

EFFECTIVENESS EVALUATION

of Best Management Practices for Stormwater Management in Portland, Oregon

September 2006

VERSION 1

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ACRONYMS

ACWA: Association of Clean Water Agencies (Oregon)	MS4: Municipal Separate Storm Sewer System
BES: Bureau of Environmental Services	NPDES: National Pollutant Discharge Elimination System
BMP: Best management practice	PCB: Polychlorinated biphenyl
BOD: Biochemical oxygen demand	PWMP: Portland Watershed Management Plan
COD: Chemical oxygen demand	SAC: Stormwater Advisory Committee
CWA: Clean Water Act	SDWA: Safe Drinking Water Act
DEQ: Department of Environmental Quality (Oregon)	SWMM: Stormwater Management Manual
DO: Dissolved oxygen	TMDL: Total maximum daily load
EPA: Environmental Protection Agency	TOC: Total organic carbon
ESA: Endangered Species Act	TSS: Total suspended solids
MEP: Maximum extent practicable	
Mg/L: Milligrams per liter	

Executive Summary

Purpose and Uses

The purpose of the Effectiveness Evaluation (evaluation) is to develop and document the effectiveness ranges and preferred (default) values for all best management practices (BMPs) either currently in use or anticipated for use in the management of stormwater quality and quantity in the City of Portland. The City will use the evaluation results to:

- Help assess the effectiveness of BMPs in achieving compliance with federal and state regulatory requirements
- Compare alternatives and evaluate actions for improving watershed health under the Portland Watershed Management Plan (PWMP)
- Provide information for a study of stormwater pricing and trading
- Update the City's Stormwater Management Manual
- Guide future monitoring efforts

A BMP Team, comprising Bureau of Environmental Services (BES) staff experts and outside consultants, conducted the evaluation, with peer review from members of the City's Stormwater Advisory Committee (SAC) and Watershed Science Advisory Group, other BES staff members, and consultants. The Bureau Leadership Team, including the BES Director, has endorsed the evaluation findings.

Scope and Sources

The great majority of existing national and regional data on BMP effectiveness relates to structural BMPs and tends to be reflective of and specific to local conditions. A process was needed to collect all existing information on both structural and non-structural stormwater BMPs and to extrapolate beyond highly qualified and verified information to derive effectiveness values relative to Portland for each BMP. The Effectiveness Evaluation documents the decision-making and estimation processes and provides all necessary qualifiers regarding the quality and reliability of the estimations.

Information for the evaluation comes from a variety of sources. Where there was no directly measured information, staff used professional judgment and estimation techniques to extrapolate from the available data. The BMP Team established a decision-making hierarchy that set priorities for selecting which information sources to use, giving highest priority to the best available information that is most applicable to Portland.

Methodology

The BMP Team developed a list of BMPs for evaluation. In selecting and assessing these BMPs, the team considered the following factors:

- The ability of the BMPs to address watershed goals and other ancillary watershed benefits.

- The characteristic ways that pollutants act in the environment, and which BMPs may be most effective for addressing the pollutants.
- 303(d) listings and TMDLs for the City of Portland, and which BMPs are needed to address these pollutants.
- Stormwater constituent concentrations by land use.
- The physical, chemical, and biological mechanisms for stormwater management (e.g., sedimentation or infiltration) and how these mechanisms apply to the various BMPs.
- Each BMP's benefit to environmental conditions and each BMP's relative cost per volume of stormwater managed.
- Limiting factors (e.g., high instream flows that limit the formation of viable biological communities) and the uses of BMPs for addressing these limiting factors.
- Site-specific conditions that affect BMP application.
- BMP type (structural, non-structural, and instream) and where the BMP is applied in the stormwater/watershed cycle (prevention/source management BMPs versus treatment BMPs)

Surrogates

To facilitate comparison between BMPs and for simplification purposes, the BMP Team decided to limit the number of pollutants considered for final comparisons to only a few. They selected pollutants that have substantial amounts of actual data and can serve as representative surrogates for whole classes of pollutants. The surrogates were selected based on their applicability to adopted TMDLs or Superfund stormwater management in Portland area waterways. The surrogates and the contaminants they represent are:

- **TSS**—for PCBs, DDT, dioxin, chlordane, phthalates, mercury, dieldrin, and total metals. TSS also correlates well to COD, BOD, and total phosphorus.
- **Dissolved zinc** (as a percent removal)—for most dissolved metals.
- **E. coli**—for most pathogens.
- **Total phosphorus**—for nutrients, and is usually the most prevalent nutrient affecting DO and pH.

The BMP Team also considered BMP effectiveness relative to other conditions of concern besides water quality surrogates: stormwater quantity (**flow rates** and **volume**), **temperature**, and **aquatic and terrestrial habitat improvements**.

BMP Effectiveness Results

The Effectiveness Evaluation results are presented in a series of tables, grouped by structural, non-structural, and instream BMPs. The tables show a range of effectiveness values for each BMP and identify the conditions that result in various points in the range. They also provide default values (“typical” or “representative” effectiveness values) within the range that can be used where generalized assumptions are needed or where there is no clear information to determine a number within the effectiveness range. In addition, the tables include information about estimation techniques, data sources, conditions for application of the effectiveness numbers, and levels of certainty.

The BMP Team condensed the information in these tables to develop a list of the most effective BMPs for various applications and site conditions. The following table summarizes the team’s general conclusions, with the BMPs presented in order greatest effectiveness for each improvement. It is guidance to City of Portland program and project managers and sets an expectation regarding which BMPs to evaluate in assessing stormwater practice applications.

Summary of Most Effective BMPs*

Stormwater Management Improvements	Structural BMPs	Non-Structural BMPs
Flow Reduction	<ul style="list-style-type: none"> • Vegetated infiltration basins • Soakage trenches • Various stormwater planters 	<ul style="list-style-type: none"> • Revegetation • Development requirements for infiltration and revegetation
Volume Reduction	<ul style="list-style-type: none"> • Vegetated infiltration basins • Infiltration stormwater planters 	<ul style="list-style-type: none"> • Development requirements • Reduction of impervious surfaces
Habitat Improvement	<ul style="list-style-type: none"> • Revegetation 	<ul style="list-style-type: none"> • Protection of stream buffers through regulation
Temperature Reduction	<ul style="list-style-type: none"> • Revegetation of riparian areas • Flow management in stream 	<ul style="list-style-type: none"> • Protection of stream buffers through regulation
Pathogen Management	<ul style="list-style-type: none"> • Filters • Stream restoration 	<ul style="list-style-type: none"> • Public education • Pet waste programs
TSS Removal	<ul style="list-style-type: none"> • Wet ponds • Swales • Vegetated infiltration basins • Various stormwater planters 	<ul style="list-style-type: none"> • Street sweeping • Maintenance of MS4 system components • Erosion control • Development regulation
Nutrient Reduction	<ul style="list-style-type: none"> • Treatment wetlands • Wet ponds • Swales 	<ul style="list-style-type: none"> • Street sweeping • Maintenance of MS4 system Components
Dissolved Metals Management	<ul style="list-style-type: none"> • Filters • Riparian restoration • Swales 	<ul style="list-style-type: none"> • Street sweeping • Downspout disconnection

Application of Results

Although the scope of the Effectiveness Evaluation was to catalog the best of what is known about the effectiveness of individual BMPs, the BMP Team also discussed the application of the BMP effectiveness values. Issues included the use of BMPs in series, interactions of BMPs that

* This table presents general conclusions only; see pages 3-7 of the report for additional detail.

might result in “double counting” estimates of their combined effectiveness, realistic overall BMP effectiveness values, BMP interactions (both complementary and interfering), and the expression of BMP effectiveness in terms of general, unitless multipliers that act only in concert with other BMP effectiveness values (e.g., for expressing the effectiveness of public education). All of these issues require resolution in evaluations to follow the evaluations contained in this report. The effective use of this information in the MS4 benchmarking, stormwater trading marketplace assessment, etc., are dependent on those follow-up discussions.

