

Appendix E

Best Management Practices Monitoring Program

System Monitoring Program Element

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City of Portland, Oregon

**Water Pollution Control Facilities (WPCF) Permit For
Class V Stormwater Underground Injection Control Systems**

Permit Number: 102830

Best Management Practice Monitoring Program

Stormwater Underground Injection Control

December 2006

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TABLE OF CONTENTS

1	Introduction and Overview	1-1
1.1	Introduction.....	1-1
1.2	Regulatory Requirements.....	1-2
1.3	Goals and Objectives	1-3
1.4	Relationship of the BMP Monitoring Program to Other Documents	1-5
1.5	BMP Monitoring Program Modifications.....	1-5
1.6	Organization of the BMP Monitoring Program	1-6
2	Water Quality BMPs	2-1
2.1	BMP Monitoring Program Development.....	2-1
2.2	General Stormwater BMPs	2-1
2.2.1	BMP Categories	2-1
2.2.2	Applying the Effectiveness Evaluation Results to UICs	2-2
2.3	Water Quality UIC BMPs.....	2-3
2.3.1	Non-structural BMPs	2-3
2.3.2	Structural BMPs	2-4
2.4	BMP Effectiveness.....	2-5
2.5	Data Gaps	2-5
3	Separation Distance BMPs	3-1
3.1	Separation Distance BMPs	3-1
3.2	BMP Effectiveness.....	3-1
3.3	Data Gaps	3-1
4	UIC BMP Monitoring Strategy	4-1
4.1	Selection of UIC BMPs for Monitoring.....	4-1
4.2	Development of Specific BMP Monitoring.....	4-2
4.2.1	Water Quality BMP Monitoring	4-2
4.2.2	Separation Distance BMP Monitoring	4-4
4.3	Monitoring and Testing Protocols	4-4
4.4	BMP Monitoring Schedule	4-4
4.5	Other Monitoring	4-4
5	Annual Reporting	5-1

Appendices

- A Summary of City of Portland BMP Effectiveness Evaluation –Water Quality BMPs
- B City of Portland BMP Development and Evaluation – UIC Separation Distance BMPs
- C Summary of Available Stormwater BMP Monitoring Information

1 Introduction and Overview

1.1 Introduction

The City of Portland (City) has prepared this Best Management Practice Monitoring Program (BMP Monitoring Program) report in compliance with the Water Pollution Control Facility (WPCF) permit issued to the City by the Oregon Department of Environmental Quality (DEQ) on June 1, 2005 for the City's underground injection control systems (UICs). The report describes the BMP Monitoring Program the City will implement throughout the permit term (June 1, 2005 – May 31, 2015) to protect groundwater quality and meet WPCF permit requirements.

The City currently has approximately 9,000 UICs that collect stormwater from public rights-of-way and discharge it to the subsurface. UICs are most prevalent in the eastern portion of the City (east of the Willamette River), where subsurface soils support greater stormwater drainage and infiltration rates. For many areas, UICs are the only available form of stormwater disposal. UICs are also an essential element of a comprehensive watershed strategy to use stormwater as a resource by infiltrating it back into the ground. UICs quickly and efficiently reintroduce stormwater into subsurface soils, which filter and cool the runoff before it finds its way to groundwater and, eventually, helps recharge streams.

As used in this document, **UIC** means any Class V underground injection control system owned or operated by the City of Portland.

The WPCF permit establishes the UIC construction, operation, and maintenance requirements the City must implement to protect groundwater for use as a drinking water resource. The permit is designed to protect groundwater by implementing a comprehensive stormwater management strategy to prevent, minimize, and control pollutants at the surface before stormwater is discharged to the ground. The WPCF permit requires the City to implement corrective actions for any UICs that do not comply with permit requirements. BMPs are one type of corrective action that can be taken. The City's strategy, to implement the permit, is described in the *UIC Management Plan* (UICMP), submitted to DEQ in December 2006.

The UICMP describes the BMPs that will be applied to the entire UIC system on an ongoing basis to meet WPCF permit requirements, protect groundwater, and support overall watershed health goals. BMPs implemented to address non-compliant UICs are described in this document and in the *Corrective Action Plan*¹. Information obtained through the implementation and evaluation of BMPs may also be used to improve actions performed under the UICMP (e.g., System Management) such as operations and maintenance procedures, education and training.

¹ The Corrective Action Plan (CAP), submitted to DEQ in July 2006, describes the process the City will use to identify, evaluate, select, implement and document corrective actions for UICs identified as noncompliant.

1.2 Regulatory Requirements

Congress enacted UIC rules in 1974 under the federal Safe Drinking Water Act (SDWA) and modified the rules in 1999. The U.S. Environmental Protection Agency (EPA) administers these rules under Title 40 of the Code of Federal Regulations (CFR) Parts 144 -148. In Oregon, EPA has delegated the regulation of UICs to DEQ. Oregon Administrative Rules (OAR) 340-044 regulate all groundwater as a potential source of drinking water and require municipalities with more than 50 UICs to operate under a permit. DEQ issued a WPCF permit to the City of Portland on June 1, 2005 (DEQ Permit Number 102830). The permit requires that the UICMP include the following:

- UIC registration database;
- Operations and Maintenance Plan;
- BMP Monitoring Program;
- UIC Monitoring Program;
- Employee training and public education; Spill Prevention and Pollution Control Plan; and
- UIC Decommissioning Plan.

The permit requires that City identify and discuss a range of BMPs (e.g., structural, non-structural, and institutional controls) that may be employed to meet permit conditions. The BMP Monitoring Program is required by Schedule D, Section 10 of the permit which reads:

- c. BMP Monitoring Program. The Permittee must include a BMP monitoring program. BMP performance is dependent upon effective public UIC maintenance. Therefore, the BMP monitoring program may be a part of the O&M Plan. The BMP monitoring Program shall be on going for the duration of the permit. The BMP monitoring program must:
- i. Evaluate the effectiveness of BMPs prior to the discharge of fluids into a public UIC to meet the discharge limits established in Table 1;
 - ii. Be designed to assess the effectiveness and limitations of applying a range of structural and non-structural BMPs in accordance with the conditions established in Table 2 and the various settings that occur throughout the City of Portland;
 - iii. Provide protocols for monitoring and testing BMPs. These protocols may be linked to the SDMP of Schedule B; and
 - iv. Provide BMP monitoring results in the annual UICMP reports.

The WPCF permit contains specific conditions that all UICs must meet. In general, a UIC is non-compliant if it meets any of the following conditions:

1. It is within 500 feet of a domestic or irrigation well and does not meet the water quality limits established in the permit.
2. It is within 500 feet or the two-year time-of-travel of a public water system and the water quality of the discharge does not meet the water quality limits established in the permit.
3. It does not meet the water quality discharge limits at the end-of-pipe discharge point into the UIC.

4. It has insufficient separation distance between the bottom of the injection well and groundwater to protect the natural water quality.
5. It is constructed into groundwater.
6. It does not meet other general permit conditions.

The WPCF permit requires the City to implement corrective actions, in accordance with a DEQ approved *Corrective Action Plan*, for any UICs that do not comply with permit requirements. Corrective actions may include a range of responses, technologies, or BMPs constructed or implemented to address or resolve the non-compliant condition. The BMP Monitoring Program describes two types of BMPs that will be implemented to address non-compliant conditions and evaluate the need for overall system improvement:

- **Water Quality BMPs.** These BMPs address UICs that do not meet water quality limits (see conditions 1-3 listed above). In other words, stormwater quality discharged at the end-of-pipe into the UIC does not meet maximum allowable discharge limits (MADLs) specified in Table 1 of the WPCF permit.
- **Separation Distance BMPs.** These BMPs address UICs that have an insufficient separation distance (see conditions 4 and 5 listed above). The WPCF permit requires that UICs more than 5 feet deep must have a minimum vertical separation distance of 10 feet between the UIC and seasonal high groundwater. UICs less than 5 feet deep must have a minimum vertical separation distance of 5 feet.

The permit requires the City to implement corrective actions for non-compliant UICs throughout the life of the permit (10 years or permit term). Non-compliant UICs must be corrected within three full Capital Improvement Program (CIP) cycles after the UIC is determined to be non-compliant. The permit recognizes and anticipates there may be situations where common problems or issues apply to a number or group of UICs within a geographic area. Regional corrective actions may be identified and performed under a permit modification or DEQ Order.

1.3 Goals and Objectives

A primary goal of the City's UIC Program and the BMP Monitoring Program is to operate, manage, and monitor the City's UIC system to ensure permit requirements are met and groundwater quality is protected. In addition, the programs help achieve the Bureau of Environmental Services' (BES) mission to:

- Protect the quality of surface and groundwater and conduct activities that promote healthy ecosystems in our watersheds, and
- Provide sewage and stormwater collection and treatment services to accommodate Portland's current and future needs.

Two goals are central to the BMP Monitoring Program:

- Protect groundwater as a drinking water resource by ensuring that stormwater discharging to UICs meets the MADLs established in Table 1 of the WPCF permit.

The most straightforward way to ensure that UICs will not adversely impact groundwater over time is to meet the MADLs established in the permit as being protective of groundwater quality. Where MADLs are not being met, BMPs can be used as corrective actions to improve the quality of stormwater discharges to the UIC system.

- Protect groundwater quality by ensuring that UICs have adequate separation distance between the bottom of the UIC and seasonal high groundwater.

The permit requires adequate separation distance as the primary mechanism to remove pollutants (e.g., bacteria) from stormwater before reaching groundwater. Where adequate separation is not present, the BMP Monitoring Program provides methods to modify the UIC to bring it into compliance.

The BMP Monitoring Program has the following objectives designed to address the BES mission, meet the above goals, and facilitate corrective actions:

1. Identify technologies that are most likely or most promising to correct non-compliant conditions (exceedance of stormwater MADLs or insufficient separation distance).
2. Demonstrate that certain types of BMP technologies are likely to meet stormwater MADLs. For example, demonstrate that stormwater planters generally provide a certain range of water quality, rather than monitor each site-specific planter used as a corrective action.
3. Identify the potential limitations of selected BMP technologies to allow for permit modifications (see Section 1.5) when best available technologies are unable to meet permit conditions.
4. Support the overall UIC Program by identifying factors that significantly affect the quality of stormwater entering the UIC system.

In summary, the BMP Monitoring Program is designed to identify and assess the effectiveness and limitations of a range of structural and non-structural BMPs. The results from the program will be used to improve the overall management of the City's UIC system.

