutant removed. The relative pollutant removal effectiveness largely follows the cost of removal per impervious acre, but is not as widely applicable, hence the use of the latter in the narrative.

Upstream Flow and Quality Controls

Upstream flow and quality controls (upstream controls) are the first line of defense for stormwater flow and quality concerns. They include techniques that delay or reduce the volume of runoff and remove pollutants before they enter the conveyance system. Reducing peak flows is especially important in Corvallis because of the need to restore more natural stream flows due to fisheries concerns. Pollution prevention with upstream controls tends to be less expensive than using inline or downstream controls. Table TM3-1 contains a summary of upstream controls.

Most of the BMPs listed in Table TM3-1 are commonly referred to as "structural BMPs." This classification of BMPs requires the construction or purchase of the treatment facility. Non-structural BMPs include street sweeping and pollution reduction actions designed primarily to prevent pollution through good housekeeping measures.

Table TM3-1. Summary of Upstream Controls

Method	Peak flow reduction	Quality improvement	Applicability/Comments
U1) Roof-top catchment	Yes, 50 percent reduction in runoff volume from roof, 10 percent reduction in peak	Minimal	Flat commercial roofs
U2) Isolation of roof drains from collection systems	Yes, total flow reduction depends on ability to percolate or store water	Minimal	Residential areas with permeable soils
U3) Infiltration	Yes, both peak and total, 100 percent	Yes, soil aquifer treatment	Need permeable soils, goes with roof drain isolation
U4) Porous pavement and concrete grid/modular pavement	Peak reduction	Yes	Susceptible to clogging, needs permeable soil.
U5) Revegetation	Yes, both peak and total	Yes	Need to remove pave-ment
U6) Vegetated swales	Some attenuation	Yes	Mild slopes
U7) Vegetated filter strips	Some attenuation	Yes	Mild slopes
U8) Street sweeping	No	Yes	Vacuum/sweepers are best
U9) Pollutant reduction (non-structural BMPs)	No	Yes, pollution prevention	Good housekeeping
U10) Catch basins	Minimal	Yes	Requires maintenance
U11) Inlet/catch basin inserts	No	Yes	Requires frequent cleaning
U12) Oil/water separators	No	Yes	Industrial and commer-cial areas
U13) Sedimentation structures and ponds	Yes	Yes	Flat areas, also used for downstream treatment

U1) Roof-Top Catchment [22, 31]. This BMP stores rainfall on rooftops. Storage through establishment of a roof-top garden is known as an eco-roof. Eco-roofs have been successfully used in many European communities. They provide a significant reduction in peak flow and volume of runoff through storage and evapotranspiration which limits the stress on the stormwater and combined sewer conveyance systems. Selecting appropriate plants for the roof that are resistant to temperature and precipitation extremes, such as sedum, a hardy, low-growing succulent, helps minimize maintenance efforts.

Studies have found that eco-roofs lower maintenance costs by providing improved insulation characteristics and lengthening the roof's life expectancy to 36 years, as opposed to 12 years for a conventional commercial roof. These benefits are the result of the increased thermal mass of the roof which limits the expansion/contraction cycle. (The following website, www.roofmeadows.com/index.htm, contains additional information as well as pictures.)

Siting. Siting is dependent on roof configuration, rather than on topography. Design limitations include the load-bearing capacity of roofs (an eco-roof will add at least 15 pounds per square foot), the pitch of the roof (pitches up to 50 degrees have been reported), and the ability of the roof to resist leaks with longer exposure to wet conditions. This BMP is best used on large commercial or industrial roofs. It is logistically more difficult to use eco-roofs on single-family residences, which also tend to have steeper pitch. Eco-roofs can be used to retrofit existing buildings where loadings are acceptable (such as roofs that already trap water for thermal mass). However, in many cases, it will be easier to use eco-roofs with new buildings.

Costs. dollars/impervious acre: high. Eco-roofs cost more to construct than conventional roofs, but result in a net saving over the roof's life span. An eco-roof with vegetation appropriate to the climate should require little or no irrigation, fertilization, or mowing after it is established (2 years or less).

U2) Isolation of Roof Drains from Collection Systems [12, 19, 29]. Roof drains may be separated from pipes and gutters and redirected through channels or into infiltration facilities. Disconnecting roof drains from the collection system allows for treatment and reduces the peak and volume of flows.

Drainage from commercial and industrial applications tends to be more polluted than that of residential areas. Therefore, only residential roof drain disconnects are usually considered for this measure. Disconnects may not be cost effective in homes with internal roof drains due to the difficulty of disconnecting these drains. The flow from roof drains has to either be infiltrated on the property or be connected to a separate storm sewer system. Infiltration possibilities may be limited in areas with bedrock close to the surface, in areas with a high groundwater table, or in areas with very impervious soils.

