ATTACHMENT 1

BMP Effectiveness/Efficiency Monitoring
Evaluation of Regional Information and Data

Project SPR - 335
Water Quality Facility Investigation

Response to Tasks 2 & 3: Information Analysis and Needs Assessment
Revised, October 4, 2002

Introduction

Task 1 of the Oregon Department of Transportation Water Quality Facility Investigation was completed on May 15, 2002. This task involved reviewing literature on performance monitoring of stormwater BMPs with an emphasis on studies and protocols specific to the Pacific Northwest Region. A references database and summary annotated bibliography was the product of Task 1. The second task, Task 2, includes analyzing the information obtained in Task 1, expanding it if necessary, and identifying the extent of regional information and data with respect to the types of water quality facilities typically designed for the treatment of highway runoff. The purpose of this task is to summarize all available and pertinent information and data in order to assess the needs, goals, and strategies of ODOT's water quality facilities investigation, that is, to accomplish Task 3 – Assess Needs.

After an initial review of this draft document, the Technical Advisory Committee (TAC) has recommended that Task 3 be incorporated into this Task 2 document and the focus of the overall project be modified. The available information referenced in this report has indicated that developing a "one-size fits all" protocol for monitoring BMPs isnot a feasible goal considering the current budget allocated for this project. Also, the four primary monitoring guidance documents cited later in the report are written principally for a technically sophisticated researcher rather than those who are likely to be conducting the actual monitoring. Consequently, the TAC has advised the Project Team to develop a concise guidance document (~4-5 pages) for developing a monitoring plan that outlines potential BMP monitoring goals and the necessary information and equipment needed to meet those goals (revised Task 4 – Development of BMP Monitoring Protocols). This guidance document will be geared toward the field

technicians, who will most likely be conducting BMP monitoring, to aid in brainstorming and the decision-making processes of developing a monitoring plan. The document will only give minimal instruction, requiring the interested user to seek more information and guidance in the referenced protocols (discussed below). The guidance document will define the technical levels of BMP monitoring, addressing several of the most common monitoring goals and different categories of BMPs, based on their physical characteristics. A decision matrix will then be presented to help the user determine the extent of the information necessary to meet monitoring goals for a specific BMP.

In addition to a revision of Task 4, the modification of the overall project includes revising Task 5 – Field Testing Monitoring Plan. Task 5 will be modified to include the development of a specific BMP monitoring plan for one or two BMPs to be selected by the TAC. The monitoring plan would use the guidance information included in the four primary documents identified and discussed in this report. ODOT personnel will use the BMP-specific monitoring plan to carry out the monitoring. After the monitoring has been completed the Project Team will critically evaluate and provide recommendations for using the monitoring plan as a template for developing future monitoring plans. This will be included in the Task 6 – Final Phase I and II Report.

The following paragraphs include a summary of ODOT's stormwater BMPs and an assessment of regional information and data. This is followed by an evaluation of the four most useful BMP monitoring guidance documents, and concluding remarks and recommendations. Appendix A provides a summary of the BMP studies evaluated in this report that have been monitored for performance in the Pacific Northwest.

ODOT Water Quality Facilities

The Oregon Department of Transportation operates several stormwater treatment facilities throughout the State. Some of these facilities are designed specifically to treat highway runoff, while others are designed for flow attenuation or spill containment in addition to water quality benefits. ODOT is currently developing (Spring, 2002) a database of their structural stormwater BMPs that includes the name and type of the facility, its location, and facility-specific notes. There are 30 structural stormwater BMPs currently contained in the database. These BMPs have been organized into four primary categories and are shown in Table 1. ODOT operates additional water quality facilities throughout the State of Oregon that are not on the current list. Also, several non-structural and source control BMPs, such as street sweeping, facility maintenance, and roadside vegetation, are being utilized throughout the state highway system.

Table 1. Stormwater quality treatment facilities currently in ODOT's database.

Facility Type	Description	No. of BMPs in Database
Extended Dry Detention Pond	Constructed ponds whose outlets have been designed to detain the volume of a water quality design storm for some minimum time (usually 24 hours) to allow for the settling of particles and associated pollutants.	9
Grassed Swale	Vegetated channels with a slope similar to that of standard storm drain channels (less than six percent), but wider and shallower to maximize flow residence time and promote pollutant removal.	5
Wet pond	Constructed ponds with a permanent pool of water (pool or dead storage) throughout most of the year (or at least throughout the wet season) for treating incoming stormwater runoff through gravitational settling and other means.	4*
Water Quality Structure	Typically a prefabricated structure, relying primarily on mechanical and/or adsorptive pollutant removal, which can be placed within the storm sewer system. Includes catchbasin inserts, swirl concentrators, oil/water separators, water quality manholes, spill control/containment devices, underground detention vaults/tanks, and other proprietary devices.	15

* Only one facility is currently included in the database; however, Jeff Moore of ODOT has provided water quality data on three other retention ponds. But these ponds were not constructed as water quality facilities, so the data should be used judiciously if used in performance assessments.

In addition to the facilities described in Table 1, ODOT maintains highway shoulders (particularly in more rural situations) that will provide some level of stormwater treatment via overland flow, which can be enhanced, especially when vegetated. A study conducted by the Washington State Department of Transportation found that vegetated highway shoulders (VHS), which are designed for the safety of motorists, have the ability to remove between 20 and 80% of total suspended solids (Yonge, 2000). This removal efficiency is comparable to the typical performance of vegetated filter strips designed specifically for water quality benefits. Therefore, when ODOT performs a full-scale characterization and assessment of its water quality treatment facilities, roadside properties should be appropriately accounted for. For example, much of I-5, especially south of the Portland metro area, drains to either the median or vegetated shoulders and/or roadside swales. Recognizing that ODOT's Draft BMP database is still in its infancy stages, the facilities contained therein will not be considered a representative fraction of all the water quality facilities owned or operated by ODOT. The stormwater BMPs of highest priority will be determined by the Technical Advisory Committee prior to the revised Tasks 4 and 5 of this project.