The BMP Team also developed three representative scenarios—residential, industrial, and mixed multifamily residential/commercial—for discussion purposes to further explore how the effectiveness numbers might be used. Although BMP interactions are not specifically addressed, the case examples indicate how BMP effectiveness values for specific contaminants and conditions may be drawn from the general tables. Further development of assumptions for their use is needed before they will fully support site-specific applications of the stormwater BMPs.

Caveats

The Effectiveness Evaluation is a work in progress that represents the current hypothesis of BMP effectiveness in Portland. That hypothesis is contained in the table/appendices of specific BMP effectiveness contained within this evaluation document. It provides no absolute values, only qualified ranges and default information. All the information has a degree of uncertainty associated with it. The information in its current form may be more suited to relative comparisons (e.g., alternatives evaluations) than absolute accounting of loads or concentrations.

The evaluation is a good starting point from which to continue coalescing research and other data into a useable, consistent, and centralized format. Discovery of new or previously unexplored information about BMPs will change the findings over time. In many cases, the evaluation will help direct the collection of new information.

Next Steps

Important next steps include:

- Holding discussions with regulatory agencies about the use of the effectiveness findings for evaluating compliance with permit and other regulatory requirements.
- Determining which BMPs, based on the findings of the evaluation, should be monitored more to reduce uncertainty, and refine the City’s hypothesis of effective stormwater management.
- Addressing the practical applications of the evaluation information.
- Evaluating how current City stormwater management practices comport with the guidance of the evaluation, determining the steps to transition to the most effective practices identified in the evaluation (as necessary), and planning the fiscal and policy adjustments needed to make that transition.

Regular updates to the Effectiveness Evaluation will occur through both ad hoc and periodic modifications. Periodic review will be timed to coincide with other planning and permit renewal cycles.

SECTION 1 INTRODUCTION

PURPOSE AND NEED

The purpose of the Effectiveness Evaluation is to develop and document the effectiveness ranges and preferred (default) values for all best management practices (BMPs) either currently in use or anticipated for use in the management of stormwater quality and quantity in the City of Portland.

Background: The Origin of BMPs

The 1987 amendments to the federal Clean Water Act (CWA) provided a framework for regulatory controls on stormwater and the administration of stormwater management. Because specific information needed to regulate stormwater management through numeric standards was limited, Congress and the U.S. Environmental Protection Agency (EPA) elected instead to manage stormwater via best management practices (BMPs). Each regulated agency is responsible for using available methods and technologies to the “maximum extent practicable” (MEP) to ensure appropriate stormwater discharge quality. That approach presumes that the BMPs used are effective and adequate to ensure protection of surface waters.

The Oregon Department of Environmental Quality (DEQ) renewed the City of Portland’s National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit in March 2004 (and subsequently revised and reissued the permit in July 2005). The City, along with its two co-permittees, the Port of Portland and Multnomah County, have developed Stormwater Management Plans (SWMPs) that describe the BMPs the jurisdictions will implement to improve stormwater quality. These BMPs are typically classified as either structural or non-structural.

Structural BMPs usually include facilities such as stormwater detention ponds or oil/water separators—discrete physical facilities with identifiable and defined stormwater inputs and outputs.

Non-structural BMPs include measures such as public education and street maintenance, where the results of those actions are either citywide in nature or affect multiple points of stormwater discharge at one time.

Need and Uses for BMP Effectiveness Evaluation

The BMP Effectiveness Evaluation was conducted to serve a number of purposes, as described below.

Compliance

The NPDES MS4 permit requires the City to evaluate the effectiveness of both structural and non-structural BMPs and to establish pollutant load reduction benchmarks. The benchmarks estimate the reduction of high-priority pollutants that can be achieved through the combined effects of implementing all individual BMPs. To make its case for the aggregated citywide improvements in stormwater management, the City needs to establish assumptions about the effectiveness and expected benefits of the BMPs. Non-structural BMPs, in particular, have been difficult to quantify in a meaningful way so they can be incorporated into benchmarks.

The effectiveness estimates will also be useful in evaluating BMPs for required Total Maximum Daily Load (TMDL) implementation plans, Underground Injection Control (UIC) program implementation, source control evaluations in the Portland Harbor Superfund Program, and program effectiveness evaluation indicated by the Endangered Species Act (ESA).

Alternatives Evaluation in Watershed Management

The Bureau of Environmental Services (BES) has developed the Portland Watershed Management Plan (PWMP), a comprehensive and integrated plan of actions intended to improve overall watershed health in the City of Portland. The PWMP has goals related to water quality, water quantity, habitat, and biological communities. In the future, it will provide the basis for the City's implementation of regulatory compliance programs. Before that happens, however, the PWMP itself needs best estimates of BMP effectiveness in order to compare and select the most effective and efficient ways to improve watershed health. BMP effectiveness values and assumptions are necessary for modeling (GRID model and Ecosystem Diagnosis and Treatment model) of the various alternatives. Both structural and non-structural BMPs will be important to the evaluation of actions under the PWMP.

Program Planning

Several current or ongoing projects or programs will benefit from better documentation of BMP effectiveness. An EPA grant is supporting a project aimed at stormwater pricing and trading. To know the value of credits traded under such a program, the effectiveness of different management actions must be quantified.

Information about BMP effectiveness will also be useful for Stormwater Management Manual (SWMM) updates. BMPs found to have a high-enough degree of confidence associated with their estimates could be included in the standard list of BMPs in the SWMM.

Monitoring Guidance

The Effectiveness Evaluation will be useful for identifying BMPs that appear to be most effective (such as those listed in the "Summary of Most Effective BMPs" table on Page EX-3) and low-cost, but that need more monitoring to confirm their value before they are broadly applied in the City. It will guide the monitoring of BMPs necessary to adaptively manage stormwater practices of the City.

SCOPE

In the past, professional and technical staff have been reluctant to accept BMP effectiveness results without substantial supporting data and information. Much attention has been given to compilations of existing data on the national and regional level. The great majority of that information relates to structural BMPs and tends to be reflective of and specific to local conditions. Compared with non-structural BMPs, structural BMPs are more readily monitored, have discrete inputs and outputs, and have a more controllable variability (at least one site at a time). Even structural BMPs, however, lack fully verifiable and local information in many cases.

A process was needed to collect all available information on stormwater BMPs and to document the decision-making process, results, and qualifications used to develop effectiveness ranges and default values for all BMPs, regardless of the amount of information available. The original focus of the evaluation was on BMPs with the least defined, most-limited available data—i.e., non-structural BMPs. As the study progressed, however, the scope was expanded to all BMPs in order to maintain consistency in presentation and form a common foundation of information.

The Effectiveness Evaluation forms the basis for future data collection and correction of effectiveness ranges as better data become available.

EVALUATION ELEMENTS

The Effectiveness Evaluation includes the elements described below.

Derive Values for BMP Effectiveness

The evaluation extrapolates beyond highly qualified and verified information to derive effectiveness values for each BMP. These values are working hypotheses that represent the best available current information and professional judgment. They represent a work in progress and are the starting point for further discussion. In many cases, the hypotheses will help direct the collection of new information.

The evaluation provides a “tool box” of stormwater management BMPs, along with all associated supporting information about the effectiveness estimates and the certainty of those estimates. The evaluation results can be used for stormwater management design and decision-making. They also provide the City with documentation useful for demonstrating regulatory compliance.

Use a Spectrum of Available Information and Methods

Information for the evaluation comes 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 staff and other professionals. Where directly measured information was unavailable, staff used professional judgment to extrapolate from available data and use whatever estimation techniques were available.

Document Decisions and Estimations

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

Provide a Range of Effectiveness Values and a Default Value

One way of presenting certainty, or at least the variability of circumstances under which estimations were derived, is to provide ranges of effectiveness. The evaluation identifies effectiveness ranges for each BMP, as well as the location-specific or application-specific conditions that result in various points in the range. In addition, the evaluation provides default 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.