Siting. This BMP is best used in areas where infiltration can be used to dispose of stormwater. Downspout infiltration systems are usually assumed to need a minimum 2 feet depth of underlying permeable soils. Slopes should be less than 25 percent. A change in the building code that requires roof drains to be connected to the sewers would be required to decouple rooftop drainage from the piped collection system.

Costs. dollars/impervious acre: high. The cost per house is usually less than $500 unless new laterals are necessary. Some areas with adverse local conditions may see higher costs.

U3) Infiltration [4, 9, 10, 16, 25, 29, 36, 43]. Infiltration facilities such as trenches and infiltration basins are designed to intercept and reduce surface runoff from developed areas. These facilities hold runoff long enough to allow it to enter the underlying soil. They can include layers of coarse gravel, sand or other media to filter the runoff before it infiltrates the soil. Infiltration helps decrease peak flow and volume of runoff.

Siting. Opportunities for larger infiltration facilities are limited in areas with clay soils, steep slopes (greater than 15 percent), or where the bedrock or water table is close to the surface (less than 4 feet from the bottom of the facility), as is the case through most of Corvallis. The only sections of the city that have areas with high infiltration rates are located in the Squaw Creek watershed, the Stewart Slough area, and along the riverbanks at the junction of the Marys and Willamette Rivers. However, most of these areas experience seasonally high groundwater tables that limit the effectiveness of infiltration when it is most needed. Potential infiltration opportunities at other locations would require a site by site evaluation.

Infiltration facilities should not be sited in areas that directly recharge underground aquifers or in areas with industrial or commercial land use.

Costs. dollars/impervious acre: high. The capital cost of infiltration facilities is relatively low, in part because they require less pipe than conventional conveyance systems. However, the maintenance costs are high due to the periodic cleaning required to remove sediment.

U4) Porous Pavement and Concrete Grid/Modular Pavement [16, 36, 43]. Porous pavement is constructed with an open-graded asphalt aggregate underlain by permeable soils or fill. Modular pavement is constructed using concrete blocks with patterns, or pavers forming open spaces that may be filled with sand and/or vegetation. Porous pavement or modular pavement may be used as a substitute for conventional asphalt pavement in low-traffic areas, such as the fringes of parking lots. They are not appropriate for most streets, which use a thick base of relatively impervious material for the foundation. The use of porous pavement or modular pavement decreases runoff and pollutants by allowing infiltration into underlying soils.

Porous pavement is very susceptible to becoming clogged with fine particulates. Sand and grit application should not be used on porous pavement. Vacuuming is required to remove fine-grain soils clogging the pavement. Corvallis building codes would need to be changed to allow the use of pavers rather than concrete or asphalt.

Siting. Must be located in areas with infiltration potential (see infiltration basins above). A 6-inch permeable base is recommended under a modular grid pavement.

Costs. dollars/impervious acre: high. Concrete grid/modular pavement is more expensive than porous pavement, but requires less maintenance. (The maintenance cost of pavers shows as a negative value in Table TM3-4 because they require less maintenance than traditional pavement).

U5) Revegetation [6, 37]. Revegetation refers to conversion of paved areas to vegetated areas. An example would be to replace some of the paved surfaces in downtown sidewalks with planted trees. Revegetation provides shade, cooler temperatures, pollutant reduction, and allows for some infiltration.

Tree interception reduces the amount of stormwater run-off by 28 percent for coniferous trees and 13 percent for deciduous trees. Conifers hold water more efficiently because on conifer needles the rain droplets remain separated. On broad leaf surfaces droplets run together and roll off. The intensity, duration, and frequency of precipitation also affect the levels of interception.

Care must be taken to select hardy species for revegetation in urban areas. Dry summer weather requires drought-tolerant plants to reduce the need for watering. In areas with heavy traffic, tolerance to exhaust fumes is important.

Siting. Revegetation may be used anywhere that soil exists for plant establishment. Poor soil conditions or heavy traffic areas may require additional soil preparation and maintenance. In completely paved areas, some benefits may be realized through the use of large planters.

Costs. dollars/impervious acre: low. The cost of revegetation is relatively low, starting at about $1 per square foot. Site preparation and irrigation, if required, can add considerable cost.

U6) Vegetated Swales [5, 11, 16, 26, 32, 41, 43]. Vegetated swales, also known as biofiltration swales, are vegetated channels with a slope similar to that of standard storm drain channels (less than six percent slope), but wider and shallower to maximize flow residence time, thereby reducing peak flows and promoting pollutant removal. Although they can be designed to allow infiltration, swales in the Corvallis area would most likely be limited to biofiltration as the pollutant removal mechanism due to the low perviousness of the soils. Swales can also be used to retrofit road medians.