1.4 Relationship of the BMP Monitoring Program to Other Documents

The City's UIC Management Program comprises four major program elements: System Management, System Monitoring, Evaluation and Response, and Corrective Actions. The UICMP is the umbrella document that describes these program elements and identifies the various documents the City has prepared to address specific program activities. The BMP Monitoring Program is a component of the System Monitoring program element.

The WPCF permit requires the City prepare a variety of documents that together describe the programmatic actions and management practices the City will implement to meet permit conditions and to protect groundwater. The relationship of these documents is described in the UICMP. Key documents include, but are not limited to, the following:

- *Systemwide Assessment* (July 2006);
- *Corrective Action Plan* (July 2006);
- *Final Stormwater Discharge Monitoring Plan* (August 2006);
- *UIC Decommissioning Procedure* (December 2006);
- *Operations and Maintenance Plan* (December 2006); and
- *Spill Prevention and Pollution Control Plan* (December 2006).

BMPs

BMPs refer to a range of structural and non-structural BMPs. These include specific actions taken to address non-compliant UICs and those BMPs applied system wide as described in the *UICMP*. The UICMP includes BMPs as part of the System Management element; those BMPs are actions applied to the entire UIC system on an ongoing basis to prevent, minimize, and control pollutants in stormwater prior to discharge to a UIC.

1.5 BMP Monitoring Program Modifications

Potential modifications to the BMP Monitoring Program may be identified during implementation of the program, sampling activities, or review and evaluation of the field and/or analytical data. Modifications will be addressed by revising this report or preparing addenda. Any revisions or addenda will describe the need for the modification and describe the planned activity and how it will be implemented (e.g., sampling and analyses). Potential modifications may include but are not limited to:

- Change in BMPs that may be monitored;
- Sampling design;
- Field procedures or analytical methods;
- Collection of groundwater data; and
- Collection of specific BMP effectiveness monitoring data.

Proposed modifications to the DEQ-approved BMP Monitoring Program will be submitted to DEQ for review and approval in accordance with the permit modification requirements (OAR 340-045-0055). The City will:

- Submit any proposed modification to DEQ for approval within 30 days of the modification.
- Have DEQ approval before implementing a modification, unless the modification is directed by DEQ.
- Include a summary of any modifications in the Annual UICMP Report.

1.6 Organization of the BMP Monitoring Program

The BMP Monitoring Program Report is organized into six main sections, as described below:

Section 1 provides an introduction, regulatory and permit requirements, BMP Monitoring Program goals and objectives and report organization.

Section 2 reviews available information about water quality BMPs and their applicability to UIC pollutants and conditions of concern. Recommendations are made regarding the application of those BMPs to UICs.

Section 3 assesses the various options for managing UICs with inadequate separation distances to groundwater and provides recommendations regarding their application.

Section 4 provides the basic elements of a BMP monitoring strategy to address information deficiencies concerning the effectiveness of water quality BMPs for UIC stormwater management. Monitoring protocols are included as part of the strategy.

Section 5 describes the annual reporting requirements applicable to the BMP Monitoring Program.

2 Water Quality BMPs

2.1 BMP Monitoring Program Development

Development of UIC water quality BMPs began as part of the City's response to requirements of Portland's National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer (MS4) permit. The MS4 permit required the City to develop a *Stormwater Management Plan* (SWMP) and a monitoring program. To quantify the impacts and effectiveness of BMPs, implemented under the SWMP, to reduce or remove stormwater pollutants, the City conducted a BMP effectiveness evaluation (*Effectiveness Evaluation of Best Management Practices for Stormwater in Portland, Oregon*, September 2006). The *Effectiveness Evaluation* focused on the removal of total suspended solids (TSS) to demonstrate reductions in pollutant discharges. This evaluation was the basis for selecting water quality BMPs for the UIC BMP Monitoring Program and is summarized in Appendix A.

2.2 General Stormwater BMPs

2.2.1 BMP Categories

The *Effectiveness Evaluation* assessed a wide variety of stormwater BMPs. Some of the BMPs are in current use within the City of Portland, while others have found some success in other parts of the country and/or are being considered for use in Portland. The *Effectiveness Evaluation* examined BMPs in the following two categories:

Structural BMPs	
<ul style="list-style-type: none"> • Swales • Wet Pond • Dry Pond • Revegetation (e.g., tree planting) • Stream Restoration • Treatment Wetlands • Planter Boxes • Filters • Sedimentation Box or Vault 	<ul style="list-style-type: none"> • Centrifugal Separators • Sediment Manholes • Green Streets • Porous Pavement • Soakage Trenches • Catch Basins • Catch Basin Inserts • Green Roofs

Non-Structural BMPs	
<ul style="list-style-type: none"> • Zoning, E-Zones • Operations and Maintenance (O&M) • Buffer Protections • Street Sweeping • Facility Cleaning • Technical Assistance • Stewardship • Education Programs – Business and Residents • Education Programs – City Employees and Other Agencies 	<ul style="list-style-type: none"> • Impervious Surface Reduction • Downspout Disconnect • Erosion Prevention • Parks Vegetation Management Practices • Truck Washing • Spill Response • Ditch and Channel Maintenance • Leaf and Needle Pickup • Landscape Management Practices

2.2.2 Applying the Effectiveness Evaluation Results to UICs

The *Effectiveness Evaluation* focuses on evaluating BMPs where stormwater is discharged to a receiving surface water body. For the BMP Monitoring Program, the BMPs were screened to identify BMPs that were likely to be used and technically feasible for use in conjunction with a UIC and on their estimated effectiveness in addressing the pollutants identified in Table 1 of the WPCF permit. Appendix A of this report summarizes the screening process.

Stormwater and its associated water quality pollutants are generally expected to be similar throughout the Portland area. The nature of stormwater is assumed to be independent of the point of discharge (surface water body versus UIC). BMPs that are effective for stormwater discharging to a surface water body (e.g., stream, river) therefore are generally expected also to be effective for stormwater discharged to a UIC system. However, differences may include, but are not limited to:

- The acceptable quality of stormwater at the point of discharge.
 For surface waters, the acceptable water quality limits are typically set to be protective of both human and ecological health (aquatic and terrestrial receptors) under the Clean Water Act. For UICs, the acceptable water quality limits are typically set to be protective of human use of groundwater (i.e., drinking water) under the Safe Drinking Water Act. Portland’s WPCF permit limits are based on groundwater protection standards established at the point of discharge (i.e., MADLs).
- The fate of stormwater particulates.
 For surface water, particulates are transported to and potentially deposited in the receiving surface water body and may result in sediment contamination. For UICs, stormwater particulates are removed by pretreatment (e.g., sedimentation manhole) if present, or settle in the bottom of the UIC. These sediments are typically contained in a sediment manhole or concrete sump base, where they are inaccessible to humans or ecological receptors. In addition, these sediments are removed on a periodic basis as described in the UIC *Operations and Maintenance Plan* (see Appendix B of the UICMP).

2.3 Water Quality UIC BMPs

In selecting water quality BMPs, the first priority was to identify BMPs that can address pollutants that exceeded MADLs² in year 1: pentachlorophenol, di(2-ethylhexyl)phthalate (DEHP), and lead. The second priority was to identify BMPs that can address other pollutants listed in Table 1 of the permit that were detected but did not exceed MADLs.

Some generalizations can be made about the nature of the various pollutant types, indicating the stormwater management mechanism to which they may respond:

- Organics tend to be readily adsorbed to particulate matter. Whatever mechanisms remove sediment and other particulars will be efficient in removing the associated organics. Solvent-type organics can also be stripped by aeration because of their volatile nature.
- Metals are also associated with particulate matter in large part, although significant and more bioavailable fractions of some metals can be in dissolved forms as well.
- Nutrients are removed by biological processes where conditions allow, but can also be removed by physical processes of filtration and settling when in particulate form.

2.3.1 Non-structural BMPs

The most effective way to address pollutants of any type is to prevent their release. The UICMP Evaluation and Response program element includes guidelines for pollutant source identification, source control, and source monitoring. The intent is to control pollutants at their source to prevent discharge into the City's UIC system. Because of the endemic nature of some pollutant sources (e.g., automobiles, utility poles, plastics, air deposition), however, it may take significant effort, public involvement, and many years to effect a change. Several non-structural stormwater BMPs evaluated in the *Effectiveness Evaluation* are recommended to reduce pollutant concentrations discharging to UICs, as shown below:

Stormwater Management Improvements	Non-Structural BMPs
Total suspended solids (TSS) removal (used also as a surrogate for organics and total metals removal)	<ul style="list-style-type: none"> • Street sweeping • Maintenance of UIC system components • Erosion control • Development regulation
Dissolved metals management	<ul style="list-style-type: none"> • Street sweeping • Downspout disconnection
Nutrient reduction	<ul style="list-style-type: none"> • Street sweeping • Maintenance of UIC system components
Pollutant reduction	<ul style="list-style-type: none"> • Source identification • Source control • Spill prevention and control • Public education and training

² The results of permit year 1 stormwater discharge monitoring are summarized in Appendix A.

These BMPs can be implemented citywide or tailored to specific problem areas where pollutants of concern are entering UICs above MADLs. Examples include, but are not limited to:

- Frequent street sweeping in areas determined to pose a higher risk to groundwater to reduce the potential for pollutants to be transported to the UIC system.
- Maintenance of sediment manholes, UIC sumps and catch basins (and any associated inserts) can be implemented as described in the O&M Plan (see Appendix B of the UICMP) to remove accumulated sediment (i.e., accumulated stormwater particulate) and debris that be transported to the UIC sump.

Non-structural BMPs may be important in reducing pollutants in stormwater. Non-structural controls may be evaluated by documenting compliance with specific corrective action goals, objectives, or requirements. The type of performance demonstration will depend on the specific action that is implemented. Examples of how performance may be documented and assessed include, but are not limited to:

- Documenting that a pollutant source has been terminated.
- Documenting the content of and number of attendees at public education events.
- Collecting feedback on the effectiveness of education or training (e.g., through surveys).
- Providing copies of public outreach materials.
- Documenting the content of in-house City training, the number of people trained, the learning objectives, etc.
- Providing copies of applicable land use restrictions, code, or policy changes.

Evaluating the effectiveness of non-structural BMPs is complicated by different measures of success or effectiveness in implementing the BMP. These measures do not typically correlate directly to pollutant removal or reduction (see Section 2.5).