Assessment of Available Information

This project's Task 1 summary report found that guidance on BMP performance monitoring is considerably limited in the Pacific Northwest. In fact, the primary guidance documents in the region are focused on general water quality monitoring or slightly more specific, stormwater monitoring. Some of these documents may be drawn upon for general monitoring information.

The Oregon Watershed Enhancement Board has developed a water quality monitoring guidebook (Ice et al., 1999), the Laboratory Division of the Oregon Department of Environmental Quality has developed a field sampling reference guide (ODEQ, 1998), and the City of Portland has developed a field guide for monitoring storm sewer outfalls (Woodward-Clyde Consultants, 1991); however, agencies in Oregon have yet to either develop a specific protocol for monitoring and evaluating the performance of stormwater BMPs or adopt national protocols such as the guidance document for complying with the requirements of the National Stormwater BMP Database (USEPA/ASCE, 2002).

Agencies in the State of Washington have developed guidance documents specifically for stormwater monitoring (Woodward-Clyde Consultants, 1995), including protocols for evaluating BMP performance (WDOE, 2002; Minton et al., 1999; EvTec, 2000). However, the focus of these protocols is primarily on emerging proprietary treatment technologies.

Because of the limitations of these regional stormwater BMP monitoring guidance documents, particularly for evaluating the performance of conventional stormwater BMPs, information may need to be extracted from a variety of different sources beyond the Pacific Northwest. Of the top twelve documents identified in Task 1 as having the highest usefulness potential to the development of ODOT's stormwater facility monitoring protocol, the four documents that will likely be the most called upon sources of outside information are: "Urban Stormwater BMP Performance Monitoring – A Guidance Manual for Meeting the National Stormwater BMP Database Requirements" (USEPA/ASCE, 2002), "Guidance Manual: Stormwater Monitoring Protocols" (Caltrans, 2000), "Guidance Manual for Monitoring Highway Runoff Water Quality" (FHWA, 2001), and "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring" (FHWA, 2000). The Caltrans document and the 2001 FHWA document provide detailed guidance on monitoring highway stormwater runoff, however there is only limited information on performance monitoring. The USEPA/ASCE and the 2000 FHWA documents fill this gap by providing specific information and methods to determine the performance of stormwater BMPs. These four documents will collectively serve as a checklist for ODOT's stormwater quality facilities monitoring protocol to ensure all of the elements of a successful monitoring effort are addressed and result in high quality, transferable data being obtained that specifically meet desired monitoring goals. The ultimate selection of protocols will likely be tiered, as in some BMP test scenarios, to accommodate ODOTs specific BMP monitoring goals. The following paragraphs provide a brief overview of each of the four primary documents and a comparison of their most relevant information and monitoring approach.

Highway Stormwater Monitoring

As mentioned above, the two primary documents that will be used in the development of stormwater monitoring protocols specific to highway runoff are the Caltrans and 2001 FHWA guidance manuals. These documents do not provide guidance on BMP performance monitoring; however, they do provide detailed guidance on preparing and implementing a highway stormwater monitoring plan.

Caltrans Guidance Manual

The primary objective of this guidance manual is to ensure consistency in monitoring methods among Caltrans' various monitoring programs and projects as to provide for data comparability and ease of data entry into the Caltrans stormwater database. Procedures for preparing and implementing a stormwater monitoring plan are outlined in two sections of the document. Preparing the monitoring plan includes developing the purpose and objectives of the monitoring effort, selecting a representative site, choosing a sampling suite of constituents, selecting the monitoring methods and equipment, and preparing a sampling and analysis plan. Implementing the plan includes installing and maintaining the monitoring equipment, training the monitoring personnel, preparing and orchestrating monitoring personnel and sampling events, collecting quality assured and quality controlled samples, analyzing the samples in the laboratory, and evaluating and reporting the data. The appendices include advantages and disadvantages of various monitoring approaches, descriptions and characteristics of analytical constituents, methods of obtaining unbiased flow-proportional water quality samples, preparation of a health and safety plan, sample bottle and equipment cleaning procedures, weather tracking, and Caltrans data reporting protocols.

This document is an excellent example of a monitoring protocol for a highway stormwater monitoring program. Useful information on developing and implementing a monitoring plan is provided. A thorough discussion of how to select monitoring methods and equipment, including equipment installation and the QA/QC procedure for data collection and analysis, is included.

2001 FHWA Guidance Manual

This document provides detailed guidance for selecting and using stormwater runoff monitoring equipment for the monitoring of highway runoff. The characteristics of highway runoff and its relative importance to regional stormwater quality are identified, as well as some of the goals and constraints of highway stormwater monitoring. Factors to consider when selecting monitoring equipment for various monitoring goals are presented, including detailed information of the different types of monitoring equipment currently available. The document also includes general guidance on the installation of monitoring equipment and how the equipment should be integrated for an efficient, reliable, and safe monitoring effort. Analytical methods and the QA/QC process are outlined to ensure precise, accurate, and representative sampling of stormwater constituents. Finally, the document stresses the need for a site-specific health and safety plan for all stormwater monitoring efforts. The appendices include data evaluation and

statistical hypothesis testing procedures, an example health and safety plan, and example standard operating procedures for field sampling.

This document provides highway runoff monitoring guidance at a national level that enables the collection of data with a high confidence of transferability. This document provides up-to-date guidance on the development of a highway stormwater monitoring program, the selection of monitoring equipment, and implementation of the monitoring program using a QA/QC process.

Document Comparison

Both the Caltrans document and the FHWA documents identify key issues that should be considered when assessing the goals and objectives of a highway stormwater monitoring program. Some of these issues include identifying the:

- physical and chemical characteristics of stormwater runoff,
- resources and constraints, and
- regulatory requirements

The FHWA document identifies five typical goals of monitoring stormwater, and the document is organized to address each one of those goals. The Caltrans document does not identify any particular monitoring goals. However, it states that the goals of the monitoring program are usually identified in preceding planning documents before the initiation of a monitoring program. Therefore, the Caltrans document is more general with respect to specific monitoring goals.