Document the Process to Facilitate Future Review and Modifications

The Effectiveness Evaluation is a work in progress. It is important to document the estimation methods in order to facilitate future review and modifications of the effectiveness assumptions and estimations and to evaluate the applicability of a particular number to a specific design.

Develop a Comprehensive Listing of BMPs

The evaluation provides a comprehensive listing of all stormwater management BMPs currently in use or planned for use in the Portland area. (This list is found in Appendix K, as discussed on page 3-1). This comprehensive listing 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. A compilation of BMPs can also frame assumptions regarding the interrelatedness of BMPs and how those BMPs may (or may not) work in series.

SOURCES

The Effectiveness Evaluation used the following primary sources.

- **Preliminary Data Summary of Urban Stormwater Best Management Practices.** August 1999. U.S. Environmental Protection Agency.

This documents the current state of knowledge about stormwater BMP costs and benefits.

- **Stormwater BMP Effectiveness Review.** May 2005. Association of Clean Water Agencies.

The scope of the study was to “...establish a common basis for assessing and documenting BMP effectiveness for use by Oregon MS4 NPDES permittees in fulfilling the evaluation and reporting requirements of the new and renewed NPDES Phase I stormwater permits, especially in relation to the 303(d) and TMDL water quality related evaluation and reporting requirements.” The study developed BMP effectiveness ranges for a variety of BMPs, specific to Oregon conditions. It focused on BMPs where significant data were available to support effectiveness conclusions, mainly structural controls. Because of limited data, the study was largely silent regarding non-structural BMPs.

The results of the Effectiveness Evaluation extrapolate from these initial ACWA findings.

- **Compilation by Lanier and Mango for Portland Conditions** – Memorandum MS4019 (October 18, 2005)

The purpose of this BES memo was “...to summarize the work that has been supported since 2004 by BES on establishing BMP effluent concentration, both for structural and nonstructural BMPs, for potential use in setting MS4 benchmarks.” The memo noted foundational materials, such as the ACWA study cited above, collection of additional Portland data, and the adjustment of results for Portland-specific conditions.

- **Numerous local and national studies**

A wide variety of data sources were used in the evaluation. Data specific to Portland were given first priority in determining BMP effectiveness. Many individual reference sources are contained in Appendix A and B shown below. Additional independent references for information used in this evaluation and its appendices/tables are as follows:

- Bureau of Environmental Bootstrap Method – Geomean (February 2006). Alicia Lanier. NPDES MS4 Permit Modeling Document MS4010. (January 20, 2006).
- Bureau of Environmental Bootstrap Method (August 15, 2005). Alicia Lanier. NPDES MS4 Permit Modeling Document MS4010. (January 20, 2006).
- Bureau of Environmental Services Bootstrap Method (June 2005). Alicia Lanier. NPDES MS4 Permit Modeling Document MS4010. (January 20, 2006).
- Cammermayer, J., Horner, R., Chechowitz, N. 2000. Vegetated Stormwater Facility Maintenance, Washington State Transportation Center, University of Washington, Seattle, WA. [http://depts.washington.edu/cuwrm/research/veg_stormwater.pdf]
- City of Portland data, sediment manhole flow reductions. City of Portland Environmental Investigations Division. Storm Summary Report – Sediment Manhole Monitoring. (September 13, 2001)
- City of Portland data: Glencoe Rain Garden, three flow tests (December 2003 - December 2005). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)
- City of Portland data: Hamilton Apartments stormwater sampling data (January 2002 - December 2005). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)

- City of Portland data: Hamilton Apartments, 12 storm samples (February 2001 - March 2005). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)
 - City of Portland data: Hamilton Apartments, eight storm samples (February 2001 - April 2003). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)
 - City of Portland data: WPCL Test Planters, three flow tests (August 2005 - October 2005). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)
 - City of Portland Stormwater Management Manual (September 1, 2004)
 - City of Portland, personal communication, Mineart and Singh (1994).
 - City of Portland. Annual Compliance Report No. Ten. (October 28, 2005). NPDES MS4 Permit No. 101314.
 - City of Portland. Technical Guidance: Estimating Watershed Benefits, Integrated Watershed Plan. (December 1998)
 - Comparative Valuation of Ecosystem Services: Lents Project Case Study, Prepared by David Evans and Associates and EcoNorthwest (June 2004)
 - Low Impact Development Center, Inc. (LIDCI). Watershed Benefits of Bioretention Techniques, LIDCI website. [www.lid-stormwater.net/bioretention/bio_benefits.htm]
 - Multnomah County Building stormwater sampling data (June 2004 - December 2005). Sustainable Stormwater Management Program. Draft Stormwater Management Facility Monitoring Report. (June 30, 2006)
 - Prince George's County, Maryland, Department of Environmental Resources (PGCM-DER). 2002. Bioretention Manual, PGCM-DER. [<http://www.goprincegeorgescounty.com/Government/AgencyIndex/DER/ESD/Bioreten tion/bioretention.asp>]
 - U.S. Environmental Protection Agency (USEPA) (1999). Storm Water Technology Fact Sheet: Bioretention, USEPA, Washington D.C. Publication #EPA 832-F-99-012. [www.epa.gov/owmitnet/mtb/biortn.pdf]
 - U.S. Environmental Protection Agency (USEPA) (2000). Bioretention Applications, USEPA, Washington D.C. Publication #EPA 841-B-00-005A. [www.epa.gov/nps/bioretention.pdf]
- **Technical Memorandum: Nonstructural Stormwater BMP Assessment** (Work Order 145 31 043). May 1, 2006. Prepared for BES by Herrera Environmental Consultants, Inc. See **Appendix A.**

This technical memorandum, provided in Appendix A, is a review of a spreadsheet model, the Watershed Treatment Model (WTM), for potential use in evaluating stormwater BMPs used in Portland's watershed management program. It also contains a brief literature review and recommends an approach for meeting MS4 permit objectives.

- **Development of BMP Assumptions for Stream Restoration Projects in Portland Streams and Rivers.** June 11, 2006. Prepared for BES by C. McConnaha (Jones & Stokes) and C. Prescott (City of Portland). See **Appendix B.**

This memorandum, provided in Appendix B, describes the assumptions and procedures used to develop those assumptions regarding stream restoration BMPs. It is not a definitive set of conclusions, but a consistent set of assumptions derived from literature review and the judgment of City professional staff regarding the value of instream BMPs.

PROCESS

BMP Team

Initial discussions for the Effectiveness Evaluation began in fall 2005. A charter was approved in January 2006 establishing the scope, approach, initial schedule, and management structure.

Dave Kliewer (BES) was the project leader. A BMP Team was formed, comprising internal staff experts and several consultants, both paid and unpaid. The team had the following characteristics:

- The team was limited to about 15 people to facilitate close, open discussion. Others were able to review the team's documentation and comment as needed.
- Team members are generally recognized as experts in stormwater management and BMPs.
- The team represented a variety of interests, work groups, and disciplines from within BES to provide the broadest set of experiences, responsibilities, and perspectives.
- The team members were critical thinkers, but also constructive problem solvers. Issues and qualifiers were identified as necessary, but the team came to conclusions and made decisions at whatever level possible with the available information.

BES Team members were:

- Dave Kliewer – Project Manager
- Patrice Mango – MS4 Section
- Dawn Sanders – Portland Harbor
- Chris Prescott - Science, Fish and Wildlife
- Eugene Lampi - Watersheds
- Mark Liebe – Systems Analysis
- Frank Wildensee - MS4 Section
- Atina Casas – Pollution Prevention Group
- Jane Kelly – Development Services
- Tim Kurtz - Sustainable Stormwater
- Linda Dobson – Sustainable Stormwater
- Jim Middaugh – Science, Fish and Wildlife
- Mike Rosen - Watersheds

Consultants were:

- Dave Felstul (Herrera Environmental Consultants)
- Chip McConnaha (Jones and Stokes, Associates)
- Krista Reininga (URS Corporation)

The BMP Team's primary work was accomplished through two workshops that occurred January 26, 2006 and March 7,

Appendix C1 and Appendix C2 contain minutes from the two BMP Team workshops.