Before selecting and implementing a BMP for a non-compliant UIC, the process described in the *Corrective Action Plan* (submitted July 15, 2006) will be followed to identify, evaluate, and select an appropriate protective action.

2.3.2 Structural BMPs

Several structural stormwater BMPs evaluated in the *Effectiveness Evaluation* are recommended to reduce pollutant concentrations discharging to UICs, as shown below.

Stormwater Management Improvements	Structural BMPs
TSS removal (used also as a surrogate for organics and total metals removal)	<ul style="list-style-type: none"> • Sedimentation manholes • Stormwater planters • Swales • Vegetated infiltration basins (e.g., curb extensions) • Filters

Stormwater Management Improvements	Structural BMPs
	<ul style="list-style-type: none"> • Wet ponds
Dissolved metals management	<ul style="list-style-type: none"> • Swales • Planters • Filters • Riparian restoration
Nutrient reduction	<ul style="list-style-type: none"> • Treatment wetlands • Wet ponds • Swales

2.4 BMP Effectiveness

Based on the results of the *Effectiveness Evaluation*, it is expected that the BMPs listed in Sections 2.3.1 and 2.3.2 will provide a significant degree of management for the majority of the pollutants (common and priority pollutant screen (PPS)) identified in the permit. Additional BMPs may be identified in the future for further evaluation (e.g., emerging or innovative technologies).

Because of the variability in BMPs, pollutants, and site-specific conditions, it is not possible to definitely determine how effective a specific BMP will be in achieving MADLs or reducing pollutant concentrations with the available data. However, the BMPs identified, in the previous sections, are those anticipated to be the most effective in improving stormwater quality. Selected BMPs will be further evaluated and/or monitoring, as described in Section 4, to demonstrate their effectiveness in meeting permit conditions and protecting groundwater. It should be noted, that before a BMP is applied to a non-compliant UIC, it will be further evaluated based on site-specific considerations, following the process described in the *Corrective Action Plan* to assure permit requirements are met and groundwater is protected.

2.5 Data Gaps

The *Effectiveness Evaluation* focused on the removal of total suspended solids (TSS) to demonstrate pollutant reduction, and TSS removal is the basis of stormwater facility design in the City's *Stormwater Management Manual*. At this time, however, it is not known if TSS is a representative surrogate for UIC pollutants such as pentachlorophenol and DEHP. It is anticipated that TSS removal would likely decrease the concentrations of these pollutants. Further evaluation is needed to demonstrate the effectiveness of the proposed structural and non-structural BMPs in achieving MADL concentrations.

TSS may be a representative surrogate for total lead, but the nature of dissolved lead relative to BMPs is less well understood. The ranges of total lead concentrations in BMP effluent (filters, swales, sediment manholes, infiltration and flow-through planters, and vegetated infiltration basins) appear to meet the total lead MADL.

Second-priority organics, metals, and nutrients should be further evaluated if they start to appear at higher levels during the stormwater discharge monitoring that will be conducted as part of the UIC Program.

Non-structural BMPs appear to be important in managing stormwater discharges. Of particular interest is the use of street sweeping to intercept pollutants on road surfaces. In addition, maintenance of stormwater facilities such as catch basins and sediment manholes will keep those facilities operating at optimum levels. Further evaluation of those practices is needed to quantify their impacts on stormwater discharges.

3 Separation Distance BMPs

The estimated 9,000 UICs in the public UIC inventory were built over many years, to a variety of design standards, and in some cases by other jurisdictions before City annexation. As a result, some UICs have been built with inadequate separation between the bottom of the UIC and seasonal high groundwater, as defined by the permit. This section identifies BMPs for addressing inadequate separation distance.

3.1 Separation Distance BMPs

BMPs that may be used to address inadequate separation distance are developed and screened in Appendix B. Most of these BMPs focus on methods that increase the separation distance. The BMPs are listed below in the recommended order for consideration.

- Fill the UIC with various types for backfill materials to achieve separation.
- Fill the UIC with various types of fill or filter materials to achieve separation and treatment.
- Fill the UIC with compactable material or grout to the appropriate level.
- Plug the openings in the UIC rings.
- Decommission the UIC; replace with a shallower UIC.
- Decommission the UIC; discharge stormwater to the piped stormwater system or combined sewer system.

The focus for the BMPs is on existing UICs, since new UICs will be constructed to be compliant with the WPCF permit.

3.2 BMP Effectiveness

The recommended BMPs listed above are considered to be effective for addressing inadequate separation distance. Before selecting and applying a BMP to a non-compliant UIC, the BMP will be further evaluated based on site-specific considerations, following the process described in the *Corrective Action Plan*.

3.3 Data Gaps

Further evaluation will be needed to determine the best methods and materials for implementing the BMPs listed above. Fill materials may be selected to provide treatment of a specific stormwater pollutant(s), if necessary, to meet MADL concentrations; in these cases, monitoring may be needed to demonstrate the effectiveness of treatment. Possible questions to explore when initiating the use of each of these BMPs include:

- What type of backfill material will provide the most protection for groundwater when used to elevate a UIC?

- How frequently must that filter material be replaced to retain filtration and infiltration capacity?
- How does filling the UIC with filter material, or raising the base of the UIC using impermeable materials, affect flow capacity? Is there a rule curve that can be developed to guide design decisions?
- How effective is plugging the openings in a UIC, both in initial installation and over time?
- What are the structural considerations and remedies (if needed) for a UIC with a portion of its openings plugged?

4 UIC BMP Monitoring Strategy

Section 2.3 of this report identifies water quality BMPs expected to provide a significant degree of management for the majority of pollutants (common and priority pollutant screen) identified in the WPCF permit. As discussed in Section 2.4, however, the estimated effectiveness of these BMPs is based primarily on TSS removal, and it is not known at this time if TSS is a representative surrogate for UIC pollutants such as pentachlorophenol and DEHP. Therefore, further evaluation is needed to demonstrate the effectiveness of the BMPs in achieving MADL concentrations.

The monitoring strategy is intended to meet the requirements established in Schedule D, Section 10(c)(ii - iii) of the WPCF permit (see Section 1.2). The UIC BMP monitoring strategy discussed below focuses on:

- Assessing the effectiveness and limitations of a range of structural and non-structural BMPs;
- Demonstrating that BMP implementation results in achieving:
 - MADLs at the point of stormwater discharge into a UIC; or
 - Adequate separation distance.
- Evaluating the feasibility of BMP implementation (e.g., site specific versus system wide)
- Supporting the overall UIC Program by identifying factors that significantly affect the quality of stormwater entering the UIC system to facilitate program improvements.

4.1 Selection of UIC BMPs for Monitoring

This section presents list of BMPs that may be further evaluated and/or monitoring under the BMP Monitoring Program. This list was developed using the BMPs identified in Section 2.3 and were represent a subset of BMPs anticipated to be the most effective in achieving stormwater discharges that meet the permit specified MADLs. In addition, the listed BMPs are those that are or are anticipated to be implemented within Portland's UIC system include:

- Improving stormwater discharge quality using:
 - Sedimentation manholes;
 - Street sweeping;
 - Maintenance of sedimentation manholes and catch basins;
 - Pollution reduction (e.g., source identification and controls; spill prevention and control; public education and training);
 - Swales (typically roadside vegetated or grass lined swales);
 - Stormwater planters;
 - Vegetated infiltration basins (i.e., curb extensions).
- Increasing Separation Distances using:
 - Filling the UIC with various types for backfill materials to achieve separation.
 - Decommission the UIC; replace with a shallower UIC(s).

In addition, additional two additional BMPs are identified that could be implemented, if necessary and appropriate, on a site-specific basis to address unique pollutant sources.

- Catch basin filters (e.g., inserts); and
- Sedimentation manhole filters (e.g., inserts).

The above lists will be used as a starting point for identifying which BMPs should be further evaluated and/or monitored under the BMP Monitoring Program to document their effectiveness and determine if they meet MADLs.

Limited data are currently available on the effectiveness of these BMPs in achieving MADLs for the pollutants specified in the permit and specifically, the three primary pollutants identified in year 1 monitoring: pentachlorophenol, DEHP, and lead (see Section 2.3). Appendix C summarizes the available monitoring information for the BMPs, based on information included in the *Effectiveness Evaluation* report.

In addition to these BMPs, the recommended non-structural BMPs or additional structural BMPs (e.g., emerging or innovative technologies) may also be evaluated, as appropriate and practicable.

Selection of specific BMPs that will be evaluated or monitored will be determined, based on a consideration of the following factors:

- Known or anticipated use (e.g. widespread or site-specific implementation);
- Nature and extent of the issue the BMP is addressing;
- Site-specific or issue-specific information;
- Pollutant characteristics;
- Specific BMP design (including consideration of variations in BMP design); and
- BMP space requirements (e.g., available land, rights-of-way); and
- Special operations and maintenance needs of the BMP (as well as the needed maintenance guidance and scheduling).

BMPs selected for evaluation or monitoring will be identified in the annual UICMP report (see Section 5).

4.2 Development of Specific BMP Monitoring

4.2.1 Water Quality BMP Monitoring

Monitoring stormwater discharge quality will be conducted on selected BMPs that are or are anticipated to be widely implemented, to reduce pollutant concentrations in stormwater discharges to City-owned UICs. Specific BMP monitoring parameters will be developed on the specific objectives of the study, nature of the issue (e.g., pollutant type), and BMP design and operation.

A key objective of the monitoring is to demonstration that specific types of BMPs can meet permit specific MADLs (i.e., a technology-specific demonstration of compliance rather than site

specific monitoring). For example, monitoring may be performed to demonstrate that stormwater planters provide a certain range of effluent water quality or pollutant reduction at the technology level (i.e., BMP type), instead of monitoring each planter that may be used as pretreatment.

BMPs selected for monitoring will be identified in the annual UICMP report. The monitoring program for the selected BMPs will be developed, based on consideration of the available effectiveness data (Appendix C) and site- or issue specific information. The primary elements of the BMP-specific monitoring program will include:

- A. A description of the specific goal(s) and/or objective(s) of the BMP monitoring.
- B. A description of the scope of the planned BMP monitoring, including but not limited to:
 - i. Sample location(s);
 - ii. Sampling frequency;
 - iii. Sampling method(s);
 - iv. Analytical method(s); and
 - v. QA/QC requirements.