The Caltrans document goes into much more detail in the general selection of monitoring sites. However, the monitoring site selection guidance in the FHWA document is more specific to monitoring program goals. The Caltrans document identifies three important factors not specifically mentioned in the FHWA document: personnel safety, equipment security, and access to electrical power and telephone. These items are addressed later in the document in the equipment selection and the site-specific health and safety plan, but not as part of the site selection process.

The typical monitoring constituents identified in each document vary slightly, but both documents contend that the complete list of water quality parameters depends on the specific goals of the monitoring project and an initial characterization of the influent stormwater. The FHWA document list is primarily for monitoring studies with the goal of estimating pollutant loads and concentrations, which is usually conducted prior to the implementation of monitoring programs with other goals such as source identification, BMP performance evaluation, water quality criteria compliance, and trends identification. Typical stormwater monitoring parameters identified in each document are shown in Table 2, as well as the pollutants of concern identified in the Oregon Department of Environmental Quality's evaluation of ODOT's 1995 stormwater data (ODEQ, 2000). Comparing the two sets of parameters, notice the Caltrans suite does not include any parameters directly associated with petroleum products such as total petroleum hydrocarbons, which are included in the FHWA and ODEQ suites and are typically

included in highway runoff monitoring studies (St. John, 1997; Yonge, 2000; Leif, 1999; Yu and Stopinski, 2001).

Table 2. Comparison of stormwater monitoring parameters in Caltrans and FHWA Guidance Manuals to pollutants of concern identified of ODEQ.

Conventional	**Caltrans**	**FHWA**	**ODEQ**
Biochemical oxygen demand (BOD)	☐	☒	☒
Chemical oxygen demand (COD)	☐	☒	☐
Conductivity	☒	☐	☐
Dissolved organic carbon (DOC)	☒	☐	☐
Total organic carbon (TOC)	☒	☐	☐
Hardness	☒	☒	☐
pH	☒	☒	☒
Temperature	☒	☒	☐
Bacteria			
Fecal coliform bacteria	☐	☒	☐
Bacteria	☐	☐	☒
Hydrocarbons			
Oil and grease	☐	☒	☐
Polyaromatic hydrocarbons (PAH)	☐	☐	☒
Total petroleum hydrocarbons (TPH)	☐	☒	☒
Solids			
Total dissolved solids (TSS)	☒	☒	☒
Total suspended solids (TDS)	☒	☒	☐
Sediment	☐	☐	☒
Nutrients:			
Ammonia (NH_3-N)	☐	☒	☐
Nitrate (NO_3-N)	☒	☐	☐
Nitrate+Nitrite (NO_3-N + NO_2-N)	☐	☒	☐
Ortho-phosphate	☒	☒	☐
Total Kjeldahl nitrogen (TKN)	☒	☒	☐
Total phosphate	☐	☒	☐
Total phosphorous	☒	☐	☐
Metals (total and dissolved)			
Arsenic	☒	☐	☐
Cadmium	☒	☒	☒
Chromium	☒	☐	☐
Copper	☒	☒	☒
Lead	☒	☒	☒
Nickel	☒	☐	☐
Silver	☐	☐	☒
Zinc	☒	☒	☒

Both documents identify several sample collection methods including manual and automated sampling techniques. The FHWA document provides an extensive comparison of the various methods and the advantages and disadvantages of the methods with respect to specific goals, parameters, and conditions. Both documents provide

information of different types of water quality samplers and gauges and devices for measuring flow rates and precipitation, as well as equipment installation procedures. The FHWA document dedicates approximately 40 pages to these topics, while the Caltrans document dedicates approximately 30 pages to these topics.

Each document has a section dedicated to quality assurance and quality control measures. The Caltrans document contains slightly more detail on this topic. However both documents cover basically the same information.

BMP Performance Monitoring

The two primary documents to be drawn upon for information on monitoring BMP performance are the USEPA/ASCE and the 2000 FHWA guidance manuals. Unlike the two documents discussed above, these documents are specific to monitoring the performance of stormwater BMPs.

USEPA/ASCE Guidance Manual

This document provides extensive guidance on the collection, analysis, and reporting of stormwater quality data with respect to BMP performance estimation. Following the introductory section, Section 2 provides an overview of BMP monitoring. Discussion is provided on the context of BMP monitoring, difficulties in assessing BMP performance, and understanding the relationship between BMP study design and the attainment of monitoring program goals. Useful analysis of data collected from BMP monitoring studies is essential for understanding and comparing BMP monitoring study results. A summary of historical and recommended approaches for data analysis is provided to elucidate the relationship between the details and subtleties of each analysis approach and the assessment of performance. Section 3 discusses the specifics of developing a monitoring program, selecting monitoring methods and equipment, installing and using equipment, implementing sampling approaches and techniques, and reporting information consistent with the National Stormwater Best Management Practices Database. In addition, four appendices have been included in this guidance document. The first appendix describes methods for calculating expected errors in field measurements. The second provides detailed information about the number of samples required to obtain statically significant monitoring data. The third appendix includes charts for estimating the number of samples required to observe a statistically significant difference between two populations for various levels of confidence and power. The final appendix is a table for estimating arithmetic descriptive statistics based on descriptive statistics of log-transformed data.

This document is the most current example of BMP performance monitoring guidance available. All of the information provided should be of some use to the development of ODOT's monitoring protocol. Meeting the requirements of the National Stormwater BMP Database by using this document as a guide will increase the value of the data obtained in ODOT's monitoring efforts because the data will be transferable on a national level.