Siting. Vegetated swales are most appropriate on relatively gentle slopes of less than 15 percent, with a drainage area of up to 15 acres. Swales can be incorporated into development and redevelopment projects, often as an amenity. They do require a larger easement than a piped system, however. Swales may also be used in right of ways along roads, similar to ditches.

Costs. dollars/impervious acre: low.

U7) Vegetated Filter Strips [4, 16, 29, 41]. Vegetated filter strips are narrow planted areas that provide filtration of stormwater before it enters ditches or streams. They are usually installed along parking lots and are often planted with grass. Their relatively narrow width allows placement in areas with limited space. They are designed to convey overland sheet flow and do not handle concentrated flows very well. Their use in areas with steep slopes is limited.

Siting. Slopes should be less than 5 percent, but with care, filter strips can work on slopes up to 15 percent.

Costs. dollars/impervious acre: low. The need to inspect and protect against channelized flows adds to maintenance costs.

U8) Street Sweeping [7, 34]. Sweeping removes debris and particulates from paved surfaces; it does not decrease the peak or volume of stormwater runoff. The pollutant removal effectiveness is dependent on the sweeper technology and frequency of cleaning. Street sweepers usually have a rotating brush, but may also have a vacuum, or jets for washing. Street sweeping technology has improved considerably over the last ten to twenty years; older models are not as effective as the newer ones. Sweeping is one of the best methods for removing stormwater pollutants in urban areas. This source control type of activity removes pollutants before the runoff enters the storm-water collection system or streams.

Restrictions on street sweeper operation are primarily due to traffic patterns and costs. For instance, state highway departments may be restricted by the amount of time that lanes can be blocked on highways for street sweeping. On residential streets, clearing the street of parked vehicles can also be difficult. Street sweepers require a high capital investment, thus limiting the number of sweepers available to a community.

Siting. Sweeping may be used on any paved area.

Costs. dollars/impervious acre: low. Street sweepers are a big ticket item to purchase ($150,000 to $250,000), but have only moderate operation and maintenance cost. Operational costs are dependent on frequency of use. Figure TM3-1 shows how sediment removal efficiency is related to the frequency of sweeping. Removal efficiency continues to improve with more frequent sweeping, with the maximum efficiency point lying between weekly and monthly sweeping. Increasing the frequency beyond once per week provides limited additional benefit.

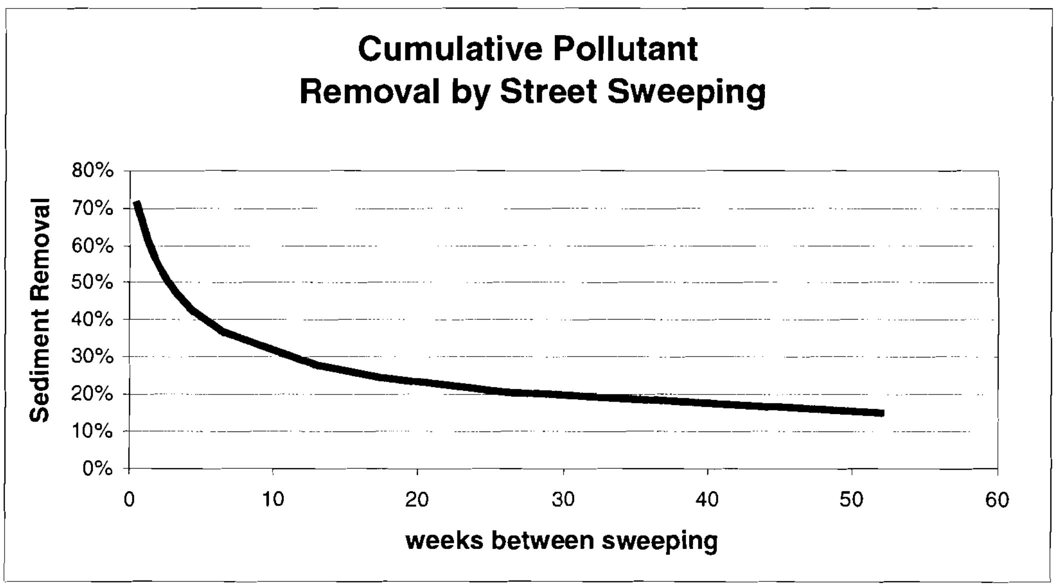

Figure TM3-1. Pollutant Removal Efficiency versus Sweeping Frequency of Street Sweepers [34]

U9) Pollutant Reduction (Non-structural BMPs). In addition to the many structural BMPs that may used to reduce the pollutants found in stormwater, there are a large number of non-structural activities that are also effective. These are often referred to as "good housekeeping" measures. Most of these activities fall into categories such as preventing the exposure of materials to rain (covering), preventing spills from entering the conveyance system (containment), and general good housekeeping measures. Non-structural BMPs may be implemented in several ways. For example, ordinances may be used to control the application of pesticides and herbicides. Public education may teach proper use of household chemicals including fertilizers. Spill prevention planning can be used to reduce problems caused by large spills of chemicals.