2006. A subgroup of the team met several times between the two workshops. The subgroup comprised Dave Kliewer, Tim Kurtz, Eugene Lampi, and Frank Wildensee, with assistance from Dave Felstul.

Review and Distribution

The City's Stormwater Advisory Committee (SAC), appointed by the Commissioner in charge on behalf of City Council, was briefed on the progress of the BMP Team's work at the SAC's January, February, and March 2006 meetings. The Watershed Science Advisory Group (WSAG) also received a briefing on the content and status of the evaluation. Selected members of the SAC and WSAG participated in a peer review of the June draft of the evaluation report, and their comments were incorporated into the evaluation.

The draft evaluation was also distributed for review to the BMP Team and other relevant BES staff members, and the evaluation was redrafted to address their comments. The evaluation findings were presented to and endorsed by the Bureau Leadership Team, including the BES Director.

The consultants engaged under the EPA stormwater-pricing grant reviewed the evaluation and provided feedback regarding its utility for their process.

The evaluation will be distributed for informational purposes to:

- Relevant BES staff
- Other City bureaus: Transportation, Development Services, Water, Planning, and Parks and Recreation
- Other jurisdictions in the region: Metro, Clean Water Services, City of Gresham, Water Environment Services, Port of Portland, and Multnomah County
- Advisory committees: Stormwater Advisory Committee, Watershed Science Advisory Group, and various watershed councils serving the Portland area
- Regulatory agencies: DEQ, EPA, Multnomah County Soil and Water Conservation District, and National Marine Fisheries Service (US Fish and Wildlife Service)
- Other interested organizations: Columbia River Estuary Partnership, Willamette Partnership, and Association of Clean Water Agencies

As a public document, the evaluation will also be available to any other parties upon request.

CAVEATS FOR USE OF THE EVALUATION

This Effectiveness Evaluation is an exciting first attempt by the City of Portland to bring together the best of what is known about stormwater management and extrapolate that information using the judgment of local experts and professionals. This first report serves as raw

material for a variety of both known and potential purposes. As is typical of initial efforts of this sort, the results are investigational, and several caveats apply to their practical use.

- The Effectiveness Evaluation is a work in progress. It is intended to document the current hypothesis of BMP effectiveness in Portland. The evaluation is a good starting point from which to continue coalescing research and other data into a useable, consistent, and centralized format. Discovery of new or previously unexplored information about BMPs will change the findings over time.
- There are no absolute values presented in this evaluation report, only qualified ranges and default information. All the information has a degree of uncertainty associated with it because of the types of BMPs considered, the site-specific nature of BMP applications, and/or the inherent high degree of stormwater variability. For that reason, the information in its current form may be more suited to relative comparisons (e.g., alternatives evaluations) than absolute accounting of loads or concentrations. Such an accounting is possible, however.
- Because the evaluation is a compilation of available information, the results are biased toward current/traditional methods that have been studied the most intensively. In selecting stormwater management techniques, the reader is cautioned to provide appropriate consideration to anticipated, new, or unique BMPs that have a lesser degree of current information, but may be valuable nonetheless.
- Some of the more general conclusions and recommendations in the evaluation are based on data of mixed quality, some of which are highly qualified. Before relying on those recommendations, a thorough examination of the underlying data is advised. The conclusions and recommendations are for guidance purposes and represent only one interpretation of the data. Site-specific conditions and their influence on the application of the recommendations will vary, and professional judgment will be needed to make appropriate selections within the effectiveness ranges.
- Conversion of the effectiveness units to a common basis would be useful. The BMP Team suggested considering the use of percentage removals, but only if the end result could be constrained by reasonable limits, such as expected mean effluent concentrations for open space land use. (See “Mean Stormwater Concentrations by Land Use” in Appendix F.)
- The Effectiveness Evaluation focused on stormwater BMPs acting individually. The effectiveness of BMPs operating in series or coincidentally is not addressed to the point of practical application. In particular, the relative value of watershed-wide BMPs with smaller individual effects (typically aimed at source control) versus single-site BMPs with larger localized impacts (usually structural BMPs) has yet to be evaluated.

A further area of work, beyond the scope of this evaluation, is how to estimate the effectiveness of BMPs combined in series. Different expressions of effectiveness, such as effluent concentration and percentage removal, each have their advantages in application. Prevention and treatment methods each require fundamentally different representations.

Joining these disparate stormwater management techniques in series requires a significant amount of further technical and policy discussion.

- Each stormwater BMP was evaluated individually by single constituent, pollutant, or condition. Project-specific objectives, selected independently of this evaluation report, will be needed to determine the relative priority of pollutants and which BMPs will address them.
- The basis of this evaluation is an assessment of technical information. Selection criteria for stormwater BMPs usually have more than a technical basis. No attempt was made to address or quantify political or policy factors that might influence or even override technical considerations.
- More monitoring is needed to support broad application of BMPs. Wide effectiveness ranges may indicate either high uncertainty or a wide variation in the types of applications that have been lumped together. Dividing a particular BMP class into more discrete groupings for discrete examination may help limit variability. Additional monitoring of each BMP group will also help define the characteristics that may narrow the ranges of effectiveness.
- The evaluation information is not sufficient to support conclusions needed for compliance with numeric stormwater limits/permit conditions. It is, however, probably appropriate for rough estimation in benchmarking efforts, within the certainty of the information.
- The evaluation information is useful for compiling total removals for use in planning-level estimates of changes in instream conditions.

NEXT STEPS

Important next steps include:

- Holding discussions with regulatory agencies about the use of the effectiveness findings for evaluating compliance with permit and other regulatory requirements. Acceptance of the report as a foundation for benchmark, load, and other calculations is essential.
- Determining which BMPs should be monitored more to reduce uncertainty, based on the findings of the evaluation. In particular additional monitoring of effectiveness related to facility maintenance and age may be needed. Other BES processes are underway to discuss monitoring prioritization for BMP effectiveness; the evaluation findings should be incorporated into those discussions.
- Addressing the practical applications of the evaluation information. In particular, this includes how to convert effectiveness units to a common basis and how to estimate the effectiveness of BMPs combined in series.
- Evaluating how current City stormwater management practices comport with the guidance of the evaluation, determining the steps to transition to the most effective practices identified in

the evaluation (as necessary), and planning the fiscal and policy adjustments needed to make that transition.

Updates

As a work in progress, the Effectiveness Evaluation needs a process to ensure regular updates. This process will include both ad hoc and periodic modifications to materials in the evaluation report.

- The ad hoc reviews will capture priority changes that are either critical to the continued usefulness of the evaluation or that include new information that will greatly improve overall implementation.
- Periodic reviews and evaluation updates will correct errors, ensure clarity of the evaluation, and make major structural changes or additions to the evaluation. These updates will occur every other year. Where possible, they will be timed to coincide with the regular updates of other documents, such as the PWMP and SWMM, and with regular permit renewal cycles. A formal solicitation for comments and corrections will occur in the months before each periodic update. A revised edition of the evaluation will be published after each update.

A specific staff member or workgroup within BES will be assigned to the update process. That role includes managing the periodic updates, collecting information between periodic updates, and determining when an ad hoc review and update is needed.

Changes that are being considered to the evaluation and associated spreadsheets will be shown on the documents (using “track changes”) and will be accessible on the BES website for informational purposes and to allow submittal of comments at any time. The latest approved version of the evaluation is the base document for revisions and will remain in force until the next periodic update.

SECTION 2

METHODOLOGY

STORMWATER CONDITIONS OF CONCERN

To guide the selection of BMPs to include in the Effectiveness Evaluation, the BMP Team identified stormwater conditions of concern, and associated goals and benefits, that need to be addressed by BMPs, as described below.

Portland Watershed Management Plan Goals

The Portland Watershed Management Plan contains four primary goals to achieve watershed health. BMPs chosen for evaluation provide benefits for one or all of these goals.