2000 FHWA Guidance Manual

The purpose of this report is to provide a planning-level review of the applicability and use of new and more traditional BMPs in ultra-urban areas. This report focuses on the unique characteristics specific to ultra-urban settings and provides specific guidance for selecting and siting stormwater management technologies. The information is structured in an informative, user-friendly format, with case studies highlighting examples of BMP monitoring throughout the country and tables illustrating the characteristics of each BMP to facilitate comparison and identification of specific technologies appropriate to a given site. BMP information is provided in fact sheets, which address applicability, effectiveness, siting and design, maintenance, and cost considerations. The report is organized into separate chapters that address ultra-urban considerations, BMP design information tailored to the ultra-urban environment, monitoring program design, and BMP selection. The monitoring program section provides a strategy for developing a monitoring program to determine the performance of highway BMPs. Useful information such as typical highway runoff constituents and concentrations/loads, BMP characterization and design considerations, and a list of possible project resources and constraints are included. In the design phase of the monitoring plan development, data quality objectives are identified and various monitoring design approaches are considered. Data collection protocols that include locating sampling sites and sensor locations, as well as the number of samples necessary to obtain statistically significant data. Database design considerations and various data analysis techniques are also included in the document.

Section 3 has fact sheets for various BMPs that could be useful if information on description/design considerations of BMPs is needed. Section 4 of the document contains the most pertinent information with respect to the ODOT monitoring protocol development. Table 25 in this section provides a good summary of the advantages and disadvantages of different sampling techniques. The only shortcoming of this document is that the efficiency ratio is the only approach mentioned as a measure of BMP performance.

Document Comparison

The topics of both documents revolve around stormwater BMPs, however they have a different focus and organization. The FHWA document focuses on “ultra-urban” stormwater BMPs, which are designed to treat runoff from highways and roads in highly urbanized environments. The first half of the document contains information on selecting BMPs. The second half contains information on developing and implementing a BMP monitoring plan followed by BMP monitoring case studies. USEPA/ASCE document does not contain any information on specific types of BMPs or guidance on selecting BMPs. However it goes into much more detail on how to develop and implement a BMP monitoring plan. The following paragraphs compare the content organization and the monitoring approaches presented in each of the documents.

Both documents begin with discussion of the regulatory background and significance of stormwater BMP monitoring, followed by a discussion of the physical and chemical characteristics of stormwater (however the FHWA is more focused on highway runoff). The USEPA/ASCE document clearly defines the differences of BMP performance,

effectiveness, and efficiency and then provides a thorough background of the different types of methods for estimating BMP performance including advantages and disadvantages of each. The document follows this discussion with the recommended approach, the effluent probability method. The FHWA document suggests the percent removal method, for which the USEPA/ASCE document identifies significant shortcomings, and the watershed method. Both documents imply that the chosen method depends on the monitoring goals.

Both documents provide a list of typical stormwater pollutants found in urban stormwater runoff. However, only the USEPA/ASCE provides general guidance on what should be used as the starting point for compiling a suite of parameters to monitor. The FHWA document suggests the chosen suite of monitoring parameters should depend on a characterization of the site water quality, but it does not suggest what parameters should be selected to begin the characterization. However, it is implied that the list of typical highway runoff pollutants should be included in the initial characterization. The USEPA/ASCE suggested list of water quality parameters is shown in Table 3.

Table 3. Typical stormwater monitoring parameters

Conventional	**Metals-Total Recoverable**
pH	Total Recoverable Digestion
Turbidity	Cadmium
Total Suspended Solids	Copper
Total Hardness	Lead
Chloride	Zinc
Bacteria	**Metals-Dissolved**
Fecal Coliform	Filtration/Digestion
Total Coliform	Cadmium
Enterococci	Copper
Nutrients:	Lead
Orthophosphate	Zinc
Phosphorus – Total	**Organics**
Total Kjeldahl Nitrogen (TKN)	Organophosphate Pesticides (scan)
Nitrate – N	

Both document go into detail on data collection methods including site selection, sampling techniques, and the importance of collecting representative samples. However, the USEPA/ASCE document provides much more information on selecting, installing, and operating monitoring equipment than the FHWA document (which does not provide much discussion on different types of available equipment). Both documents provide a discussion of statistical data analysis methods and reporting protocols. However, the USEPA document provides more complete guidance on both of these topics.

Overall, both documents can be drawn upon for information to assemble a BMP monitoring protocol for ODOT. The FHWA document provides more information relevant to highway runoff, while the USEPA/ASCE document provides more detailed information on general BMP monitoring.

Assessment of Available Data

Very few stormwater BMP effectiveness studies have been conducted by public organizations in the Pacific Northwest. Much of the available effectiveness data are for ultra-urban stormwater treatment technologies (mostly proprietary devices) that have been tested primarily in laboratory settings. The study design, parameters evaluated, level of quality control, and types of statistical analyses performed vary considerably between the available studies making comparison of results between studies difficult. The numbers of BMP performance studies that were found during the agency inquiry and literature investigation are shown in Table 4. All of the studies are from either Washington or Oregon, all of which were located on the west side of the Cascade Range. Also included in the table is an assessment of the number of studies with adequate quantitative performance information,, which was determined by the type and quantity of water quality samples taken. The study was considered to be adequate ("good" quality) if greater than 5 storms were monitored with flow-weighted composite samples. The study was also considered to be adequate ("medium" quality) if greater than 5 storms were monitored with multiple grab samples or if greater than 20 storms were monitored with single grab samples. Any study that sampled less than 5 storms was considered not very useful. No BMP assessment studies were found on the east side of the Cascade Range. Information on the individual BMPs can be found in Appendix A.

Table 4. Total numbers of regional BMP performance studies.