Most non-structural methods are not designed to decrease the rate of stormwater runoff, but to limit pollution. Their effectiveness varies widely and is difficult to quantify with any accuracy.

Siting. No siting constraints.

Costs. dollars/impervious acre: NA. The cost of most non-structural methods varies, but is relatively, inexpensive compared to structural methods.

U10) Catch Basins [4, 5, 7, 11, 23, 32, 43]. Catch basins may be designed with or without a bottom compartment that is designed to trap particulates. Without the trap, the catch basin does not remove any pollutants, and requires little maintenance. With the trap and regular cleaning, the catch basin will remove coarser particulates. Catch basins may also be constructed to trap oils and floatable trash. A drop inlet catch basin has a goose-necked outlet pipe that maintains a semi-permanent pool, trapping floatables, oils, and coarse solids.

A number of catch basin inserts are available on the market. They are designed to improve pollutant removal by inserting a series of trays, absorbent material, or filters between the catch basin inlet and the outlet pipe (see BMP U11 for details).

Siting. Catch basins are an integral part of Corvallis' conveyance system. Each catch basin typically has only a small contributory drainage area, 1/8 acre or so, when all of the City of Corvallis' (City) catch basins are considered, the overall impact of catch basins can be significant.

Costs. dollars/impervious acre: low. The cost per catch basin is relatively low, but each catch basin treats only a small drainage area, so the capital cost of the entire drainage system may be high. The operational costs are largely dependent on the frequency of cleaning. Figure TM3-2 shows that a cleaning frequency of between 6 and 9 months is probably ideal for most catch basins, although less frequent cleanings will also help. The City cleans its catch basins every year in high-traffic and leaf litter sites and every other year for other sites.

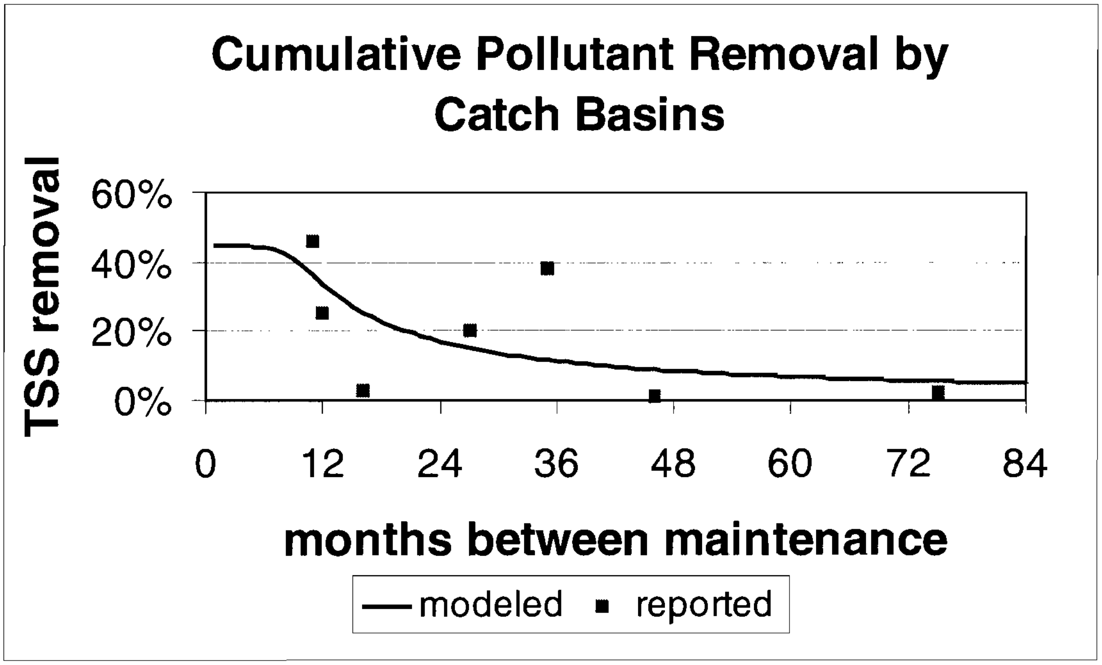

Figure TM3-2. Catch Basin Pollutant Removal versus Cleaning Frequency [7, 23]

U11) Inlet/Catch Basin Inserts [15, 27, 29, 30]. Inlet/catch basin inserts are devices that are placed within a stormwater inlet or catch basin to trap pollutants. The most common type is a fabric liner or sock. A more complex device is an arrangement of trays that have wells for sediment removal and high flow bypass capability. Field testing of inserts has shown varying degrees of effectiveness. In general, rigid inserts allow the washing out of particulates after a few storms. Fabric inserts are more effective at trapping particulates, but are usually temporary in nature and require more frequent maintenance.