Monitoring will be performed in accordance with the *Stormwater Discharge Monitoring Plan* (August 2006), to the extent practicable and feasible. The sampling program will be designed to meet the requirement of the permit (e.g., method detection and reporting limits, notification of concentrations exceeding MADLs).

- C. A description of how the results of the BMP monitoring will be evaluated. This may include, but not be limited to:
 - i. Evaluating the effectiveness and general performance of the BMP;
 - ii. Determining if the BMP demonstrates permit compliance;
 - iii. Determining if additional monitoring is needed to meet the objectives of the BMP effectiveness investigation or to address data gaps identified by the investigation; and
 - iv. Initiating BMP design changes to increase the effectiveness of the BMP.

The results of BMP effectiveness monitoring may be used to demonstrate that UIC corrective actions are protective of groundwater quality. However, some corrective actions may require specific sampling and analyses to document their effectiveness or performance. If site-specific data are needed, the data will be collected and analyzed to the extent required and feasible to be consistent with the *Corrective Action Plan*, the *Stormwater Discharge Monitoring Plan*, and the *BMP Monitoring Program*. Performance data and/or sampling results collected to demonstrate the effectiveness of a corrective action will be reported to DEQ in the Annual UICMP Report submitted in November of each year and will be used to the extent applicable to evaluate the BMPs described in this report.

4.2.2 Separation Distance BMP Monitoring

The Separation Distance BMPs are considered effective at increasing the distance of the floor of the UIC from the seasonal high groundwater table to meet permit requirements. Therefore, the BMP Monitoring Plan will focus on developing potential UIC backfill alternatives, defining criteria to identify UICs where these BMPs are applicable and evaluating the feasibility of broad application based on consideration of:

- Constructability (e.g., permitting issues, material availability, construction methods, vertical separation needed, site constraints, design limitations, utilities);
- Effectiveness (e.g., ability of UIC to handle quantity of flow with reduced infiltration capacity);
- Acceptability (e.g., legal constraints, political considerations);
- Unit Costs (e.g., operational and capital present worth expense); and
- Operational impacts (e.g., difficulty of operating and maintaining).

4.3 Monitoring and Testing Protocols

To the extent practicable, BMP monitoring data will be collected in accordance with the following documents, as applicable and appropriate:

- *Stormwater Discharge Monitoring Plan* (SDMP; August 2006), including:
 - Sampling and Analyses Plan (SAP)
 - Quality Assurance Project Plan (QAPP)
- *Decommissioning Procedure* (December 2006), including:
 - UIC Program Standard Operating Procedure (SOP) #1.00 – Sediment Sample Collection Procedures for UIC Decommissioning
 - UIC Program SOP #2.00 – Water Sample Collection Procedures for UIC Decommissioning

4.4 BMP Monitoring Schedule

The BMP monitoring schedule will be presented in the annual UICMP report submitted to DEQ each November.

4.5 Other Monitoring

Because of the ubiquitous nature of several pollutants detected in stormwater discharged to the City's UIC system (e.g., pentachlorophenol, DEHP, and total lead), specific studies may be needed to identify and document the source(s) of these pollutants. The UICMP Evaluation and Response program element includes guidelines for identifying potential pollutant sources,

performing various investigations to determine UIC compliance, and evaluating groundwater protection, as needed. Data collected under these guidelines may in some instances inform the BMP monitoring and evaluation process. To the extent practicable and feasible, similar monitoring protocols, analyte lists, and analytical methods/detection limits will be used so the data between the program elements are comparable.

Stormwater monitoring conducted as part of the Corrective Action process will also be collected using similar monitoring protocols, analyte lists, and analytical methods/detection limits to facilitate the BMP monitoring and evaluation process, to the extent practicable and feasible.

The City may collect stormwater-monitoring data associated with other programs, issues, or priorities. Those data will be incorporated into the evaluation of specific BMPs if appropriate and if the data are of known and verifiable quality.

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5 Annual Reporting

This section is intended to meet the requirements of Schedule D, Section 10(c)(iv) of the permit.

BMP monitoring data and/or sampling results collected to demonstrate the effectiveness of a BMP will be reported to DEQ in appropriate technical memorandum or reports, as necessary and appropriate, and will be summarized in the annual UICMP report submitted in November of each year. The annual UICMP report will include the following information as necessary and appropriate:

1. Information accumulated during the annual reporting period, such as:
 - a. A summary and analysis of BMP monitoring information accumulated during the annual reporting period;
 - b. Type of BMP(s) evaluated;
 - c. Characteristics of the UIC drainage basin(s) where the BMP(s) are evaluated (e.g., location, traffic type and volume, and nature of land use); and
 - d. Conclusions regarding BMP performance or effectiveness,
2. Summary of monitoring or activities planned for the upcoming permit year such as:
 - a. Monitoring elements (e.g., objectives, protocols, analytical methods); and
 - b. Schedule.

BMP monitoring data, performance data, records, and reports will be maintained in the UIC Program files and will be available for review upon request.

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Appendix A

Summary of City of Portland BMP Effectiveness Evaluation Water Quality Based BMPs

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Summary of City of Portland BMP Effectiveness Evaluation Water Quality Based BMPs

A-1 General Stormwater BMPs

The *Effectiveness Evaluation of Best Management Practices for Stormwater in Portland, Oregon* (Effectiveness Evaluation), dated September 2006, assessed a wide variety of stormwater BMPs, some of which are in current use within the City of Portland, others that have found some success in other parts of the country and or are being considered for use in Portland. The team participating in the development of the *Effectiveness Evaluation* examined BMPs in two primary categories as follows:

Structural BMPs	
<ul style="list-style-type: none"> • Swales • Wet Pond • Dry Pond • Revegetation (e.g., tree planting) • Stream Restoration • Treatment Wetlands • Planter Boxes • Filters • Sedimentation Box or Vault 	<ul style="list-style-type: none"> • Centrifugal Separators • Sediment Manholes • Green Streets • Porous Pavement • Soakage Trenches • Catch Basins • Catch Basin Inserts • Green Roofs

Non-Structural BMPs	
<ul style="list-style-type: none"> • Zoning, E-Zones • Operations and Maintenance (O&M) • Buffer Protections • Street Sweeping • Facility Cleaning • Technical Assistance • Stewardship • Education Programs—Business and Residents • Education Programs—City Employees and Other Agencies 	<ul style="list-style-type: none"> • Impervious Surface Reduction • Downspout Disconnect • Erosion Prevention • Parks Vegetation Management Practices • Truck Washing • Spill Response • Ditch and Channel Maintenance • Leaf and Needle Pickup • Landscape Management Practices

A-2 Stormwater BMP Effectiveness

The *Effectiveness Evaluation* provides a “tool box” of stormwater management BMPs currently in use or planned for use in the Portland area, along with supporting information about how the effectiveness estimates were derived, and the certainty of those estimates. The *Effectiveness Evaluation* results are intended to facilitate stormwater management design and decision-making.

The evaluation develops and documents the range of effectiveness (e.g., percent removal) and preferred values (default) for numerous stormwater BMPs. Effectiveness is described as a range for each BMP, as well as the location-specific or application-specific conditions that may affect BMP effectiveness. In addition, default effectiveness values (“typical” or “representative” effectiveness values within the range) that can be used when there is limited information about the use of a BMP, or when standard conditions apply when the BMP is functioning as expected.

Information for the *Effectiveness Evaluation* came from a variety of sources. Each source was evaluated for its significance, and the best available information was used. The process included both the use of prior studies (as they can be applied locally) and the judgment of BES staff and other professionals. Where directly measured information was unavailable, staff used professional judgment to extrapolate from available data and use various estimation techniques as appropriate. The values presented in the *Effectiveness Evaluation* report represent the best available current information and professional judgment. The values should be considered “a work in progress” and a starting point for further discussion.

The comprehensive list of BMPs evaluated enables the BMPs to be compared against each other. It also helps identify significant elements of unavailable data and resulting uncertainty regarding BMPs. If some pollutants or conditions have few effective BMPs associated with them, future study or development of BMPs can be directed at those pollutant or conditions, if necessary. A compilation of BMPs can also frame assumptions regarding the interrelatedness of BMPs and how those BMPs may (or may not) work in series.

The report also documents the decision-making and effectiveness estimation process and provides necessary qualifiers regarding the quality and reliability of the effectiveness estimates. This information is important to decision makers so they can assess levels of confidence in the evaluation and effectively manage risk and uncertainty in applying the effectiveness values.

A summary of the water quality based UIC BMPs identified as applicable to stormwater discharged to UICs and included in the *Effectiveness Evaluation* is provided in Table A-1, presented at the end of this appendix. The spreadsheet in Table A-1 identifies: BMP type, applicable contaminant class, BMP effectiveness range, qualifiers, and certainty estimates.

A-3 Water Quality Based UIC BMPs

A-3.1 BMP Screening

This section describes the process that was used to develop a list of stormwater management BMPs that would be expected to effectively protect groundwater quality from adverse impacts associated with stormwater discharges to UICs. This list represents a subset of the BMPs evaluated in the *Effectiveness Evaluation*, described above and was developed based on consideration of the types of pollutants detected in stormwater discharged to the UIC system.

A-3.2 UIC Stormwater Water Quality Criteria

Table 1 of the WPCF permit specifies the maximum allowable discharge limits (MADL) allowed in stormwater discharges to UICs and groundwater compliance limits. The BMPs selected for evaluation in the BMP Monitoring Program must be relevant to the pollutants of concern in the permit. Common pollutants identified in the permit are analyzed in all stormwater discharge samples collected in accordance with the *Stormwater Discharge Monitoring Plan* (SDMP, City of Portland, 2006). Priority pollutant screen (PPS) analytes are analyzed in permit years 1, 4, and 9. This document focuses on common pollutants. The annual mean stormwater discharge concentrations to UICs must stay below the permit specified MADLs. In the event, a PPS analyte is detected above its respective MADL, many of the BMPs used for the common pollutants are expected to be effective as well, due to similar chemical properties and anticipated pollutant fate and transport.

As described in the *Annual Stormwater Discharge Monitoring Report* for permit year 1 (City of Portland, July 15, 2006), five UIC sampling events were completed as required by the permit, between October 2005 and May 2006. Stormwater samples from discharges to City owned UICs were analyzed for both common pollutant and PPS analytes (*e.g.*, metals, volatile organic compounds, semivolatile organic compounds, and pesticides) as defined by the permit. Thirteen of the 14 common pollutants were detected during Year 1 including: benzene, toluene, xylenes, benzo(a)pyrene, di(2-ethylhexyl)phthalate (DEHP), pentachlorophenol, arsenic, cadmium, chromium, copper, lead, zinc, and total nitrogen. Ethylbenzene was not detected in Year 1. Seven of the 27 PPS analytes were detected during Event 1 and included: antimony, barium, beryllium, mercury, selenium, 2,4-D, and dinoseb. These seven PPS analytes were monitored during Events 2 through 5 to obtain a total of five samples as required by the permit.