- **Hydrology:** Move toward normative stream flow conditions to protect and improve watershed and stream health, channel functions, and public health and safety.
- **Physical Habitat:** Protect, enhance, and restore aquatic and terrestrial habitat conditions and support key ecological functions and improved productivity, diversity, capacity, and distribution of native fish and wildlife populations and biological communities.
- **Water Quality:** Protect and improve surface water and groundwater quality to protect public health and support native fish and wildlife populations and biological communities.
- **Biological Communities:** Protect, enhance, manage and restore native aquatic and terrestrial species and biological communities to improve and maintain biodiversity in Portland's watersheds.

Ancillary Watershed Benefits

Watershed management is most effective and programmatically efficient where multiple objectives are considered in choosing implementation measures. Drawing from the broadest set of goals across all programs areas provides the greatest gains for the City, builds a broader constituency and advocacy for these programs, and creates avenues to the resources of other programs. In the tradition of the Clean River Program, the following ancillary watershed benefits that may result from BMP implementation were considered:

- Aesthetics and quality of life
- Air purification
- Aquatic habitat
- Habitat diversity and connectivity
- Avian and terrestrial habitat

The Clean River Program was an initiative of the Portland City Council adopted in the spring of 1990. It emphasized multi-objective management of watershed needs.

- Carbon sequestration
- Flood storage and connection; stream morphology improvements
- Removal of obstructions to migration
- Food stock improvements
- Temperature regulation: instream and reduction of heat island effects

Pollutants of Concern

The characteristic ways that pollutants act in the environment provide guidance regarding which BMPs may be most effective for addressing these pollutants. Appendix D presents physical/chemical properties for stormwater pollutants of concern.

Appendix D provides information about pollutants of concern.

Regulatory Drivers

Appendix C provides 303(d) listings and TMDLs for the City of Portland. The BMP Team used these regulatory drivers as the basis for the first-level prioritization of pollutants and the BMPs needed to address those pollutants.

Appendix E provides 303(d) listings and TMDLs for the City of Portland

Pollutant Surrogates

To facilitate comparison between BMPs and for simplification purposes, the BMP Team decided to focus on a few core pollutants. They selected pollutants that have substantial amounts of actual data and can serve as representative surrogates for whole classes of pollutants. The effectiveness values of these surrogates can be extended to similar pollutants within each pollutant class.

The surrogates were selected based on their applicability to adopted TMDLs or Superfund stormwater management in Portland area waterways. The TMDL and Superfund pollutants of concern coincidentally cover the range of water quality concerns usually found in waterways. Surrogates are used for those constituents or conditions where specific monitoring data and analysis are greatly limited or not available. Surrogates are also based on the expected consistency of their stormwater management mechanisms between the surrogate and the pollutant/condition being examined.

The surrogates and the contaminants they represent are as follows:

- **TSS** was chosen to represent all Superfund- related constituents (exclusive of arsenic, which is thought to be background-associated): PCBs, DDT, dioxin, chlordane, phthalates, and mercury. For TMDL constituents, TSS is a surrogate for DDT/DDE, PCBs, mercury, dioxin, dieldrin, and total metals, and also correlates well to COD, BOD, and total phosphorus. These all tend to be substances that adsorb to or are themselves particulate materials. TSS is representative of materials that are settleable.

- **Dissolved zinc** is a surrogate (as a percent removal) for most dissolved metals. The mechanisms (such as filtration, precipitation, or adsorption) that remove one dissolved metal have similar effects on other dissolved metals in that chemical class. Although metals may partition into dissolved and total forms in different proportions, depending on environmental conditions (pH, TOC, etc.), the percent removals tend to be comparable among the different dissolved metals.
- For the bacteriological TMDL, **E. coli** is a surrogate for most pathogens. The water quality standards developed by DEQ acknowledge E. coli as a surrogate (albeit an imperfect one) for human waste contamination and all forms of pathogenic materials. Virus and bacteria survival and die-off rates tend to be affected by similar environmental conditions, such as temperature and disinfection.
- **Total phosphorus** is a surrogate for nutrients and is usually the most prevalent nutrient affecting DO and pH. Most nutrients are related to over-production by algae and its effects (pH and DO variations) in the water column. Phosphorus is well correlated to those effects and often tracks with anthropogenic nitrogen sources such as fertilizers.

The Department of Environmental Quality listed temperature TMDLs as shade targets for riparian areas. Direct solar radiation on surface waters has the greatest influence on their temperature during the period of most concern (summer). Stormwater does not typically affect receiving water temperatures during the period of concern, so stormwater BMPs are not part of temperature compliance. Because temperature is important to the management of instream health, however, the Effectiveness Evaluation still considers it as a condition of concern and lists temperature as a surrogate.

Similarly, flow rates and volume of stormwater are not typically part of TMDL or Superfund listings, but they are critically important to physical and habitat functionality of area waterways. For this reason, stormwater quantity elements (flow rate and volume reduction) are considered as conditions of concern in evaluating BMP effectiveness, along with the stormwater quality surrogates listed above. However, flow and volume reduction effectiveness are subject to the assumptions applied to the various BMPs. Typically those assumptions are specified in the Stormwater Management Manual.

Aquatic and terrestrial habitats are also important conditions for overall watershed health. To the degree that those conditions can be directly managed through BMPs, a “habitat” surrogate also represents them.

Stormwater Quality by Land Use

The Association of Clean Water Agencies (ACWA) developed a database of stormwater quality by land use for Willamette Valley municipalities for the period of 1991 through 1996. The BMP Team used that database, along with some refinements specific to the Portland area, to develop a list of mean land use concentrations. Appendix F shows these concentrations as a range of expected values, including the low, high, and mean values. These values are

Appendix F shows stormwater concentrations by land use.

used directly in some of the estimation techniques. For example, the open space TSS concentration is used to calculate the potential soil loss from new construction sites (previously undisturbed). In some cases they also serve as a “reality check” on the results in applying BMPs alone or in series. For example, the Parks and Open Space (POS) values are probably an appropriate representation of predevelopment conditions; improvements beyond that are suspect and require additional explanation to justify them.

SELECTION OF BMPS FOR REVIEW

The BMP Team considered the background information about pollutants of concern (as discussed above) to develop a list of potential BMPs for further evaluation and documentation. In developing and evaluating the list of BMPs, the team also considered the factors discussed below: stormwater management mechanisms, benefits and costs to environmental conditions, limiting factors and site-specific conditions that affect BMP application, and BMP categorization by type of BMP and by where the BMP is applied in the stormwater/watershed cycle.

Stormwater Management Mechanisms

The BMP Team evaluated the various mechanisms for stormwater management. Those mechanisms typically involve physical, chemical, or biological processes, or a combination thereof. Each mechanism was given a two-letter identifier for reference (e.g., SD = sedimentation and IN = infiltration). The BMP Team originally tried to identify mechanisms that are directly associated with each of the four watershed goals; however, no mechanisms unique to habitat or biological communities were identified because all of the mechanisms are inherent to some degree in those two goals.

Appendix G identifies stormwater management mechanisms related to water quality and water quantity.

BMP List

The list of potential BMPs was divided into structural and non-structural categories, based on a list developed for the ACWA Stormwater BMP Effectiveness Review (see references listed as part of Appendix A).

Appendix H identifies the potential BMPs considered by the BMP Team.

Each potential BMP was assigned an estimated high, medium, or low benefit to environmental conditions (water quality, water quantity, and habitat) and a high, medium, or low cost per volume of stormwater managed. The comparison of cost to benefits—basically, the value of the BMP—indicates where future research and quantification efforts might be focused. For example, BMPs with high potential value are candidates for broader usage, so information about them should be fairly certain, especially if they have medium to high costs.

For each BMP, all applicable stormwater management mechanisms were identified, in accordance with the two-letter identifiers shown in Appendix G. The mechanisms link the BMPs to the environmental conditions they are trying to resolve. For example, if erosion is the problem, applicable BMPs would include sedimentation (SD) in their list of mechanisms. The

BMP Team ensured that the list of potential BMPs adequately represents all types of stormwater management mechanisms, and thereby the associated list of problems.