BMP Type	**No. of Studies**	**Adequate Studies**
Biofilter Strip	3	3
Grassed Swale	7	6
Wetland Swale	1	1
Wetland Basin With Open Water Surface	3	1
Wet Pond	10	5
Dry Detention Basin	4	2
Underground Detention Tank/Vault	1	0
Catch Basin Insert	11	0
Filter – Other Media	5	4
Filter – Sand	2	1
Hydrodynamic Device	2	0
Oil & Water Separator	1	1
Porous Pavement – Asphalt	1	1
Maintenance Practice– Roadside Ditch Cleaning and Restoring	3	2
Maintenance Practice – Street Sweeping	3	2

Many of the studies with adequate quantitative performance data were conducted prior to the release of the two primary BMP performance guidance documents discussed above. Furthermore, the other adequate studies that were conducted after these documents were published do not indicate that a non-project specific protocol was followed.

Conclusion and Recommendations

The available information referenced in this report has indicated that developing a "one-size fits all" protocol for monitoring BMPs is not likely to be feasible considering the current budget allocated for this project. Also, the four primary monitoring guidance documents cited above are written principally for the technically sophisticated researcher. Consequently, on the advice of the TAC, the Project Team will develop a concise guidance document (~4-5 pages) for developing a monitoring plan that outlines potential BMP monitoring goals and the necessary information and equipment needed to meet those goals (revised Task 4 – Development of BMP Monitoring Protocols). This guidance document will be geared toward field technicians that would most likely perform the monitoring and would aid in the brainstorming and decision-making processes of developing a monitoring plan.

With the collection of guidance documents and BMP monitoring case studies, there is an adequate amount of information available to develop a stormwater quality facilities monitoring protocol for this purpose. Using existing guidance documents as a template will help to ensure that ODOT's protocol is within the framework of regional as well as national BMP monitoring methods and principles and that data will be useful not only to ODOT, but to anyone interested in stormwater BMP performance.

The limited amount of regional data cannot be solely relied upon as a relative measure of expected performance of all ODOT facilities. The regional studies deemed adequate in the discussion above will be good sources of information for individual BMP monitoring projects. However, the information is of limited use for the development of monitoring protocols. Data from outside the Pacific Northwest will likely need to be used to compare BMP performance monitoring results from future ODOT studies until more regional data are available.

The BMPs reported in ODOT's database represent only part of the total number of stormwater treatment facilities maintained by ODOT, especially given the amount of "non-planned" but effective BMPs that exist throughout the state highway system. Therefore, it is difficult to assess information and data needs based on the distribution of BMP types throughout the state using solely the ODOT database, which is still in its preliminary development stages.

Of the BMPs listed in the database, the discrepancy in the available data lies most prominently with the water quality structures. There are 15 water quality structures reported in the database and only 6 regional studies (includes catch basin inserts, filters, hydrodynamic devices, and oil/water separators) that have been found with adequate quantitative performance information. Due to the several possible variations in these types of devices, finding transferable data is at best difficult. As mentioned above, there are several regional guidance documents available for testing and approving emerging proprietary treatment technologies. The most recent of these documents, "Stormwater Treatment Facility Performance Evaluation Guidance Document" (WADOE, 2002), should be considered along with other national protocols if the treatment technology has not been previously tested and/or it is desirable to obtain data acceptable to local government agencies.

Performance data on dry detention ponds could also be expanded to match the number of these types of BMPs operated by ODOT. Only two regional studies of dry detention basins that include quality data were found in the data investigation, and ODOT reports nine of these BMPs in its database. The performance of dry detention basins depends primarily on the physical processes of sedimentation, which are mainly a function of flow rate and depth. Because these physical processes do not vary substantially with location, performance data may be more appropriately transferred with these types of BMPs, as long as enough metadata are provided.

The USEPA/ASCE BMP Database is a good source of peer-reviewed studies that can be used to estimate or compare the performance of current or future ODOT BMPs. After a BMP-specific monitoring plan is developed (Task 5) and monitoring begins, this database may prove to be an invaluable tool for assessing the performance of the BMP(s) with respect to national data.

In conclusion, to narrow the focus of Phase II: Develop Testing Protocols and Monitoring Plan, the Technical Advisory Committee (TAC) should provide the following information to the Project Team before continuing to the Task 4: Development of BMP Monitoring Protocols.

1. A list of BMPs considered high priority for performance monitoring.
2. An estimate of the annual resources (funds and labor) that will be allocated to the monitoring of ODOT's BMPs, so that only realistic monitoring strategies are included in the protocol.
3. Clearly defined BMP monitoring goals (i.e., what will the collected data be used for?).
4. A list of stormwater monitoring parameters required by ODOT's MS4 Permit.

Once this information is available, additional informational needs can be assessed so that a menu of potential strategies for BMP monitoring and a list of monitoring pollutants can be compiled. The pollutants identified in the primary reference documents along with the pollutants of concern reported in ODOT's MS4 permit could serve as the starting point for compiling a list of BMP monitoring constituents. This list will be included in the draft BMP monitoring plan guidance document.

In the long term, it is recommended that ODOT continue to expand its database of stormwater treatment facilities as funding becomes available to include more detailed information such as the specific type of facilities, design flow rate, dimensions, drainage areas, and primary land uses. The database should eventually include a representative fraction, if not all, of ODOTs stormwater BMPs. Structural BMPs that do not have well-defined boundaries, such as vegetated highway shoulders, as well as source control BMPs and maintenance practices, such as street sweeping and catch basin cleanout, should be at least summarized in the database. If possible, ODOTs rural highway design standards (structural and/or hydrological design standards such as width and slope of shoulders) be compared with local stormwater BMP standards (e.g., the design specifications for vegetated filter strips in the City of Portland's Stormwater Management Manual). This

information in conjunction with BMP monitoring data can be used to provides an indication of how well ODOT's statewide stormwater quality controls are working without the need to monitor every ODOT BMP.