Thirty-five ancillary pollutants³ were detected at low concentrations (generally less than 1 µg/L) in Year 1. Twenty-one of these were detected at a frequency of less than 9% including 16 that were detected at a frequency of less than 3% during individual sampling events. The nine compounds that were detected at the highest frequencies during the individual sampling events were polycyclic aromatic hydrocarbons (PAHs). Of these naphthalene had the highest

³ Ancillary pollutants are defined as analytes detected by the DEQ approved analytical methods in the SDMP. The permit requires these pollutants be included in the annual monitoring report.

concentration (3.61 µg/L); the maximum concentrations of the other PAHs were, in general, less than about 0.6 µg/L.

Three common pollutants were detected in Year 1 at concentrations above their respective MADLs during individual sampling events:

1. Pentachlorophenol (nine UIC locations),
2. DEHP (four UIC locations), and
3. Lead (three UIC locations)

Annual mean concentrations were all below their respective MADLs, with the exception of pentachlorophenol, which exceeded the MADL at five UIC locations. The detected concentrations of PPS analytes were below their respective MADLs for both individual events and annual mean concentrations.

For purposes of this report, the common pollutants detected in Year 1 above their respective MADLs, pentachlorophenol, DEHP, and lead, constitute the first priority for identification of BMPs to address those COCs. The second priority for identification of associated BMPs is the other common pollutants detected but not exceeding MADLs

The pollutants selected as priorities in the prior section are listed in Table A-2 below along with some chemical characteristics, as appropriate, as clues to the stormwater management mechanisms to which they might respond. Some generalizations can be made about the nature of the various pollutant types:

- i. Organics tend to be readily adsorbed to particulate matter. Whatever mechanisms remove sediment and other particulars will be efficient in removing the associated organics. Solvent-type organics can also be stripped by aeration due to their volatile nature.
- ii. Metals, in large part, are particulate associated as well, although significant and more bioavailable fractions of some metals can be in dissolved forms as well.
- iii. Nutrients are removed by biological processes where conditions allow, but can also be removed by physical processes of filtration and settling when in particulate form.

A-3.3 Potential BMP Constraints for Application to UICs

The great majority of City-owned UICs are located within paved public rights of way (ROW). Typically these are areas with limited space, being very visible to adjacent properties and competing with other ROW utilities as well as parking demands. BMP application to address stormwater pollutants must consider traffic safety and be amenable to the rigors of vehicle and pedestrian intrusions. Depending on the pollutant of concern, the BMP itself may not be designed with high rates of infiltration to assure groundwater protection.

A-4 Effectiveness Evaluation Data Limitations

TSS has been extensively monitored and so has relatively high quality information about pollutant removals. Those results, however, are expressed in a variety of ways for the BMP and pollutants of concern including pounds per year for specific application, percent removals and effluent concentrations. For purposes of evaluating the applicability and sufficiency of particular BMPs to meeting MADLs, effluent concentrations are needed.

There is no information about how various BMPs might influence effluent concentrations when used as part of a treatment train (rather than just individually). Due to space limitations at the typical UIC (sump) site, use of series BMP may be impractical. So this issue may be of less concern.

Also, the specific relationship between TSS, as a surrogate, and the two organic constituents of concern, pentachlorophenol and DEHP, has not been established. A correlation between each organic pollutant and TSS is needed to convincingly use the available TSS effluent concentrations.

No information was available about the impact of sediment manhole maintenance on effluent concentrations for the three pollutants of concern. Measurements of “before” and “after” maintenance are needed for a series of “full” conditions for the manholes to evaluate the optimum maintenance trigger condition for each type of pollutant.

Total lead reduction has much more information associated with it. Conversion of pounds per year information to effluent concentrations is still required for street sweeping and catch basin maintenance. As noted above, there were no studies of sediment manholes identified in the *Effectiveness Evaluation* for total lead removal.

The MADLs for PCP, DEHP and total lead are 1.0 ug/L, 5.0 ug/L, and 50.0 ug/L, respectively. The only BMPs that can be directly related to those MADLs on an effluent concentration basis, based on information from the *Effectiveness Evaluation*, are total lead reductions using swales, curb extensions, stormwater planters, sediment manholes, and catch basins. All of those BMPs, even at the high effluent concentration end of the ranges, reduced total lead concentrations below the MADL. That was true also of sediment manholes and catch basins with or without the addition of filters: based on the general effluent concentrations for filters there was little benefit to including insert filters to either of those BMPs.

Significant amounts of TSS can be removed by all the chosen BMPs, but whether that would result in concentrations low enough to achieve MADLs cannot be determined. Typical stormwater influent concentrations of the three pollutants of concern tend to be low to begin with (even when exceeding MADLs), so attaining any level of removal may be difficult and potentially unpredictable.

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Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	BMP Effectiveness Range				Default Positive Impact	Qualification	Certainty (H, M, L, or %)
					Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Dissolved Copper	ug/L	75	High influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	63	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Dissolved Copper	ug/L	75	high influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	63	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Dissolved Copper	ug/L	75	high influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	63	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Filters	Sand, gavel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Dissolved Copper	ug/L	5.8	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	2.2	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	3.7	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Dissolved Copper	ug/L	7.5	High velocities, poor infiltration, low facility size to drainage area ratio	4.3	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	5.7		M
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Dissolved Copper	ug/L	9.1	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	3.7	Low influent concentrations; high O&M frequency; adequate depth below outlet	6.2		L
Filters	Sand, gavel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Dissolved Lead	ug/L	0.16	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	0.11	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	0.13	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Filters	Ecoroofs	Metals	Dissolved Lead	ug/L	0.64	Soil media with high mineral content, thinner soil(?)	ND	Soil media with high organic content, thicker soil(?)	0.20	Default value is the average of the concentrations for both soil media for all events.	L
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Dissolved Lead	ug/L	0.42	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	0.14	Low influent concentrations; high O&M frequency; adequate depth below outlet	0.26		L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Dissolved Lead	ug/L	0.69	High velocities, poor infiltration, low facility size to drainage area ratio	0.34	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	0.5		M

Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

					BMP Effectiveness Range						
BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts	Default Positive Impact	Qualification	Certainty (H, M, L, or %)
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Dissolved Lead	ug/L	25	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	11	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Dissolved Lead	ug/L	25	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	11	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Dissolved Lead	ug/L	25	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	11	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Filters	Sand, gavel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Dissolved Zinc	ug/L	13	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	4.8	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	8.3	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Dissolved Zinc	ug/L	24	High velocities, poor infiltration, low facility size to drainage area ratio	17	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	20		M
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Dissolved Zinc	ug/L	50	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	26	Low influent concentrations; high O&M frequency; adequate depth below outlet	38		L
Filters	Ecoroofs	Metals	Dissolved Zinc	ug/L	66.2	Soil media with high mineral content, galvanized metal on roof, use of moss control chemicals, larger storms	7.7	Soil media with high organic content, smaller storms	24.3	Default value is the average of the concentrations for both soil media for all events.	L
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Dissolved Zinc	ug/L	560	high influent concentrations, low metal content in soil	110	Low influent concentrations, high metal content in soils	240	Based on synthetic stormwater for 1 facility (Inglewood, Maryland). Values not indicative of local, Portland conditions.	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Dissolved Zinc	ug/L	560	high influent concentrations, low metal content in soil	110	Low influent concentrations, high metal content in soils	240	Based on synthetic stormwater for 1 facility (Inglewood, Maryland). Values not indicative of local, Portland conditions.	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Dissolved Zinc	ug/L	560	high influent concentrations, low metal content in soil	110	Low influent concentrations, high metal content in soils	240	Based on synthetic stormwater for 1 facility (Inglewood, Maryland). Values not indicative of local, Portland conditions.	10%

Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	BMP Effectiveness Range				Default Positive Impact	Qualification	Certainty (H, M, L, or %)
					Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Metals, general	% Removal	43	Low influent concentrations, faster draining soils (gravels & sands), high metal content in soils, runoff from roofs	98	High influent concentrations, slower draining soils (silts & clays), low metal content in soil, runoff from streets	90	Literature seldom gives effluent concentrations; consistent removals for dissolved and total > 90%; not much difference with depth. Roof runoff typically contains much higher proportions of dissolved metals.	M
Infiltration Stormwater Planters	Infiltration Planters	Metals	Metals, general	% Removal	43	Low influent concentrations, faster draining soils (gravels & sands), high metal content in soils	98	High influent concentrations, slower draining soils (silts & clays), low metal content in soil	90	Literature seldom gives effluent concentrations; consistent removals for dissolved and total > 90%; not much difference with depth.	M
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Metals, general	% Removal	43	Low influent concentrations, faster draining soils (gravels & sands), high metal content in soils	98	High influent concentrations, slower draining soils (silts & clays), low metal content in soil	90	Literature seldom gives effluent concentrations; consistent removals for dissolved and total > 90%; not much difference with depth.	M
Filters	Sand, gravel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Total Copper	ug/L	8.4	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	3.4	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	5.7	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Total Copper	ug/L	14.7	High velocities, poor infiltration, low facility size to drainage area ratio	8.4	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	11.4		M
Filters	Ecoroofs	Metals	Total Copper	ug/L	27.1	Soil media with high mineral content, newer ecoroof, unestablished vegetation	4.9	Soil media with high organic content, older ecoroof, established vegetation	11.5	Default value is the average of the concentrations for both soil media for all events.	L
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Total Copper	ug/L	19.7	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	10.3	Low influent concentrations; high O&M frequency; adequate depth below outlet	14.7		L
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Total Copper	ug/L	85	high influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	69	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Total Copper	ug/L	85	high influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	69	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Total Copper	ug/L	85	high influent concentrations, low metal content in soil	55	Low influent concentrations, high metal content in soils	69	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%

Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	BMP Effectiveness Range				Default Positive Impact	Qualification	Certainty (H, M, L, or %)
					Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Filters	Ecoroofs	Metals	Total Lead	ug/L	0.88	Soil media with high mineral content, thinner soil(?)	ND	Soil media with high organic content, thicker soil(?)	0.30	Default value is the average of the concentrations for both soil media for all events minus one outlier on west side.	L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Total Lead	ug/L	8.8	High velocities, poor infiltration, low facility size to drainage area ratio	5.6	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	7.2		M
Filters	Sand, gravel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Total Lead	ug/L	10.2	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	6.1	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	8	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Total Lead	ug/L	12.3	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	6.2	Low influent concentrations; high O&M frequency; adequate depth below outlet	9.1		L
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Total Lead	ug/L	26	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	16	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Total Lead	ug/L	26	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	16	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Total Lead	ug/L	26	high influent concentrations, low metal content in soil	6.7	Low influent concentrations, high metal content in soils	16	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Filters	Sand, gravel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Metals	Total Zinc	ug/L	185	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	10	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	15	Use high values for sand, low values for compost, activated carbon, zeolite.	L
Swales	Broad, shallow, vegetated channels and infiltration swales	Metals	Total Zinc	ug/L	58	High velocities, poor infiltration, low facility size to drainage area ratio	39	Low velocities, good infiltration, use of mulch (adsorption), presence of some clay fines for adsorption, high facility size to drainage area ratio	48		M
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Metals	Total Zinc	ug/L	119	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	68	Low influent concentrations; high O&M frequency; adequate depth below outlet	92		L

Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	BMP Effectiveness Range				Default Positive Impact	Qualification	Certainty (H, M, L, or %)
					Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Metals	Total Zinc	ug/L	1400	high influent concentrations, low metal content in soil	120	Low influent concentrations, high metal content in soils	390	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Infiltration Stormwater Planters	Infiltration Planters	Metals	Total Zinc	ug/L	1400	high influent concentrations, low metal content in soil	120	Low influent concentrations, high metal content in soils	390	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Metals	Total Zinc	ug/L	1400	high influent concentrations, low metal content in soil	120	Low influent concentrations, high metal content in soils	390	Based on synthetic stormwater for 1 facility (Inglewood, Maryland).	10%
Swales	Broad, shallow, vegetated channels and infiltration swales	Nutrients	Total Phosphorus	mg/L	0.26	High velocities, high P content in native soils, low infiltration rates (or none), low facility size to drainage area ratio	0.17	Low velocities, low P content in native soils, good infiltration rates, high facility size to drainage area ratio	0.21	Values exceed TMDL for Fanno Creek; function of inflow concentration.	M
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Nutrients	Total Phosphorus	mg/L	0.29	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	0.15	Low influent concentrations; high O&M frequency; adequate depth below outlet	0.22		M
Filters	Sand, gravel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Nutrients	Total Phosphorus	mg/L	0.3	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	0.19	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	0.15	High effluent concentrations with sand or compost. Low effluent with zeolite, activated carbon.	L
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Nutrients	Total Phosphorus	% Removal	16	Shallow soil (< 12"), high P levels in soil, flow-through system	70	Greater soil depth (> 24"), low P levels in soil, infiltration system	50	Assumes 18-24" of soil	L
Infiltration Stormwater Planters	Infiltration Planters	Nutrients	Total Phosphorus	% Removal	50	Shallow soil (< 12"), high P levels in soil, flow-through system	87	Greater soil depth (> 24"), low P levels in soil, infiltration system	70	Assumes 18-24" of soil	L
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Nutrients	Total Phosphorus	% Removal	50	Shallow soil (< 12"), high P levels in soil, flow-through system	87	Greater soil depth (> 24"), low P levels in soil, infiltration system	70	Assumes 18-24" of soil	L

Table A-1 Summary of BMP Effectiveness

BMP Group: Structural

BMP Type	Specific BMPs Included in Type	Contaminant/Condition Class	Specific Contaminant/Conditions Included in Class	Units	BMP Effectiveness Range			Default Positive Impact	Qualification	Certainty (H, M, L, or %)	
					Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts				Conditions Favoring High Positive Impacts
Swales	Broad, shallow, vegetated channels and infiltration swales	Sediment	TSS	mg/L	29	Channelized flow, poor infiltration rates, steep (> 5%), > 3:1 side slopes, sparsely vegetated or grass too tall (little or no mowing), high intensity storm events	19	Non-channelized flow, good infiltration rates, gentle slope (<= 5%), <= 3:1 side slopes, heavily vegetated, routinely mowed resulting in high stem density, check dams, low intensity storm events	24		M
Filters	Sand, gravel, compost, peat or other media systems: Flow through planters, Stormfilter, sand filters, vegetated filters	Sediment	TSS	mg/L	52.7	Extreme local conditions, e.g. erosion; low O&M frequency; incorrect match of media to pollutants, e.g. inert media to dissolved pollutants	32.9	Low influent concentrations; high O&M frequency; correct match of media to pollutants, e.g. sorptive media to dissolved parameters	42	Removal rates are heavily dependent on filter material and pollutant form. Inert media, such as sand, removes only particulates and associated pollutants. Sorptive media (compost, activated carbon, zeolite) can remove both particulates and dissolved substances.	L
Sediment Manholes	In-line sedimentation manholes and vaults/boxes	Sediment	TSS	mg/L	90	Extreme local conditions, e.g. erosion; low O&M frequency; relatively shallow depth below outlet	45	Low influent concentrations; high O&M frequency; adequate depth below outlet	66		L
Flow-through Stormwater Planters	Flow-through planter Planter boxes (Filterra, New Columbia)	Sediment	TSS	% Removal	81	Faster draining soils (gravels & sands)	90	Slower draining soils (silts & clays)	85		M
Infiltration Stormwater Planters	Infiltration Planters	Sediment	TSS	% Removal	81	Faster draining soils (gravels & sands)	90	Slower draining soils (silts & clays)	85		M
Vegetated Infiltration Basins	Veg Infil Basins, Rain Gardens, Curb Extensions	Sediment	TSS	% Removal	81	Faster draining soils (gravels & sands)	90	Slower draining soils (silts & clays)	85		M

Table A-1 Summary of BMP Effectiveness

BMP Group: Non-Structural					Effectiveness Range				Default Positive Impact	Qualification	Certainty (H,M,L or %)
BMP Types	Specific BMPs Included in Type	Contaminant/ Condition Class	Contaminant/ Conditions Included in Class	Units	Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Impervious cover disconnect (Roofs)	Downspout disconnect multi-family residential	Metals	Total Copper	lbs reduced/year	1.0	These values were calculated using the lowest concentration of metals found in roof runoff.	19	These values were calculated using the highest concentration of metals found in roof runoff.	2	Assume that 100 multi-family residential buildings had the rooftops disconnected and that the average rooftop is 15000 sf.	H
Impervious cover disconnect (Roofs)	Downspout disconnect single-family residential	Metals	Total Copper	lbs reduced/year	31	These values were calculated using the lowest concentration of metals found in roof runoff.	436	These values were calculated using the highest concentration of metals found in roof runoff.	54	Assume that 22400 single family homes had the rooftops disconnected and that the average rooftop is 1500 sf.	H
O & M	Catch Basin Cleaning	Metals	Total Copper	lbs reduced/year	0.000011655		0.005326668	Assume a cleaning frequency of once a month (12 times per year)	0.00058275	The default assumes cleaning once a year. The effectiveness of pollutant removal depends on the frequency of cleaning. Pollutant removal is low if catch basins are not cleaned at least every 15-20 months and there is a steep decline in effectiveness if cleaned more than once every six months.	M
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Metals	Total Copper	%	20		23		22	Not directly analogous, since they're comparing different maintenance schemes and don't have a "do nothing" control	L
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Metals	Total Copper	lbs reduced/year	18	Assume that 5,000 feet of ditch are cleaned per year	55	Assume that 15,000 feet of ditch are cleaned per year.	43	Assume that for every foot of ditch that is cleaned there is one cubic foot of sediment removed. The default assumes that 11,727 feet of ditch are cleaned per year based on the City of Portland annual submittal year 10. The high and low values are estimates based on best professional judgment.	L
O & M	Street Sweeping Residential Area	Metals	Total Copper	lbs reduced/year	34	Assume a street sweeping frequency of 6 times per year.	57	Assume a street sweeping frequency of 49 times per year.	47	Default assumes a street sweeping frequency of 12 times per year. Assume that there are 10,000 lane miles swept per year	M
O & M	Street Sweeping Industrial Area	Metals	Total Copper	lbs reduced/year	42	Assume a street sweeping frequency of 6 times per year.	109	Assume a street sweeping frequency of 87 times per year.	92	Default assumes a street sweeping frequency of 23 times per year. Assume that there are 5,000 lane miles swept per year.	M
O & M	Street Sweeping Commercial Area	Metals	Total Copper	lbs reduced/year	160	Assume a street sweeping frequency of 23 times per year.	242	Assume a street sweeping frequency of 6 times per year.	210	Default assumes a street sweeping frequency of 49 times per year. Assume that there are 10,000 lane miles swept per year.	M
O & M	Catch Basin Cleaning	Metals	Total Lead	lbs reduced/year	0.000042		0.0191952	Assume a cleaning frequency of once a month (12 times per year)	0.0021	The default assumes cleaning once a year. The effectiveness of pollutant removal depends on the frequency of cleaning. Pollutant removal is low if catch basins are not cleaned at least every 15-20 months and there is a steep decline in effectiveness if cleaned more than once every six months.	M
Impervious cover disconnect (Roofs)	Downspout disconnect multi-family residential	Metals	Total Lead	lbs reduced/year	0.1	These values were calculated using the lowest concentration of metals found in roof runoff.	32	These values were calculated using the highest concentration of metals found in roof runoff.	4	Assume that 100 multi-family residential buildings had the rooftops disconnected and that the average rooftop is 15000 sf.	H
Impervious cover disconnect (Roofs)	Downspout disconnect single-family residential	Metals	Total Lead	lbs reduced/year	2	These values were calculated using the lowest concentration of metals found in roof runoff.	735	These values were calculated using the highest concentration of metals found in roof runoff.	81	Assume that 22400 single family homes had the rooftops disconnected and that the average rooftop is 1500 sf.	H
O & M	Street Sweeping Residential Area	Metals	Total Lead	lbs reduced/year	73	Assume a street sweeping frequency of 6 times per year.	123	Assume a street sweeping frequency of 49 times per year.	101	Default assumes a street sweeping frequency of 12 times per year. Assume that there are 10,000 lane miles swept per year	M
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Metals	Total Lead	lbs reduced/year	66	Assume that 5,000 feet of ditch are cleaned per year	198	Assume that 15,000 feet of ditch are cleaned per year.	155	Assume that for every foot of ditch that is cleaned there is one cubic foot of sediment removed. The default assumes that 11,727 feet of ditch are cleaned per year based on the City of Portland annual submittal year 10. The high and low values are estimates based on best professional judgment.	L
O & M	Street Sweeping Industrial Area	Metals	Total Lead	lbs reduced/year	90	Assume a street sweeping frequency of 6 times per year.	234	Assume a street sweeping frequency of 87 times per year.	196	Default assumes a street sweeping frequency of 23 times per year. Assume that there are 5,000 lane miles swept per year.	M
O & M	Street Sweeping Commercial Area	Metals	Total Lead	lbs reduced/year	340	Assume a street sweeping frequency of 23 times per year.	517	Assume a street sweeping frequency of 6 times per year.	449	Default assumes a street sweeping frequency of 49 times per year. Assume that there are 10,000 lane miles swept per year.	M
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Metals	Total Lead	%		No data		No data		Not directly analogous, since they're comparing different maintenance schemes and don't have a "do nothing" control	