Evaluation of Limiting Factors

The Portland Watershed Management Plan identifies limiting factors in each stream and locale relative to achieving watershed health goals. The BMP Team assessed the uses of BMPs for addressing those limiting factors and identified needs/conditions of concern. The extent and type of limiting factors pointed to the need for specific BMPs or BMP types. For example, if high flows in stream limit the formation of viable biological communities, stormwater BMPs that reduce the flow rates and volumes of stormwater are needed to prevent stream washout.

Site-Specific Conditions Constraining BMP Application

Not every BMP is applicable or appropriate to every site or circumstance. The BMP Team noted several site-specific factors that constrain the application of BMPs. These constraints are grouped into categories: physical, political, applicability, and threat/risk. Although this effectiveness evaluation does not attempt to screen the BMPs on the basis of these constraints, the constraints are important considerations in the ultimate selection and application of BMPs.

Appendix I identifies factors constraining BMP use.

BMP Categorization

The BMP Team assessed two kinds of BMP categorization—BMP type and where the BMP is applied in the stormwater/watershed cycle—to determine if these categories matter in the ultimate application of BMPs or their characterization.

BMP types include structural and non-structural (usually applied in upland areas of the watershed) and instream/riparian (directly influencing waterways). These categories are not terribly distinct or very intuitive in many cases. In attempting to identify rules, the BMP Team discussed many exceptions. In general, however, structural BMPs tend to be specific to individual site applications, while non-structural BMPs are areawide or citywide in their application. Instream BMPs are specific to riparian locations, but can be non-structural (such as statutes protecting stream buffer areas) or structural (such as revegetation or channel restoration).

The other type of category pertains to the location of BMPs in the stormwater cycle—i.e., prevention/source management BMPs versus treatment BMPs. Treatment methods deal with stormwater influences after they happen. Source management methods prevent the influences from ever occurring.

Neither kind of categorization appeared absolute, but such categorization did help advance the overall discussion of BMPs. The BMP Team ultimately decided for a comprehensive review of BMPs rather than the use of categories to focus the discussion on any particular group of BMPs. For the sake of organization, however, the BMPs were roughly divided by type for purposes of

recording their effectiveness within the tables of the evaluation. The use of BMP categories is consistent with common conventions.

DECISION-MAKING HIERARCHY

Following selection of the BMP list, the BMP Team established a decision-making hierarchy, collected available information about BMP effectiveness, and evaluated that information for applications specific to Portland.

The essence of the decision-making hierarchy is that the BMP Team would first and foremost use the best available information most applicable to Portland. The BMP Team would use less-specific estimation or derivation techniques only as substitution for nonexistent or poor-quality data.

Appendix J shows the decision-making hierarchy for determining BMP effectiveness.

As an example, to determine the effectiveness of stormwater filters, the BMP Team first looked for Portland projects with statistically significant data sets where the range of uncertainty was small and the application of the filters was reasonably representative of Portland conditions. Those data sets were limited.

Where a “complete” data set was lacking, the available data were evaluated for Portland-specific conclusions, with any necessary caveats documented. Where possible, experience or observation could be used to confirm that information or at least narrow the range of uncertainty caused by limited information.

The next preferred source of data was from other parts of the state or country, especially where a significant data set was available or where conditions were similar to Portland’s. That is essentially what was used to determine effectiveness values for filters. The values identified in the ACWA Stormwater BMP Effectiveness Review were derived from a combination of several Oregon (including Portland) and national datasets; the BMP Team adjusted those values for Portland conditions, as appropriate.

If that option had not been available, the next preferred source of information would be modeling of Portland conditions where BMPs had been applied, to essentially “back out” the value of individual BMPs.

The next option would be to evaluate stormwater mechanisms anticipated to be effective in managing a particular pollutant and extrapolate data from other pollutants where that same mechanism appeared effective. For instance, if metals are taken as a group, a BMP that removes one metal may likely be effective, to the same degree, for another metal.

The last option would be the use of best professional judgment and more probabilistic estimation techniques.

SECTION 3

RESULTS AND APPLICATION

RESULTS

The results of the BMP Team’s research and discussions were collected in a series of spreadsheets divided roughly by BMP type into structural, non-structural, and instream (structural) categories. These results are discussed below.

Results Expressed by BMP

A master set of spreadsheets (Appendix K) shows:

- BMP effectiveness sorted by BMP
- Linked calculations/assumptions
- An explanation of the spreadsheets

Appendix K contains master spreadsheets showing BMP effectiveness, sorted by BMP.

These spreadsheets are sorted by BMP, with the available information on effectiveness shown for each BMP. This format aided the BMP Team’s research and discussions, since available studies tend to focus on individual BMPs rather than on pollutants or conditions. The BMPs provided in those spreadsheets were initially based on the listing from Appendix H, but were expanded as information on additional BMP types were collected.

The centerpiece of this information is the effectiveness ranges. Numbers are listed for highest and lowest anticipated positive impacts of each BMP relative to each contaminant/condition; more importantly, the conditions favoring those range end points are also provided. For instream BMPs, the default value is the only number assigned and serves as a starting point for further investigation, based on the specifics of a particular site. Appendix B provides more information about the development of the instream spreadsheets and the use of various terms therein.

Another feature of the spreadsheets is the assignment of a “default positive impact” value for each contaminant/condition. In most cases, the BMP Team determined the range of potential effectiveness values and then discussed a single, most-applicable effectiveness value. That single value is assigned as the default value and represents the impact of a BMP in “normal” operation. The default value can be used where generalized assumptions across a number of BMP sites are needed or where there is no clear information for a specific site circumstance to determine a number within the effectiveness range. The default is intended to force the assignment of an effectiveness value, even on a coarse basis. The value of this information is not only the effectiveness values provided, but also the documentation of the assumptions and characteristics that result in those values. Where possible, the team attempted to qualify the certainty of the effectiveness values and the reasons for that certainty. Documentation of the assumptions will allow users to evaluate the appropriateness of the values to any particular application and make adjustments to meet design needs.

Other items of note concerning these spreadsheets:

- **Effectiveness is expressed in a variety of ways.** Depending on the BMP, effectiveness is presented as effluent concentrations, load removed or load removed per unit, percent removal, effectiveness multipliers acting on other BMPs or land use means, and unitless comparisons. In some cases, potential conversion factors are provided for the various ways of expressing effectiveness; however, conversion depends on the particular application of the BMPs. For example, for TMDL evaluations, it is most convenient to use BMPs expressed as load reductions, while it is easier to use effluent concentrations to compare individual BMPs and their site-specific applications. In any case, these mixed units will continue to be a challenge for assessing BMPs, especially where BMPs are used in series. Comparison is also difficult because the measures of positive impact may be inverted numerically; a high load reduction is “good,” while a high effluent concentration is “bad.”
- **Estimation certainty is only roughly described.** The certainty of these numbers is given only as high, medium, or low, which does not provide much differentiation for purposes of implementation. That problem is compounded by the inherent variability of stormwater and site conditions themselves, so that very few of these estimations rose above the medium certainty level. Uncertainty can be managed by limiting the variability in any particular application; data collected for the same types of site, climate, pollutant, and weather conditions will greatly reduce that uncertainty for that application. However, transferability of that information to other projects or applications with other conditions is probably limited. A very large data set representative of the wide range of site conditions is needed to significantly limit uncertainty associated with effectiveness ranges. At this early stage of stormwater management science, such large data sets are rarely available.
- **Values for prevention BMPs must be expressed differently from values for treatment BMPs.** For prevention BMPs, the default is the status quo condition: do nothing or keep doing what is already being done, so there will be no positive or negative impacts. For example, adequate protection of vegetative buffers and their associated shade canopy on streams protects the temperature status quo. If those buffers are lost, the stream converts to a “no shade canopy” status, the low end of the effectiveness range. If the buffers are improved through revegetation, they move toward achieving the high end of the range.