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Appendix A – Regional BMP Performance Studies

BMP Type Biofilter - Grass Strip

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample Type
WsDOT	10/6/96 - 8/28/97	13	Test plot 1, SR 8 shoulder, Nutra Mulch compost substrate	0.03	Highway	TCd, DCd, TCu, DCu, TPb, DPb, TZn, DZn, BOD, COD, NO3-N, NO3+NO2, OP, TP, TSS, TDS,	Flow-weighted
Overall Study	Good						
WsDOT	10/6/96 - 8/28/97	13	Test plot 3, SR 8 shoulder, top soil substrate	0.03	Highway	TCd, DCd, TCu, DCu, TPb, DPb, TZn, DZn, BOD, COD, NO3-N, NO3+NO2, OP, TP, TSS, TDS,	Flow-weighted
Overall Study	Good						
WsDOT	10/6/96 - 8/28/97	13	Test plot2, SR 8 shoulder, Native soil substrate	0.03	Highway	TCd, DCd, TCu, DCu, TPb, DPb, TZn, DZn, BOD, COD, NO3-N, NO3+NO2, OP, TP, TSS, TDS,	Flow-weighted
Overall Study	Good						

BMP Type Biofilter - Grass Swale

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Municipality of Metropolitan Seattle	11/17/91 - 4/29/92	6	100-foot Swale Configuration - Mountlake Terrace	15.5	Residential - Med Density	NO2+NO3 as N, OP, TP, BAP, TSS, turb, TCu, TPb, TZn, TAl, TFe, fecal coliform, O&G, TPH, DCu, DPb, DZn, DAl, DFe	Flow-weighted
Overall Study	Good						

BMP Type Biofilter - Grass Swale

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Municipality of Metropolitan Seattle	6/20/91 - 10/31/91	6	200-foot Swale Configuration - Mountlake Terrace	15.5	Residential - Med Density	NO2+NO3 as N, OP, TP, BAP, TSS, turb, TCu, TPb, TZn, TAl, TFe, fecal coliform, O&G, TPH, DCu, DPb, DZn, DAl, DFe	Flow-weighted
Overall Study	Good						
Portland BES	1/6/98; 3/21/98; 5/19/98; 12/1/98; 1/14/98 2/5/98; 11/8/99;	9	Parkrose Bioswale	1.4	Parking Lot	pH, cond, temp, E. coli, DO, BOD,COD, hard, NO3-N, O-PO4-P; TKN, TP, TSS COD, hard, total oil&grease, TSS, tot & dis metals (Cd, Cu, Pb, Zn) tot & dis metals (Cd, Cu, Pb, Zn)	Time-weighted
Overall Study	Medium						
Portland BES	4/30/01; 11/15/01; 1/18-19/02; 4/13-14/02	4	Russell Pond Swale	56	Residential - Low Density	pH, cond, temp, E. coli, NH3-N, BOD, COD, hard, NO3-N, O-PO4-P, fecal coliform, total and TDS, TKN, TP, TS, TSS, tot & dis metals nonpolar oil&grease (As, Cd, Cu, Pb,	Multiple grab
Overall Study	Not very useful						
Portland Bureau of Environmental Services	2/16/99 - 6/10/00	6	BES Bioswales - East Swale	-50	Residential - High Density	DCd, TCd, COD, DCu, TCu, DPb, TPb, DZn, TZn, NO3-N, NH3-N, O&G, DO, pH, OP, TP, TDS, TSS, conductivity, temp, E.Coli, fecal coliform, hardness	Time-weighted
Overall Study	Medium						
Portland Bureau of Environmental Services	2/16/99 - 6/10/00	6	BES Bioswales - West	-50	Residential - High Density	DCd, TCd, COD, DCu, TCu, DPb, TPb, DZn, TZn, NO3-N, NH3-N, O&G, DO, pH, OP, TP, TDS, TSS, conductivity, temp, E.Coli, fecal coliform, hardness	Time-weighted
Overall Study	Medium						

BMP Type Biofilter - Grass Swale

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
WA State Dept. of Ecology	4/3/91 - 3/22/93	9	Dayton Swale, Seattle, WA --> In ASCE/EPA Database	90	Residential - High Density	TSS, Fecal Coliforms, turbidity, NO2+NO3, TP, SRP, BAP, TCu, DCu, TPb, DPb, TZn, DZn, TAl, DAl, TCd, DCd, TFe, DFe	Flow-weighted
Overall Study	Good						

BMP Type Biofilter - Wetland Vegetation Swale

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County Surface Water Management Division	03/03/93 - 01/02/94	15	Upland Wetland Swale	17	Residential - Low Density	TSS, TP, SRP, BAP, NO3-N, NH3-N, TCu, TPb, TZn	Flow-weighted
Overall Study	Good						

BMP Type Catch Basin Insert

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County, Snohomish County,	3/30/94, 5/25/94, 8/16/94	3	Aqua-net Basket w/ Absorbent: Maintenance ShopYard	0.16	Parking Lot	TSS, turbidity, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
Overall Study	Not very useful						
King County, Snohomish County,	3/30/94, 5/25/94, 8/18/94	3	Enviro-Drain w/ One Tray of Abs: Maintenance Shop	0.14	Parking Lot	TSS, turbidity, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
Overall Study	Not very useful						

BMP Type Catch Basin Insert

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County, Snohomish County, **Overall Study**	3/30/94, 5/26/94, 6/21/94, 8/16/94 Not very useful	4	Aqua-net Basket w/ Absorbent: Park and Ride	0.3	Parking Lot	TSS, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 5/26/94, 6/21/94, 8/16/94 Not very useful	4	Enviro-Drain w/ TwoTrays of Abs: Park and Ride	0.23	Parking Lot	TSS, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 5/26/94, 6/21/94, 8/16/94 Not very useful	4	Stormwater Services Type II-O, Sock w/ polypropolene strips	0.23	Parking Lot	TSS, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 6/16/94, 8/18/94 Not very useful	3	Aqua-Net w/out Absorbent: Arterial Road	0.11	Highway	TSS, turbidity, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 6/16/94, 8/18/94 Not very useful	3	Enviro-Drain w/ TwoTrays of Abs: Arterial Road	0.115	Highway	TSS, turbidity, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 6/16/94, 8/18/94 Not very useful	3	Stormwater Services Type II-O, Sock w/ polypropolene strips	0.13	Highway	TSS, turbidity, TP, O/G, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
King County, Snohomish County, **Overall Study**	3/30/94, 6/8/94, 8/23/94 Not very useful	3	Aqua-Net w/out Absorbent: Industrial yard	0.23	Industrial	TSS, turbidity, TP, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab

BMP Type Catch Basin Insert

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County, Snohomish County,	3/30/94, 6/8/94, 8/23/94	3	Enviro-Drain w/ Tray of Abs, Tray of Activated Carbon: Industrial yard	0.23	Industrial	TSS, turbidity, TP, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
Overall Study	Not very useful						
King County, Snohomish County,	3/30/94, 6/8/94, 8/23/94	3	Stormwater Services Type I, Double box: Industrial	0.23	Industrial	TSS, turbidity, TP, hardness, TCu, TPb, TZn, DCu, DZn	Multiple grab
Overall Study	Not very useful						

BMP Type Detention - Underground Vault, Tank or Pipe(s)

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Portland BES (info pending)		0	Whitaker Ponds PRF	0			
Overall Study							

BMP Type Detention Basin (Dry) - Surface Grass-Lined Basin That Empties Out After A Storm

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County Surface Water Management Division	01/28/92	1	Gunshy Pond	25	Residential - Med Density	TSS, TP, TCu, TPb, TZn	Flow-weighted
Overall Study	Not very useful						
State of Washington Water Research Center	11/19/1984 - 5/18/85	7	Boeing Computer Services, Seattle, WA --> In ASCE/EPA Database	18	Parking Lot	TSS, TP, NO3, NO3-N, O/G, As, Cd, Cr, Ni, Pb, and Zn	Multiple grab
Overall Study	Medium						

BMP Type Detention Basin (Dry) - Surface Grass-Lined Basin That Empties Out After A Storm

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Unknown	10/27/1981 - 2/18/1982	14	Whispering Heights Residential Pond, Bellevue, WA --> In ASCE/EPA Database	76	Residential - Med Density	TSS, heavy metals, O/G, TP, and COD	Multiple grab
Overall Study	Medium						
Washington County Clean Water Services	3/25/2001; 5/14/2001; 6/1/2001	3	Stoller Extended Dry Detention Pond	24	Residential - Med Density	BOD, COD, pH, TDS, TSS, NH3, TKN, NO3+NO2, TP, OP, Hardness, Cl, E.Coli, DCd, TCd, DCu, TCu, DPb, TPb, DZn, TZn	Flow-weighted
Overall Study	Not very useful						

BMP Type Filter - Other Media

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Snohomish County	4/1/96 - 12/30/96	8	Lake Stevens compost filter, WA --> In ASCE/EPA Database (New Studies)	0.23	Unknown	TP, TPb, TSS, TCu, TZn, Oxygen demand	Flow-weighted
Overall Study	Good						
Snohomish County Surface Water Management	11/27/95 - 12/30/96	8	Lake Stevens Bridge Deck Filter	0.23	Highway	TSS, Tot. Cu, TZn, TPb, TP, FC, TPH, COD	Multiple grab
Overall Study	Medium						
Snohomish County Surface Water Management	11/27/95 , 10/04/96	2	Lake Stevens Bridge Approach Filter	0.7	Highway	TSS, Tot. Cu, TZn, TPb, TP, FC, TPH, COD	Multiple grab
Overall Study	Not very useful						
Stormwater Management, Inc.	10/8/01 - 11/04/01	4	StormFilter at West Hills Plaza	4.3	Commercial	TSS, TP, TKN, TZn	Flow-weighted
Overall Study			Medium				

BMP Type Filter - Other Media

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Unified Sewerage	1991 - 1994	15	185th Ave Compost Stormwater Filter	74	Mixed Use	Turbidity, TSS, COD, TP, TKN, Fe, Cr, Cu, Pb, Zn	Flow-weighted
Overall Study	Good						

BMP Type Filter - Sand

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Alaska Marine Lines	1994	20	Alaska Marine Lines Filter BMP	12.4	Commercial	TSS, turbidity, fats/oils/grease, TPH, TP, Cu, Zn	Flow-weighted
Overall Study	Good						
Portland BES	6/11/01; 12/12/02; 4/9/02; 6/17/02	4	Parkrose Sand Filter	0.82	Highway	pH, cond, temp, E. coli, NH3-N, BOD, COD, hard, NO3-N, O-PO4-P, fecal coliform, total and TDS, TKN, TP, TS, TSS, tot & dis metals nonpolar oil&grease (As, Cd, Cu, Pb, Hg {tot only}, Ag, Zn),	Multiple grab
Overall Study	Not very useful						

BMP Type Hydrodynamic Devices (e.g. Swirl Concentrator, StormCeptor™, etc..)

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Portland BES (info pending)		0	Buffalo Slough PRF - Vortechnics	0			
Overall Study							

BMP Type Hydrodynamic Devices (e.g. Swirl Concentrator, StormCeptor™, etc..)