Siting. Can be used with any standard configuration of inlet.

Costs. dollars/impervious acre: high. Inlet/catch basin inserts require frequent inspection and maintenance.

U12) Oil/Water Separators [16, 18, 36, 43]. Oil/water separators are multi-chambered devices that are designed to remove hydrocarbons from stormwater runoff as water flows through. Three main variations exist: spill control separators, American Petroleum Institute (API) separators, and coalescing plate separators. Spill control separators are the cheapest and least complex of the three. They consist of a simple underground vault or manhole with a "T" outlet designed to trap small spills. American Petroleum Institute separators are long vaults with baffles designed to remove sediment and hydrocarbons from urban runoff. Coalescing plate separators include a series of parallel inclined plates which encourage the separation of materials of different densities. The plates are typically made of fiberglass or polypropylene and are closely spaced to improve the hydraulic conditions in the separator and promote oil removal.

These devices can be used under a wide variety of physical conditions. They need to be placed underground, and are limited to treating runoff from small areas since low flow velocities are required to achieve treatment efficiencies.

Oil/water separators do not reduce peak flows or the volume of runoff. They can be effective at removing oil and grease and floatable trash, but are ineffective at removing fine particulates and soluble pollutants.

Siting. Slopes less than 15 percent and drainage areas less than 1 acre are suitable. Separators are sized according to runoff velocity and volume.

Costs. dollars/impervious acre: high. Purchase costs are high, but maintenance costs are low.

U13) Sedimentation Structures and Ponds [5, 29, 32, 43]. Extended detention ponds are the best example of this type of BMP. The ponds are earthen structures designed to retain water or they may be an open concrete vault designed for easy sediment removal by heavy equipment.

Siting. Slopes should be less than 10 percent. Drainage area is usually less than 10 acres.

Costs. dollars/impervious acre: medium. As with other surface structures, sedimentation ponds are often limited by the availability and cost of land.

Inline Flow and Quality Control

Inline controls are those that act on stormwater that has entered the conveyance system. They are all structural in nature and tend to be more dispersed and smaller than the downstream controls. In highly developed areas, most inline controls are located underground. Table TM3-2 contains a summary of inline controls.

Table TM3-2. Summary of Inline Controls

	Method	Peak and total volume reduction	Quality improvement	Applicability/comments
I1)	Vortex solids separation (hydrodynamic)	Minimal	Yes, depends on design and type	Also downstream treatment, good for floatables removal and settleable solids
I2)	Wet tank vault	Minimal	Yes	Washout is a problem
I3)	Sand filters	No	Yes	Also downstream control
I4)	Other filtration media	No	Yes	Also downstream control
I5)	Vortex valves and hydrocarbons	Peak flows only	No	Flow attenuation
I6)	Detention ponds	Yes, beak reduction	Yes, good pollutant removal	Need large flat area for siting

I1) Vortex Solids Separation (Hydrodynamic) [1, 2, 17, 39]. This type of device works by directing incoming water at an angle to create a vortex. The vortex directs coarser particulates toward the center where they are either stored at the bottom or removed by an underdrain for further treatment. Vortex solids separation is most effective when used with systems that have high solids loading, such as combined sewer systems. It is less effective when used with stormwater, which typically has smaller solids concentrations. However, only limited data is available from tests of these devices in the field.

> ***Siting.*** Facility size is dependent on flow. The smallest unit is about the size of a standard manhole. Siting requires adequate depth to accommodate the size of unit.
>
> ***Costs.*** dollars/impervious acre: medium.

I2) Wet Vault Tank [14, 18]. Wet vault tanks are underground tanks with baffled chambers that contain a standing pool of water. They are larger in size than most oil/water segregators, but act according to the same physical principles. They temporarily retain a portion of the stormwater runoff and remove solids by settling, and, depending on configuration, biological activity. Like most vaults, sediment washout from the previous event can be a problem if the vault is not properly designed, and during periods of dry weather, maintaining a wet pool for enhanced treatment is difficult.

Recently, Brevard County, Florida, has reported success with baffled boxes, a type of wet vault, to provide an end of pipe treatment method for up to 100 acres of drainage. These baffled boxes are constructed in line and are divided into 2 or 3 chambers by weirs. To minimize hydraulic losses, the weirs are set at the same level as the pipe invert. Trash screens or skimmers are included to trap floating debris.

> ***Siting.*** Siting information is given for the traditional style of wet vaults. Wet vaults require slopes of less than 15 percent. They typically treat drainage areas of up to 5 acres.
>
> ***Costs.*** dollars/impervious acre: low.