By comparison, treatment BMPs assume a degraded initial condition for the stormwater and make improvements from that baseline. Less improvement results in the low end of the effectiveness range, and the greatest expected improvement results in the high end.

- **Limited data are available across the broad spectrum of BMPs.** Various estimation techniques were needed to fill in all cells in the spreadsheets. Following the decision-making hierarchy, data were used first, but in many cases surrogates, analogous BMP values, and estimation were substituted for direct measurement.
- **Some BMPs could (should) not be estimated.** BMPs such as illicit discharge management, spill response, and truck washing are localized in effect, episodic, and variable in pollutant

type. They are unpredictable at the citywide scale and must be evaluated when the specific applications are known.

- **Primary stormwater benefits and secondary generalized environmental benefits are both provided.** Although the focus of the evaluation is the primary positive stormwater management impacts of BMPs, other environmental benefits can play an important role in multiple-objective decision-making for watersheds. Although rather subjective, a unitless system (0, +, ++, +++, +++) was used to determine the relative, qualitative value of the BMPs for secondary benefits such as carbon sequestration and air purification.

Results Expressed by Contaminant/Condition

A second set of spreadsheets (Appendix L) re-sorts the information in the master spreadsheet (Appendix K) to present the information by contaminant/condition. These spreadsheets are simplified, removing some of the columns regarding conversion factors and sources of information.

Appendix L contains simplified BMP effectiveness spreadsheets, sorted by contaminant/condition.

The intent is to provide a document more compatible with implementation. In the design process, a known site condition is usually addressed (as opposed to starting with the BMP type), so a reference spreadsheet sorted by condition provides more ready comparisons. For example, all BMP types providing zinc removal can be viewed in one section of the table. The table is further sorted by the default values to rank the BMP types roughly by their relative effectiveness. These spreadsheets are consistent with the values in the master spreadsheets, where all the details are documented.

Results Expressed by Contaminant/Condition – Surrogates Only

As noted previously, surrogates can be used where existing data are not available. For example, if a new organic pesticide must be managed but no data on management of that substance are available, TSS can act as a surrogate if the pesticide is likely to bind to particulates (see Appendix B). To facilitate the use of the surrogates selected by the BMP Team, the contaminants/conditions in Appendix L are reduced in Appendix M to just the primary surrogates. No surrogates were determined for instream BMPs in these tables.

Appendix M contains simplified BMP effectiveness spreadsheets, sorted by contaminant/condition for surrogate contaminants/conditions only.

APPLICATION OF BMP EFFECTIVENESS VALUES

Although the scope of the Effectiveness Evaluation was to catalog the best of what is known about the effectiveness of individual BMPs, the application of the BMP effectiveness values was also considered preliminarily. As discussed below, issues touched on included the use of BMPs in series, interactions of BMPs that might result in “double counting” their combined effectiveness, realistic overall BMP effectiveness values, BMP interactions (both complementary and interfering), and the expression of BMP effectiveness in terms of general, unitless multipliers that act only in concert with other BMP effectiveness values (e.g., for expressing the

effectiveness of public education). Further discussions are needed to fully address each of these topics.

BMPs in Series

If several BMPs are placed in series and their effectiveness is expressed as a percent removal, adding those removals could result in more than 100 percent of the pollutant being removed from the effluent. Multiplying the percent removals may not reflect actual effectiveness, either, since effectiveness may diminish with reduced amounts of pollutants in the influent to each subsequent BMP: the treatment train. For example, a BMP with 90 percent effectiveness combined with a BMP with 80 percent effectiveness would equal 98 percent effectiveness when multiplied together, but is it realistic to expect 80 percent effectiveness with influent that has already had 90 percent of the pollutants removed?

With effluent concentrations, no double counting will occur because the BMP with the best effluent quality will dominate the final effectiveness. However, that method does not account for actual changes in effectiveness based on wide variations in influent quality. It also removes the incentive for using several BMPs in series, which in reality can provide improved levels of effectiveness.

Creating a maximum effectiveness limit could act as a check on unintended and unrealistic additive or multiplicative effects when combining multiple BMPs in series. As an example, a BMP could be limited to achieving effluent levels no better than recorded mean open space concentrations. Another option might be to limit concentrations to the lowest effluent concentration of the most effective BMP, provided that other conditions are met (such as known or assumed/estimated low influent concentrations, well-maintained BMPs, and BMPs in series).

BMP Interactions

In some cases, BMPs can work for a coordinated result. For example, a settling basin (forebay) is an important element of the design for a constructed wetland or other facilities sensitive to sediment loads. BMPs can also interfere with each other. For example, a wet pond is potentially very effective at removing a number of constituents of concern, but can aggravate temperature concerns where open water is exposed to solar radiation.

Application of General Multipliers

Some BMPs never act independently of other BMPs. For example, public education can have a direct effect on the application, maintenance, and effectiveness of certain BMPs, but can only act in that way where those BMPs are present; it has a multiplier effect that enhances the effectiveness of those BMPs. As an illustration, property owners who are aware of potential stormwater impacts are more likely to maintain swales in the right-of-way, not park in them, and not dump grass clippings and used automotive oil. So the “Public Engagement Effects on other BMPs” multiplier might increase the effectiveness of a swale up to 5%.

Some of the value of general public education, however, is completely independent of other BMPs. School assemblies and general public information campaigns are typical of that type of BMP. In those cases, an effectiveness multiplier is applied to the expected land use concentrations, such as concentrations for residential or commercial land use areas.

In all cases, the application of general multipliers must be limited so it does not result in effluent concentrations lower than the lowest effluent concentrations found in the available data for that use or application.

SELECTION OF BMPS

The selection of best management practices can be based on a variety of factors. Strategically, however, the use of BMPs should ultimately serve the goals and objectives stated in the Portland Watershed Management Plan (PWMP). Table 4.2 of the PWMP (shown in Appendix N of this report) identifies the connections between strategies and actions, and the goals and objectives they serve. When those same strategies and actions are compared to the principal categories and indicators used in the Effectiveness Evaluation (Appendix O), a similar pattern of relationships is evident. When placed side-by-side, these two tables begin to reveal the connection of the PWMP goals and objectives with the BMPs intended to meet them.

Appendix N shows links between PWMP strategies/actions and goals/objectives.

Appendix O shows links between PWMP strategies/actions and the categories/indicators used in the BMP Effectiveness Evaluation.

Using the effectiveness values from the spreadsheets in Appendices K through M, Appendix P provides recommendations regarding the “most effective” BMPs for a range of site conditions relative to slope, soil/groundwater level, site size, and land use.

Appendix P recommends the most effective BMPs for various application conditions.

Recommendations are provided under the same categories of surrogates as in Appendix O, and are divided into structural and non-structural BMP types. The recommendations are provided in order of effectiveness.

In some cases, the list of highly effective BMPs was adjusted to reflect site conditions. For example, a structural BMP such as soakage trenches may be effective in reducing flow rate, but is not appropriate in areas of shallow groundwater where groundwater contamination is of concern. Similarly, wet ponds and treatment wetlands are very effective in managing nutrients, but typically are not cost effective on residential sites or small parcels where space is limited. BMPs were sometimes eliminated altogether as inappropriate; other times, they were moved down in priority because of their reduced effectiveness under certain site conditions.

Appendix P is a guide for BMP selection. Any application of these guidelines requires a degree of judgment by the designer, based on site conditions and other constraints.

The following table summarizes the general conclusions of Appendix P. The BMPs are presented in order of effectiveness.