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Washington County Clean Water Services	3/25/2001; 6/1/2001; 6/27/2001	3	Vortechnics	14	Residential - Med Density	BOD, COD, pH, TDS, TSS, NH3, TKN, NO3+NO2, TP, OP, Hardness, Cl, E.Coli, DCd, TCd, DCu, TCu, DPb, TPb, DZn, TZn	Flow-weighted
Overall Study	Not very useful						

BMP Type Maintenance Practices - Roadside Ditch Cleaning and Restoring

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
WsDOT	01/09/00 - 05/24/00	7	Ditch A (75% excavated, resodded)	0.46	Highway	Temp, pH, turbidity, conductivity, TSS, TP, SRP, TCu, DCu, TZn, DZn	Flow-weighted
Overall Study	Good						
WsDOT	01/09/00 - 05/24/00	4	Ditch B (100% excavated, 3" hand-applied straw)	0.62	Highway	Temp, pH, turbidity, conductivity, TSS, TP, SRP, TCu, DCu, TZn, DZn	Flow-weighted
Overall Study	Not very useful						
WsDOT	01/09/00 - 05/24/00	10	Ditch C (75% excavated, 3" hand-applied straw)	3.21	Highway	Temp, pH, turbidity, conductivity, TSS, TP, SRP, TCu, DCu, TZn, DZn	Flow-weighted
Overall Study	Good						

BMP Type Maintenance Practices - Street Sweeping

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Port of Seattle	1996	8	Pier 66 Street Sweeping (Kurahashi and Associates)	400	Commercial	TSS, TP, TPb, TZn, TCu	
Overall Study	Not very useful						

BMP Type Maintenance Practices - Street Sweeping

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Storm and Combined Sewer Program	2/24/80 - 1/10/82	95	Lake Hills, Bellevue, WA --> In ASCE/EPA Database	101.7	Mixed Use	TSS, turbidity, TP, pH, TKN, Conductivity, COD, TZn, TPb	Flow-weighted
Overall Study	Good						
Unknown	1/14/80 - 1/17/82	107	Surrey Downs, Bellevue, WA --> In ASCE/EPA Database	95.1	Residential - Med Density	TSS, turbidity, TP, pH, TKN, Conductivity, COD, TZn, TPb	Flow-weighted
Overall Study	Good						

BMP Type Oil & Water Separator

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
State of Washington Water Research Center	11/19/1984 - 5/18/95	7	Boeing Computer Services, Seattle, WA --> In ASCE/EPA Database	18	Commercial	TSS, TP, NO3, NO3-N, O/G, As, Cd, Cr, Ni, Pb, and Zn	Multiple grab
Overall Study	Medium						

BMP Type Porous Pavement - Asphalt

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
University of Washington	11/7/95 - 8/2/96	11	South Shoulder of NE Woodinville-Duvall	0.02	Highway	TSS, BOD, COD, TP, OP, Pb, Cu, Zn	Flow-weighted
Overall Study	Good						

BMP Type Retention Pond (Wet) - Surface Pond With a Permanent Pool

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
King County Surface Water Management Division	01/10/92 - 7/15/93	10	Glenwood Pond	7.7	Residential - Med Density	TSS, TP, SRP, BAP, NO3-N, NH3-N, TCu, TPb, TZn, DCu, DPb, DZn	Flow-weighted
Overall Study	Good						
King County Surface Water Management Division	02/18/94 - 04/15/94	5	Sammamish View East	49.4	Residential - Med Density	TSS, TP, TCu, TPb, TZn	Flow-weighted
Overall Study	Not very useful						
King County Surface Water Management Division	Summer 1993	1	Sammamish Park Place	4	Parking Lot	TSS, TP, TCu, TPb, TZn	Flow-weighted
Overall Study	Not very useful						
Oregon Graduate Center	9/14/87 - 12/12/87	8	OGC Detention Ponds	11	Parking Lot	TCu, DCu,	Single grab
Overall Study	Not very useful						
Portland BES	4/13-14/00; 5/26/00; 5/30-31/00; 10/9-10/00;5/14/01; 5/15-16/01; 5/13/02;	10	Lexington Hills BMP	27	Residential - Low Density	pH, cond, DO, temp, E. coli, NH3-N, BOD, COD, hard, NO3-N, O-PO4-P, fecal coliform, total and TDS, TKN, TP, TS, TSS, tot & dis metals nonpolar oil&grease (As, Cd, Cu, Pb, Hg {tot only}, Ag, Zn),	Multiple grab
Overall Study	Medium						
Portland BES (info pending)		0	138th	0			
Overall Study							
University of Washington	10/4/96 - 4/7/97	17	Pond A	99	Mixed Use	TSS, TP, SRP, BAP, Cd, Cu, Pb, Zn	Flow-weighted
Overall Study	Good						

BMP Type Retention Pond (Wet) - Surface Pond With a Permanent Pool

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
University of **Overall Study**	10/4/96 - 4/7/97 Good	17	Pond C	12.4	Mixed Use	TSS, TP, SRP, BAP, Cd, Cu, Pb, Zn	Flow-weighted
US Bureau of Reclamation Office of Water Research **Overall Study**	8/5/82 - 2/6/1983 Medium	6	The Seattle METRO Site, Bellevue, WA --> In ASCE/EPA Database	15	Industrial	TSS, total and soluble metals (Zn, Pb, Cd, Cr, Ni, As, Cu), TP, OP, O/G, and turbidity.	Time-weighted
Washington County Clean Water Services **Overall Study**	11/29/2000; 2/15/2001; 4/10/2001 Not very useful	3	Cascade Woods	4.95	Residential - High Density	BOD, COD, pH, TDS, TSS, NH3, TKN, NO3+NO2, TP, OP, Hardness, Cl, E.Coli, DCd, TCd, DCu, TCu, DPb, TPb, DZn, TZn	Flow-weighted

BMP Type Wetland - Basin With Open Water Surfaces

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Portland BES (info pending) **Overall Study**		0	Brookside Wetland	0			
Portland BES (info pending) **Overall Study**		0	Ramsey Wetland	0			

BMP Type Wetland - Basin With Open Water Surfaces

Sponsoring Agency	Sampling Dates	No of Events	Station Name	Catchment Area	Major Landuse	Parameters Sampled	Sample
Portland Bureau of Environmental Services	5/26/98 - 11/23/98	7	BES Water Garden	50	Residential - High Density	DCd, TCd, COD, DCu, TCu, DPb, TPb, DZn, TZn, NO3-N, NH3-N, O&G, DO, pH, OP, TP, TDS, TSS, conductivity, temp, E.Coli, fecal coliform, hardness	Time-weighted
Overall Study	Medium						