I3) Sand Filters [2, 8, 10, 18, 38]. Sand filters are devices that filter stormwater runoff through a sand layer into an underdrain discharge system. The underdrain conveys the treated runoff to a detention facility or to the ultimate point of discharge. A number of variations of sand filters have been developed, open units and those constructed in vaults. They generally consist of an inlet structure, sedimentation chamber, sand bed, underdrain piping, and liner to protect against infiltration.

The most typical configuration for a highly urbanized area is a sand filter contained in a vault. They are applicable to a wide variety of conditions. Like most filtration devices, they treat relatively small areas and require pretreatment in areas with high solids loadings to avoid media clogging.

Sand filters do not reduce peak flows or volumes of runoff. However, they are effective at removing most pollutants, although less effective for dissolved pollutants.

Siting. Up to 10 percent slope and 5 acres.

Costs. dollars/impervious acre: high. Capital cost is moderate, but sand filters tend to be maintenance-intensive due to their tendency to become clogged.

I4) Other Filtration Media [2, 5, 7, 11, 29]. Filtration may be achieved with media other than sand, including compost material or iron compounds. The device operates in a similar manner to a sand filter, but the configuration may be more complex. For example, the compost filter systems take the form of bales or cartridges, allowing easy replacement when they become clogged. Like sand filters, filtration with other media does not decrease peak flow or volume of runoff. Filtration with organic media, such as compost, is one of the better BMPs for removing dissolved metals. On the other hand, organic media have a tendency to add dissolved nutrients to runoff. Some recent work suggests that filtration with iron compounds may be effective in removing nutrients, but more field tests are needed.

Siting. Filtration media facilities generally serve 5 acres or less. Like other underground facilities, filtration facilities need adequate depth above the bedrock/water table.

Costs. dollars/impervious acre: medium.

I5) Vortex Valves and Hydrobrakes (various configurations) [19, 20, 40]. Vortex valves and hydrobrakes are devices which use vortex motion to restrict flow. Examples include Steinscrew, hydrobrake, wirbeldrossel, and flow valves. Passage is unrestricted at low flow rates. As flow rates increase, passage become restricted as a vortex is created by an orifice structure. As flow rates continue to increase, eventually the vortex breaks down and the normal full pipe capacity is utilized. They are often used to slow flows into the piped conveyance system by creating a pond of stormwater behind the flow restrictor, either on the surface or in the piped conveyance system. Vortex valves require less operation and maintenance effort than other flow control systems due to a lack of moving parts and control systems. They also pass a relatively constant flow rate, which aids in the operation of treatment facilities downstream.

Siting. If water is to be stored on the surface or in streets, relatively flat areas are required. The siting of vortex valves requires engineering/modeling analysis to determine where flows can be restricted without causing flood damage or damage to roadways.

Costs. dollars/impervious acre: NA. Installation into existing pipe is easy and it does not require frequent maintenance.

I6) Detention Ponds [4, 7, 9, 10, 16, 24, 36]. Ponds are one of the oldest and most effective methods of solving both flooding and water quality problems. Detention ponds are constructed to decrease flooding by lowering peak flows. (Water quality ponds are discussed as part of BMP D1.) They store runoff in an excavated or bermed basin with discharge controlled through an outlet pipe or orifice. Detention solely for flood control allows water to be impounded for much shorter periods of time, usually 24 hours or less, and does not require a permanent pool of water.

Ponds have several drawbacks: they require a large surface area, they can increase the temperature of stored water, and they may be a safety hazard. Increases in stormwater temperature may create problems where there are discharges into channels with temperature restrictions. Use of ponds in Corvallis is limited mainly because of lack of open space. Fencing may be required to address safety issues.

Siting. May be sited on slopes up to 10 percent. They can be sized to treat very large areas, but space limitation usually limits the drainage area to 20 acres or less.

Costs. dollars/impervious acre: medium. As with other surface structures, detention ponds are often limited by availability and cost of land. However, they are usually designed to minimize maintenance requirements, with up to 20 years between sediment removal.

Downstream Flow and Quality Controls

Downstream flow and quality controls (down stream controls) are located at the bottom of the drainage system. They manage higher flows and higher pollutant loads than upstream or inline controls. Downstream facilities tend to have high capital costs, due in part to their large size. But if costs are based on the number of impervious acres, downstream facilities are often quite competitive. Table TM3-3 contains a summary of downstream controls.