Table A-1 Summary of BMP Effectiveness

BMP Group: Non-Structural					Effectiveness Range				Default Positive Impact	Qualification	Certainty (H,M,L or %)
BMP Types	Specific BMPs Included in Type	Contaminant/ Condition Class	Contaminant/ Conditions Included in Class	Units	Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
Impervious cover disconnect (Roofs)	Downspout disconnect multi-family residential	Metals	Total Zinc	lbs reduced/year	0.2	These values were calculated using the lowest concentration of metals found in roof runoff.	86	These values were calculated using the highest concentration of metals found in roof runoff.	25	Assume that 100 multi-family residential buildings had the rooftops disconnected and that the average rooftop is 15000 sf.	H
O & M	Catch Basin Cleaning	Metals	Total Zinc	lbs reduced/year	0.0000644		0.02943264	Assume a cleaning frequency of once a month (12 times per year)	0.00322	The default assumes cleaning once a year. The effectiveness of pollutant removal depends on the frequency of cleaning. Pollutant removal is low if catch basins are not cleaned at least every 15-20 months and there is a steep decline in effectiveness if cleaned more than once every six months.	M
O & M	Street Sweeping Residential Area	Metals	Total Zinc	lbs reduced/year	101	Assume a street sweeping frequency of 6 times per year.	170	Assume a street sweeping frequency of 49 times per year.	140	Default assumes a street sweeping frequency of 12 times per year. Assume that there are 10,000 lane miles swept per year	M
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Metals	Total Zinc	lbs reduced/year	101	Assume that 5,000 feet of ditch are cleaned per year	304	Assume that 15,000 feet of ditch are cleaned per year.	237	Assume that for every foot of ditch that is cleaned there is one cubic foot of sediment removed. The default assumes that 11,727 feet of ditch are cleaned per year based on the City of Portland annual submittal year 10. The high and low values are estimates based on best professional judgment.	L
O & M	Street Sweeping Industrial Area	Metals	Total Zinc	lbs reduced/year	125	Assume a street sweeping frequency of 6 times per year.	324	Assume a street sweeping frequency of 87 times per year.	272	Default assumes a street sweeping frequency of 23 times per year. Assume that there are 5,000 lane miles swept per year.	M
Impervious cover disconnect (Roofs)	Downspout disconnect single-family residential	Metals	Total Zinc	lbs reduced/year	5	These values were calculated using the lowest concentration of metals found in roof runoff.	1967	These values were calculated using the highest concentration of metals found in roof runoff.	564	Assume that 22400 single family homes had the rooftops disconnected and that the average rooftop is 1500 sf.	H
O & M	Street Sweeping Commercial Area	Metals	Total Zinc	lbs reduced/year	472	Assume a street sweeping frequency of 23 times per year.	716	Assume a street sweeping frequency of 6 times per year.	622	Default assumes a street sweeping frequency of 49 times per year. Assume that there are 10,000 lane miles swept per year.	M
O & M	Catch Basin Cleaning	Nutrients	Total Phosphorus	lbs reduced/year	0.0003003		0.13724568	Assume a cleaning frequency of once a month (12 times per year)	0.015015	The default assumes cleaning once a year. The effectiveness of pollutant removal depends on the frequency of cleaning. Pollutant removal is low if catch basins are not cleaned at least every 15-20 months and there is a steep decline in effectiveness if cleaned more than once every six months.	M
O & M	Street Sweeping Residential Area	Nutrients	Total Phosphorus	lbs reduced/year	538	Assume a street sweeping frequency of 6 times per year.	904	Assume a street sweeping frequency of 49 times per year.	747	Default assumes a street sweeping frequency of 12 times per year. Assume that there are 10,000 lane miles swept per year	M
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Nutrients	Total Phosphorus	lbs reduced/year	472	Assume that 5,000 feet of ditch are cleaned per year	1,416	Assume that 15,000 feet of ditch are cleaned per year.	1,107	Assume that for every foot of ditch that is cleaned there is one cubic foot of sediment removed. The default assumes that 11,727 feet of ditch are cleaned per year based on the City of Portland annual submittal year 10. The high and low values are estimates based on best professional judgment.	L
O & M	Street Sweeping Industrial Area	Nutrients	Total Phosphorus	lbs reduced/year	666	Assume a street sweeping frequency of 6 times per year.	1,723	Assume a street sweeping frequency of 87 times per year.	1,448	Default assumes a street sweeping frequency of 23 times per year. Assume that there are 5,000 lane miles swept per year.	M
O & M	Street Sweeping Commercial Area	Nutrients	Total Phosphorus	lbs reduced/year	2,511	Assume a street sweeping frequency of 23 times per year.	3,815	Assume a street sweeping frequency of 6 times per year.	3,312	Default assumes a street sweeping frequency of 49 times per year. Assume that there are 10,000 lane miles swept per year.	M
O & M	Catch Basin Cleaning	Sediment	TSS	lbs reduced/year	0.35	Assume a cleaning frequency of 0.01 times per year .	159.96	Assume a cleaning frequency of once a month (12 times per year)	17.5	The default assumes cleaning once a year. The effectiveness of pollutant removal depends on the frequency of cleaning. Pollutant removal is low if catch basins are not cleaned at least every 15-20 months and there is a steep decline in effectiveness if cleaned more than once every six months.	M
O & M	New developments and redevelopments - post-construction condition	Sediment	TSS	lbs/year	71,023		710,227		213,068	Assumes the SWMM is effective as currently designed and written. Intensity and volume is managed at 90%.	
O & M	Street Sweeping Residential Area	Sediment	TSS	lbs reduced/year	253,333	Assume a street sweeping frequency of 6 times per year.	425,455	Assume a street sweeping frequency of 49 times per year.	351,515	Default assumes a street sweeping frequency of 12 times per year. Assume that there are 10,000 lane miles swept per year	M
O & M	Street Sweeping Industrial Area	Sediment	TSS	lbs reduced/year	313,333	Assume a street sweeping frequency of 6 times per year.	810,909	Assume a street sweeping frequency of 87 times per year.	681,212	Default assumes a street sweeping frequency of 23 times per year. Assume that there are 5,000 lane miles swept per year.	M

Table A-1 Summary of BMP Effectiveness

BMP Group: Non-Structural					Effectiveness Range				Default Positive Impact	Qualification	Certainty (H,M,L or %)
BMP Types	Specific BMPs Included in Type	Contaminant/ Condition Class	Contaminant/ Conditions Included in Class	Units	Low Positive Impacts	Conditions Favoring Low Positive Impacts	High Positive Impacts	Conditions Favoring High Positive Impacts			
O & M	Maintenance and cleaning of MS4 components (ditch and channel maintenance primarily)	Sediment	TSS	lbs reduced/year	550,000	Assume that 5,000 feet of ditch are cleaned per year	1,650,000	Assume that 15,000 feet of ditch are cleaned per year.	1,289,970	Assume that for every foot of ditch that is cleaned there is one cubic foot of sediment removed. The default assumes that 11,727 feet of ditch are cleaned per year based on the City of Portland annual submittal year 10. The high and low values are estimates based on best professional judgment.	L
O & M	Street Sweeping Commercial Area	Sediment	TSS	lbs reduced/year	1,181,818	Assume a street sweeping frequency of 23 times per year.	1,795,152	Assume a street sweeping frequency of 6 times per year.	1,558,788	Default assumes a street sweeping frequency of 49 times per year. Assume that there are 10,000 lane miles swept per year.	M
O & M	Erosion from construction sites	Sediment - West Portland	TSS	lbs/year	109,379	Assumes erosion controls are ineffective at some sites due to unusually poor soils, steep slopes, poor installation, and ineffective inspection and enforcement. (10% removals??)	1,053,150	Erosion control program is completely effective and implemented at every site where soil disturbance occurs (100% removals).	514,796	Assumes the existing Erosion Control Program (Title 10) is in place and effective (70% removals??)	
O & M	Erosion from construction sites	Sediment -East Portland	TSS	lbs/year	54,690	Assumes erosion controls are ineffective at some sites due to unusually poor soils, steep slopes, poor installation, and ineffective inspection and enforcement. (10% removals??)	526,575	Erosion control program is completely effective and implemented at every site where soil disturbance occurs (100% removals).	257,398	Assumes the existing Erosion Control Program (Title 10) is in place and effective (70% removals??)	

Table A-2 Summary of Pollutant Characteristics and Treatment Technologies

Priority for BMP Selection	Pollutant Type	Pollutant Name	H ₂ O Solubility (mg/L)	Log K _{ow}	Potential Treatment Technologies
First	Organic	Pentachlorophenol	2,000	5.1	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation
	Organic		0.34	5.1	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation
	Metal	Lead	870	0.73	Sedimentation, filtration, adsorption
Second	Organic	Benzene	1,800	2.1	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation, volatilization
	Organic	Toluene	530	2.7	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation, volatilization
	Organic	Xylenes	180	3.1	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation, volatilization
	Organic	Benzo(a)pyrene	0.0016	5.1	Sedimentation, filtration, adsorption, biological uptake and conversion, degradation
	Metal	Arsenic	120,000	0.68	Sedimentation, filtration, adsorption
	Metal	Cadmium	1,700	- 0.07	Sedimentation, filtration, adsorption
	Metal	Chromium	600,000	0.23	Sedimentation, filtration, adsorption
	Metal	Copper	570	-0.57	Sedimentation, filtration, adsorption
	Metal	Zinc	1,400	NR	Sedimentation, filtration, adsorption
	Nutrient	Total Nitrogen	High in soil & Water	NR	Sedimentation, filtration, adsorption, biological uptake

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Appendix B

City of Portland BMP Development and Evaluation UIC Separation Distance BMPs

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City of Portland BMP Development and Evaluation UIC Separation Distance BMPs

B-1 BMP Screening

This section provides an assessment of the various options for managing UIC with inadequate separation distances to groundwater and provides recommendations regarding their application.