Summary of Most Effective BMPs¹

Stormwater Management Improvements	Structural BMPs	Non-Structural BMPs
Flow Reduction	<ul style="list-style-type: none"> • Vegetated infiltration basins • Soakage trenches • Various stormwater planters 	<ul style="list-style-type: none"> • Revegetation • Development requirements for infiltration and revegetation
Volume Reduction ²	<ul style="list-style-type: none"> • Vegetated infiltration basins • Infiltration stormwater Planters 	<ul style="list-style-type: none"> • Development requirements • Reduction of impervious surfaces
Habitat Improvement	<ul style="list-style-type: none"> • Revegetation 	<ul style="list-style-type: none"> • Protection of stream buffers through regulation
Temperature ³ Reduction	<ul style="list-style-type: none"> • Revegetation of riparian areas • Flow management in stream 	<ul style="list-style-type: none"> • Protection of stream buffers through regulation
Pathogen Management ⁴	<ul style="list-style-type: none"> • Filters • Stream restoration 	<ul style="list-style-type: none"> • Public education • Pet waste programs
TSS Removal ⁵	<ul style="list-style-type: none"> • Wet ponds • Swales • Vegetated infiltration basins • Various stormwater planters 	<ul style="list-style-type: none"> • Street sweeping • Maintenance of MS4 system components • Erosion control • Development regulation
Nutrient Reduction ⁴	<ul style="list-style-type: none"> • Treatment wetlands • Wet ponds • Swales 	<ul style="list-style-type: none"> • Street sweeping • Maintenance of MS4 system Components
Dissolved Metals Management ⁴	<ul style="list-style-type: none"> • Filters • Riparian restoration • Swales 	<ul style="list-style-type: none"> • Street sweeping • Downspout disconnection

¹ The more detailed tables in the appendices contain information about a broader list of “secondary” positive impacts of BMPs for use in evaluating the full range of objectives a BMP might satisfy. This information only represents available experience and information: as a result it tends to favor past practice and available data. Some practices like leaf pick up for nutrients reduction, or retrofitting per the SWMM and dissolved metals management need more testing and quantification to be included.

² Little information is available about volume reduction from other types of facilities.

³ Increasing infiltration near streams will also increase base flow and decrease water temperature.

⁴ Total reduction of all pollutants discharged to surfacewaters (metals, nutrients, and pathogens) will result for the portion of stormwater infiltrated.

⁵ Much of stormwater management to date has focused on TSS removal as an indicator of overall effectiveness, so much more is known about TSS management by BMPs. No information available on in-stream processes, although preliminary information from the Fanno Creek watershed indicates instream processes are a significant source of TSS.

CASE EXAMPLES

The BMP Team developed three representative scenarios—residential, industrial, and mixed multifamily residential/commercial—for discussion purposes to further explore how the effectiveness numbers might be derived. Although BMP interactions are not specifically addressed, the case examples indicate how BMP effectiveness values for specific contaminants and conditions might be drawn from the general tables.

Residential

Scenario: A single-family residential lot with Naturescaping, a vegetated curb extension, a catch basin, and street sweeping.

Discussion: The following values of BMP effectiveness could be used for each of the elements of this scenario to quantify TSS. Other constituents or conditions, such as metals or bacteria reduction, could be addressed in a similar fashion. No attempt has been made to identify how these various elements might interact, so in practical terms final application of these numbers awaits additional discussions regarding those interactions.

The mean land use concentration for Parks and Open Space is 54 mg/L, with a measured high concentration of 94 and a low value of 21. The Parks and Open Space land use values for TSS provide a reality check for the calculated effectiveness of these practices in combination since undisturbed or open space lands generally define the desired baseline condition for land use concentrations. So, estimated improvements in TSS would not be expected to go much below 54 mg/L normally, but certainly never below the lowest measured open space concentration value of 21 mg/L. If the calculated value goes below 21, then 21 would be used instead of the calculated amount.

Case Example: Residential Site –TSS

BMP	Units	Low	High	Default	Comments
Naturescaping	lbs reduction/ pervious acre/year	1.54 (0.009 lbs/yr)	13.47 (0.077 lbs/yr)	7.70 (0.044 lbs/yr)	Assume 250 sq ft pervious area per lot.
General education - residential	Factor applied against mean land use concentration	60/1.00 = 60.0 mg/L	60/1.03 = 58.3 mg/L	60/1.01 = 59.4 mg/L	Based on mean residential land use effluent concentration of 60 mg/L.
Vegetated curb extension (vegetated infiltration basin)	% removal	81	90	85	Apply against the results of the “general education” calculation.
Catch basin	lbs reduced/ year/ basin	0.35	159.96	17.50	
Public engagement effects on BMPs	Factor applied to curb extensions and catch basin, above	1.00	1.05	1.03	
Street sweeping (half a street on 75-foot frontage)	lbs reduced/year on all residential streets	253,333 (3.6 lbs/yr)	425,455 (6.0 lbs/yr)	351,515 (5.0 lbs/yr)	1,000 lane miles per year for whole city, so this example is one lane of 75 lineal ft/5,280 ft per mile/1,000 lane miles.

Industrial

Scenario: A metals fabrication business with exposed inventory stored on the site, a large parking lot and loading dock, clogged inlets in the parking lot and in the street, extensive vehicle parking (various shifts on a 24-hour work day) on a secondary street, and bark dust landscaping washing off into the street.

Discussion: The following values of BMP effectiveness for lead could be used for this example. Other constituents or conditions could be addressed in a similar fashion. Expected effectiveness of all BMP elements in combination should not exceed that of typical open space land concentrations. The mean land use concentration for Parks and Open Space for dissolved lead is 0.13 ug/L, with a high value of 0.15 ug/L and a low value of 0.11 ug/L. Estimated improvements in dissolved lead are therefore not likely to go much below 0.13 ug/L, but certainly never below 0.11 ug/L.

Case Example: Industrial Site – Lead

BMP	Units	Low	High	Default	Comments
Street sweeping on one lane - industrial	lbs/year (total Pb all industrial lane miles)	90 (or 0.005 lbs)	234 (or 0.012 lbs)	196 (or 0.010 lbs)	For 5,000 lane miles, 0.25 lane miles per site.
Education for business – P2 program	lbs/year	1.07	1.07	1.07	Heavy metals based on 3.5-acre site.
General education - industrial	Factor applied against mean land use concentration	3.3/1.00 = 3.3 ug/L	3.3/1.03 = 3.2 ug/L	3.3/1.01 = 3.3 ug/L	Based on mean industrial land use effluent concentration of 3.3 ug/L.
Public engagement effects on BMPs	Factor applied to catch basin and swales	1.00	1.05	1.03	
Industrial stormwater permitting	lbs/year for whole city	132/143 = 0.9	529/143 = 3.7	132/143 = 0.9	Average of 143 sites managed per year.
Catch basin cleaning	lbs reduced/year/basin	0.000042 x 4 = 0.002 total	0.0191952 x 4 = 0.077 total	0.0021 x 4 = 0.008 total	Four catch basins assumed for the site.
Swales	ug/L total lead	8.8	5.6	7.2	Assume half the site (mostly parking) is managed by swales, and use average seasonal rainfall to convert to pounds removed.

Mixed Multifamily Residential/Commercial

Scenario: About 50 acres of mixed residential/commercial drains to a pond in a neighborhood park that has considerable use by pet owners and wildfowl. The area has limited residence by families. Street sweeping is more frequent on commercial than residential streets. Multifamily buildings have ecoroofs, and stormwater runoff from those roofs is stored in cisterns for reuse on site (toilets and irrigation).

Discussion: The following values of BMP effectiveness for stormwater flow could be used for this example. Other constituents or conditions could be addressed in a similar fashion. The

nominal stormwater flow condition is represented by Parks and Open Space land use; however, the aggregate effect of flow impacts in an urban environment are so significant that flow reductions up to and including zero discharge may be pursued and can occur.

Case Example: Mixed Uses – Flow

BMP	Units	Low	High	Default	Comments
General education - residential	Factor applied against other percent removal values	1.00	1.03	1.01	Public engagement increases acceptance and maintenance of these types of facilities. Add factors before applying.
Public engagement effects on BMPs	Factor applied to wet pond, ecoroof, and cisterns	1.00	1.05	1.03	
Ecoroofs	% removal	30	90	60	Used filter values.
Wet pond	% removal	3	7	5	
Cisterns	% removal	0	100	50	Highly dependent on size of cisterns and frequency of storms (values not from tables).