Table TM3-3. Summary of Downstream Controls

Method	Peak and total volume reduction	Quality improvement	Applicability/ comments
D1) Constructed wetlands and water quality ponds	Yes, peak reduction	Yes, good pollutant removal	Need large flat area for siting
D2) Fine screens	No	Yes, floatable reduction	A CDS unit has been installed in Eugene

D1) Constructed Wetlands and Water Quality Ponds [4, 10, 11, 16, 24, 36, 43]. Constructed wetlands and water quality ponds operate in much the same manner. They provide effective, long-lasting stormwater treatment. They require more space than many of the other techniques, which limits their application in fully-developed areas. Desirable wetland vegetation may be adversely affected by large changes in the water surface experienced between dry and wet seasons. Increases in stormwater temperature may be a concern with impounded water, especially when discharging into channels with temperature concerns or regulatory limits. Wetlands differ from ponds in that they are shallower, which allows more vegetation to grow. Wetlands provide greater habitat benefits than ponds and their pollutant removal effectiveness may be slightly greater.

Siting. Limited to flat areas, slopes of 5 percent or less. Can be used with drainages of up to 50 acres or more, but the size of wetlands usually becomes prohibitive in terms of land requirements. The catchment ratio is the ratio of the pond's surface area to the drainage area. The catchment ratio needs to be a minimum of 0.5 to 1.0 percent to be effective, and 1.5 percent for shallow wetlands (greater than 3 feet depth). Figure TM3-3 shows the sediment removal effectiveness of different sized ponds. The three lines in the graph represent different runoff coefficients. According to the chart, a 3-foot deep pond covering 1 percent of a drainage area with a runoff coefficient of 0.50, would remove about 75 percent of incoming suspended solids.

Costs. dollars/impervious acre: medium. As with other surface structures, wetlands are often limited by the availability and cost of land.

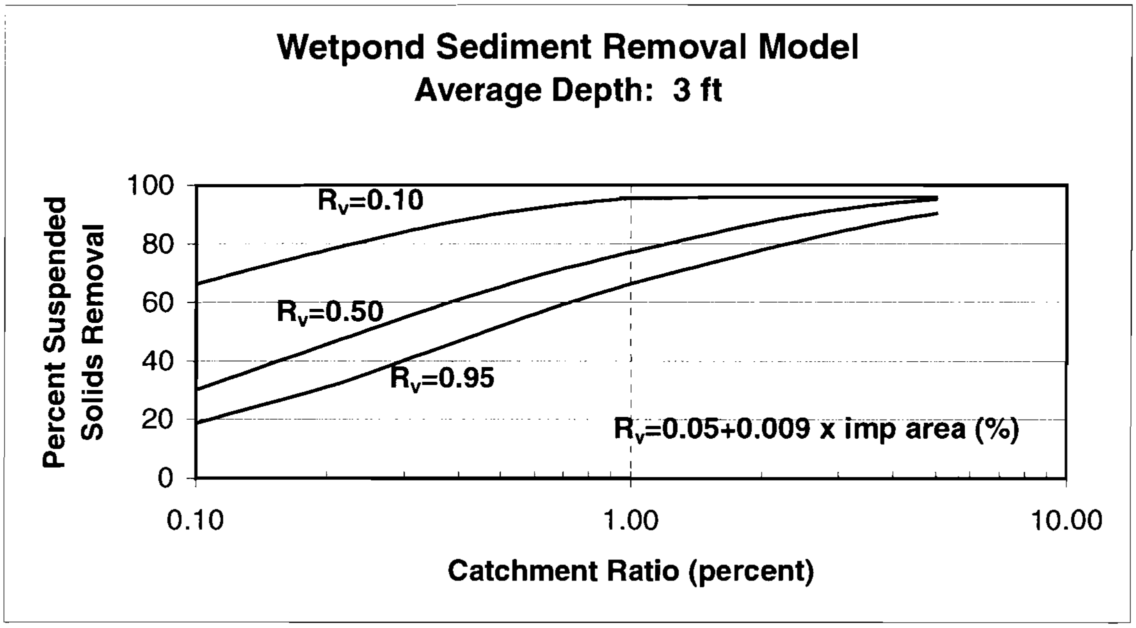

Figure TM3-3. Sediment Removal Effectiveness of Different Sized Ponds

D2) Fine Screens [17, 33, 42]. An example of the use of fine screens for CSO/stormwater treatment is a proprietary device called a Continuous Deflective Separator (CDS) system. A CDS is installed underground in a storm or combined sewer line. Like a vortex swirl concentrator, flows enter at an angle, swirling around and concentrating coarse particulates and floatables in the center. The CDS adds a fine screen on the outside of this swirling action, which deflects smaller particulates out of the water before it exits the device through the screen. Adsorbent material can be added to the center of the device to remove oil and grease.

Siting. Siting concerns are similar to those for vortex solids separators. The typical size is about that of a manhole, but when used as a downstream measure, it will need to be larger. Requirements include adequate depth to bedrock, which is dependent on drainage area and size of unit.