B-2 Identification of Problem

The 9,000 UICs in the public UIC inventory were built over many years, to a variety of design standards, and in some cases by jurisdictions prior to City annexation. As a result some of those UICs may have been built with inadequate separation distance as defined by the permit. The focus of this discussion is on existing sumps, since new sumps or other UICs will be constructed to be compliant with the WPCF.

A UIC (*i.e.*, sump) is a specialized injection system used by the City predominantly in the right-of-way to manage stormwater discharges. Most sumps are pre-cast reinforced concrete structures similar to a typical sewer manhole. Sumps are constructed using 48-inch-diameter perforated rings stacked in sections to a total depth of between 10 and 30 feet. Newer systems have a two- or three-foot section at the bottom of a pre-cast sump that is not perforated and has a solid concrete floor. This section collects sediments, keeping the sump from clogging the surrounding native soils and keeping pollutants that adhere to those sediments out of the groundwater. The middle and upper rings (except the manhole cone, if present) are perforated to allow for infiltration.

Water is directed into the UIC sumps from sedimentation manholes and inlets at the street surface. Stormwater discharged into an UIC sump (without a sedimentation manhole) falls to the bottom, settles out larger sediment, and then infiltrates through the perforations in the ring sections to flow through the backfilled gravels into the surrounding native soil structure.

This configuration is not universal, but the most common feature is significant depth. The *Systemwide Assessment* (City of Portland, July 15, 2006) identified approximately 400 UICs with potentially inadequate separation distance. Therefore, potential methods of increasing separation distance were evaluated to identify BMPs to address this issue.

B-3 Identification and Evaluation of Potential Technologies to Increase Separation Distance

Four basic technologies and their associated BMPs were identified to increase separation distances to meet permit requirements. The BMPs were screened against basic criteria used in the corrective action process (see *Corrective Action Plan*, July 2006), including:

- Constructability – space available to build, potential utility conflicts, permitting issues, construction methods available, room vertically to get out of groundwater
- Effectiveness – able to handle quantity of flow while meeting MADLs
- Acceptability – aesthetics, legal constraints, political considerations
- Unit Costs – operational and capital present worth expense
- Operational impacts – difficulty of operating and maintaining

The evaluation of the technologies and BMPs are presented below. The basis for retaining or rejecting the BMP for further evaluation or consideration is included.

1. Decommission the UIC altogether or replace it with a shallower UIC

- Decommission the UIC (see UICMP and *UIC Decommissioning Plan* submitted December 2006);

Evaluation: BMP rejected. Decommissioning a UIC without provisions for ongoing stormwater management (infiltration or transport) is not acceptable.

- Decommission the UIC, replace with a shallower UIC or horizontal UIC (e.g., infiltration gallery)

Evaluation: BMP retained. Because a shallower UIC facility will require much more space to provide the same amount of infiltration, the likelihood of utility conflicts is higher and available sighting is lower. Such a facility is also more likely to create disruptions in traffic and inconvenience to neighbors. Maintenance of such a UIC depends on the particular design, but may be problematic. Costs of decommissioning and the new installation could be significant. In specific circumstances, however, a shallower UIC may be a viable and necessary option.

- Decommission the UIC, discharge to piped stormwater system or combined sewer

Evaluation: BMP retained. Technically this alternative uses fairly conventional piped solutions for management of stormwater. Practically, however, an alternate discharge point is not likely to be very convenient to the UIC location. UICs have historically been used in areas where stormwater systems are distant or non-existent. Their more recent use in combined sewer areas has been to remove stormwater volume from the combined system to reduce the potential for combined sewer overflows. Both stormwater system or combined sewer discharge are expensive options involving either installation of lengthy stormwater conveyance systems, expansion of system capacity (stormwater or combined), or both. Only in very limited and unusual circumstances will this alternative be considered.

2. Artificially lower the groundwater table using groundwater extraction

Evaluation: BMP rejected. Groundwater extraction not feasible or practical due to operation and maintenance costs, lack of facility for extracted water disposal, and political and legal constraints.

3. Elevate the lowest point of discharge from the UIC to a depth that achieves the required separation distance

- Plug the openings in the sump rings

Evaluation: BMP retained. The construction of this alternative is more complicated, potentially requiring confined space entry and specialized equipment. Obtaining a watertight seal to the level required might not be possible, especially with older UIC installations. There may also be hydraulic loading concerns in that the UIC will extend below the water table creating external pressure not considered in the original UIC design. Concerns regarding loss of effective infiltration capacity and volume apply. An advantage to this design is the retention of the deepest part of the UIC as a settling chamber, similar to a sediment manhole providing additional water quality capacity.

- Fill the sump with compactable material or grout to appropriate level

Evaluation: BMP retained. As with 4A filling the UIC with compactable materials or grout is a relatively simple operation. Grout is more expensive than compactable material, but probably more effective as a barrier assuming that is a design objective. The loss of infiltration area and water storage volume in the UIC is more likely than 4A. This configuration may require an additional facility (and associated costs and potential area disruption) to manage excess stormwater rates and volumes. Operational expense for this design is less once the facility is modified, but if another facility is needed to augment the original, overall operational expenses will increase. Space may not be available if another facility is needed.

- Install a new, higher floor in the sump

Evaluation: BMP rejected. This alternative would have the same overall effect as 3B, but absent filling the UIC first with materials upon which the new floor could be built, would require significant structural modification of the UIC to support the new floor. Maintaining an inaccessible void space below the new floor is operationally impracticable.

- Install a slip-liner in the sump, but with a base at the level of adequate separation

Evaluation: BMP rejected. This is essentially the same as 3C but using an unproven, and potentially unavailable, technology for this purpose. Such a liner is unlikely to be installed without fill underneath it for structural support.

4. Fill the UIC with appropriate backfill or filter materials

- Filling the sump with various types for backfill materials (e.g., sand, gravel) to get separation

Evaluation: BMP retained. Selected backfill materials could retain the UICs flow management capacity while providing the same water quality management characteristics as the native soil surrounding the UIC. No additional space is required at ground level, and assuming the necessary infiltration capacity and storage volume for flows served; no other facilities must be constructed. Filling of the UIC is a relatively low cost operation once the appropriate level of fill is determined. The presence of the backfill materials must be documented for maintenance purposes to prevent inadvertent removal, and the materials may need to be replaced periodically assure filtration and infiltration capacities.

- Fill the sump with various types of fill or filter materials (e.g., total organic carbon, activated carbon, organoclay) to get separation and treatment.

Evaluation: BMP retained. Same as 4A, however material also selected to provide some stormwater treatment.

Appendix C

City of Portland Summary of Available Stormwater BMP Monitoring Information

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Summary of Available Stormwater BMP Monitoring Information

Stormwater BMP	Status of Available Information		
	Pentachlorophenol	DEHP	Total Lead
Street sweeping	Information limited to TSS reduction (as a surrogate for organic pollutant removal) in pounds per year	Information limited to TSS reduction (as a surrogate for organic pollutant removal) in pounds per year	Directly measured reduction values in pounds per year, with differentiation by residential, commercial and industrial land use areas
Maintenance of sediment manholes	No direct measurement or surrogate estimates of effectiveness	No direct measurement or surrogate estimates of effectiveness	No direct measurement or surrogate estimates of effectiveness
Maintenance of catch basins	Information limited to TSS reduction (as a surrogate for organic pollutant removal) in pounds per year	Information limited to TSS reduction (as a surrogate for organic pollutant removal) in pounds per year	Directly measured reduction values in pounds per year
Swales	Information limited to TSS effluent concentration (as a surrogate for organic pollutant removal) ranging from 19 mg/L to 29 mg/L	Information limited to TSS effluent concentration (as a surrogate for organic pollutant removal) ranging from 19 mg/L to 29 mg/L	Directly measured effluent concentrations ranging from 5.6 ug/L to 8.8 ug/L
Curb extensions (identified as vegetated infiltration basins)	Information limited to TSS reduction (surrogate for organic pollutant removal) as percent removals of TSS ranging from 81 to 90%	Information limited to TSS reduction (as a surrogate for organic pollutant removal) as percent removals of TSS ranging from 81 to 90 %	Directly measured effluent concentrations ranging from 6.7 ug/L to 26.0 ug/L, and in another study as percent removals for general metals removal from 43 to 98%.
Stormwater planters	Information limited to TSS reduction (surrogate for organic pollutant removal) as percent removals of TSS ranging from 81 to 90 %	Information limited to TSS reduction (as a surrogate for organic pollutant removal) as percent removals of TSS ranging from 81 to 90%	Directly measured effluent concentrations ranging from 6.7 ug/L to 26.0 ug/L, and in another study as percent removals for general metals removal from 43 to 98%.
Sediment manhole filters (inserts)	Information limited to TSS effluent concentrations (as a surrogate for organic pollutant removal). Sediment manholes without filters range from 45 mg/L to 90 mg/L for TSS. General filter values for TSS range from 32.9 mg/L to 52.7 mg/L	Information limited to TSS effluent concentrations (as a surrogate for organic pollutant removal). Sediment manholes without filters range from 45 mg/L to 90 mg/L for TSS. General filter values for TSS range from 32.9 mg/L to 52.7 mg/L	Directly measured effluent concentrations for sediment manholes without filters ranging from 6.2 ug/L to 12.3 ug/L. Generally filter effluent concentrations range from 6.1 ug/L to 10.2 ug/L
Catch basin filters inserts	Information limited to TSS effluent concentrations (as a surrogate for organic pollutant removal). General filter values for TSS range from 32.9 mg/L to 52.7 mg/L	Information limited to TSS effluent concentrations (as a surrogate for organic pollutant removal). General filter values for TSS range from 32.9 mg/L to 52.7 mg/L	Generally filter effluent concentrations range from 6.1 ug/L to 10.2 ug/L

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