Costs. dollars/impervious acre: low.

Comparison of BMP Cost and Effectiveness

All of the management measures discussed above are included in Table TM3-4. The table includes columns that show pollutant removal (percent Total Suspended Solids removal) and flood control. Capital costs, operations and maintenance costs, and expected facility life are shown and then combined to give the annual cost of the facility. By estimating the area served by the facility and the incoming pollutant load, the cost per impervious acre and cost per pound of sediment removed were calculated.

The estimates of cost and facility effectiveness in Table TM3-4 are based on many assumptions of both facility configuration and drainage characteristics. As much as possible, facility configurations were based on the most common application of that type of facility. Actual facility types will vary in size, configuration, and operational characteristics. Facility effectiveness was calculated from pollutant removal models and based on the literature sources. The literature is presented in the Reference Section.

The high, medium, and low ranges for the cost per impervious area and per pound of pollutant removed shown at the bottom of the table were used to derive the costs in the narrative.

Table TM3-4. Stormwater BMP Comparative Cost and Effectiveness

	Reported efficiency		Total capital cost ($)	Annual O&M cost ($)	Expected life (years)	Annual cost $/facility	Equivalent annual cost $/impervious acre	Treatment efficiency $/lb pollutant removed	Data sources
	% TSS removal	Flood control							
Upstream Flow and Quality Control									
Rooftop catchment (eco-roof), per acre of roof	0	yes	261,360	0	36	7,260	7,260	NA	22, 31
Isolation of roof drains from collection system	0	yes	1,900	0	20	95	2,759	NA	12, 19, 29
Infiltration	80	yes	10,164	1,098	10	2,114	3,020	8.33	4, 9, 10, 16, 25, 29, 36, 43
Porous paving, per acre	90	yes	108,900	523	10	11,413	11,413	27.99	16, 36
Concrete grid/modular pavement, per acre	90	yes	226,512	-2,091	20	9,235	9,235	22.65	16, 43
Revegetation, per acre	50	yes	800	139	10	219	313	1.38	6
Vegetated swales	60	yes	20,000	139	50	539	77	0.28	5, 11, 16, 26, 32, 41, 43
Vegetated filter strips	65	no	400	100	20	120	171	0.58	4, 16, 29, 40
Street sweeping with recent technology, per sweeper	75	no	200,000	455,800	20	465,800	51	0.31	7, 34
Pollutant reduction (good "housekeeping" measures)	NA	no	NA	NA	NA	NA	NA	NA	

NA = Not Available
Note: Costs do not include land acquisition

	Equivalent annual cost	Treatment efficiency
	L < $300/ac	L<$2/lb
	M=$300-$1500/ac	M=$2-$10/lb
	H=>$1500/ac	H>$10/lb

Table TM3-4. Stormwater BMP Comparative Cost and Effectiveness (continued)

	Reported efficiency		Total capital cost ($)	Annual O&M cost ($)	Expected life (years)	Annual cost $/facility	Equivalent annual cost $/impervious acre	Treatment efficiency $/lb pollutant removed	Data sources
	% TSS removal	Flood control							
Catch basin (trapped, no inserts)	45	no	2,000	15	50	55	220	1.08	4, 5, 7, 11, 23, 32, 43
Inlet/catch basin inserts	22	no	2,400	36	5	516	2,064	20.71	15, 27, 29, 30
Oil/water separators	15	no	21,600	24	50	456	456	6.71	16, 18, 36, 43
Sedimentation structures (extended detention)	45	yes	32,243	1,290	10	4,514	645	3.16	5, 29, 32, 43
Inline Flow and Quality Control									
Vortex solids separation	52	no	5,000	250	25	450	643	2.73	1, 2, 17, 39
Wet vault tank	30	no	4,000	60	15	327	47	0.34	14, 18
Sand filters	80	no	152,460	10,672	25	16,771	2,396	6.61	2, 8, 10, 18, 38
Other filtration media (compost filter)	80	no	39,000	2,500	20	4,450	890	2.46	2, 5, 7, 11, 29
Vortex valves	0	yes	1,000	15	50	35	NA	NA	19 ,20, 40
Detention ponds	60	yes	36,554	2,000	20	3,828	547	2.01	4, 7, 9, 10, 16, 24, 36
Downstream Flow and Quality Control									
Constructed wetlands	80	yes	9,504	5,203	10	6,154	879	2.43	4, 10, 13, 16, 24, 36, 43
Fine screens (CDS)	52	no	55,000	400	25	2,600	60	0.25	17, 33, 42

NA = Not Available
Note: Costs do not include land acquisition

L < $300/ac	L<$2/lb
M=$300-$1500/ac	M=$2-$10/lb
H=>$1500/ac	H>$10/lb

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