Water Quality Facility Investigation Report

Final Summary of Project and Evaluation of Monitoring Plan Implementation

Response to Phase 3, Tasks 7&8
Project SPR - 335

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Introduction

The Oregon Department of Transportation (ODOT) has installed several stormwater treatment facilities throughout the State to improve the quality of runoff discharged from highways. These facilities include a variety of both above ground and below ground structures, such as vegetated swales, filter strips, detention basins, infiltration ponds, catch basin filters, and various proprietary systems. To complement existing work devoted to providing effectiveness and efficiency information of stormwater best management practices (BMPs) (www.bmpdatabase.org), ODOT is interested in evaluating the performance of the stormwater treatment facilities that are currently employed and identify the ones that are most appropriate for Oregon's highways.

Project Background and Summary

The overall purpose of this project was to provide monitoring guidance and information that would assist ODOT with the development of monitoring plans for future BMP performance studies. The project has been conducted in three phases: Phase1) Summary of Existing Information and Needs Assessment, Phase 2) Develop Testing Protocols and Monitoring Plan, and Phase 3) Facility Testing and Reporting. The project team, which was a partnership between Oregon State University and GeoSyntec, compiled information and developed monitoring plans during Phases I and II, while ODOT was responsible for BMP monitoring in Phase III with assistance from the team in data analyses and reporting (contained herein). The following summarizes the project according to each of phase of the project.

Phase 1: Summary of Existing Information and Needs Assessment

Phase 1 of the project consisted of three primary tasks: Task 1) Literature Search, Task 2) Information Analysis, and Task 3) Assess Needs. Task 1 involved surveying organizations and agencies with regard to their BMP monitoring activities and reviewing literature on performance monitoring of stormwater BMPs with an emphasis on studies and protocols specific to the Pacific Northwest Region. Task 2 included analyzing the information obtained in Task 1, expanding where necessary, and identifying the extent of regional information and data with respect to the types of water quality facilities typically designed for treating highway runoff. The final Phase 1 report (see Attachment 1) summarized and assessed the information collected during Tasks 1 and 2. As presented in that report, the investigators found that there is adequate guidance available for developing a monitoring protocol for ODOT water quality facilities, but only a limited amount of regional BMP data for estimating the performance of ODOT facilities.

With respect to developing an ODOT BMP monitoring protocol, the Phase 1 report identified four documents that would likely be the most useful sources of outside information: "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 more 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.

With respect to estimating the performance of ODOT water quality facilities with regional data, **Table 1** shows the number of BMP performance studies that were found during the agency inquiry and literature investigation. All of the studies are from the west side of the Cascade Range in either Washington or Oregon. 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. A study was considered to be adequate ("good" quality) if greater than 5 storms were monitored with flow-weighted composite samples. As shown in the table, swales, wet ponds, and filters have the most studies with adequate data for estimating performance of similar facilities owned by ODOT. The regional performance of biofilter strips and dry detention basins are the next best described with three and two studies, respectively. Only one adequate study each was found for wetland swales, wetland basins, sand filters, oil/water separators, and porous pavement. No regional studies were found to be adequate that evaluated underground tanks/vaults, catch basin inserts, or hydrodynamic devices. As for maintenance practices, there were two adequate studies each for evaluating the performance of roadside ditch cleaning and street sweeping.

Table 1. 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

Phase 2: Develop Testing Protocols and Monitoring Plan

This phase of the project originally included three tasks: Task 4) Development of BMP Monitoring Protocols, Task 5) Field Testing Monitoring Plan, and Task 6) Final Phase 1 and 2 Report. Based upon recommendations that the Technical Advisory Committee (TAC) provided during a project meeting on October 15, 2002, the focus of the overall project was modified to reflect the realization that developing a "one-size fits all" protocol for monitoring BMPs was not a feasible goal considering the complexity of such a task and the current budget allocated for the project. Consequently, instead of developing a general BMP monitoring protocol for Task 4, the TAC and ODOT requested that a BMP monitoring plan template be developed. Once this template was developed by the project team, it was then used to prepare two site-specific monitoring plans (one low-level plan and one mid-level plan) for Task 5. At the direction of the TAC, a high-level monitoring plan that included the purchase of equipment (e.g., automated samplers, flow meters, etc.) and required a higher level of expertise was not feasible given the budget and ODOT staff available for monitoring, as it was the responsibility of ODOT to field test the monitoring plans during this task. Task 6 was removed from this phase of the project to become part of the final Phase 3 report.

The Monitoring Plan Template was submitted in December 2002 in response to the modified Task 4 (see Attachment 2). The Template was designed for relatively quick and easy development of a site-specific BMP monitoring plan. Each section contains a brief description of the minimum informational requirements, as well as sections and page numbers from the four primary reference documents for finding specific guidance on each particular section topic.

Using the Template described above, the project team prepared two site-specific draft monitoring plans, which were submitted in May 2003:

- "Rockfall Milepoint 49 Monitoring Plan for Check Dams on Mt. Hood Highway," and
- "UIC Stormwater Monitoring Plan for Central Oregon Highway 20"

The first of these, Highway 26 Plan, details an approach for monitoring roadside ditch sediment traps located on Highway 26 in the Mt. Hood National Forest. As discussed in the next section, monitoring at this site has been conducted in close accordance with the Plan, except for time-weighted composite grab samples could not be obtained due to logistical constraints of the ODOT monitoring team at getting to the site for the entire duration of a storm event. The second plan, Highway 20 Plan, details an approach for monitoring the effectiveness of stormwater BMPs constructed as part of an improvement project on Highway 20 between 10th Street and Providence Drive in the City of Bend, Oregon. The BMPs at this site were specifically designed to treat highway runoff prior to discharging to underground injection controls (UICs). ODOT has not completed monitoring at this site due to safety, logistical, and budgetary constraints, as described below.

Phase 3: Facility Testing and Reporting

After revising the overall project as discussed above, this phase of the project included four separate tasks: Task 6) Collect Data, Task 7) Evaluate Monitoring Data and BMP Effectiveness, Task 8) Final Report, and Task 9) Develop BMP Monitoring Guidance Document.

Task 6 was performed by ODOT personnel and involved the execution of the monitoring plans developed in Phase 2. As mentioned above, Highway 26 monitoring has been completed, but Highway 20 monitoring has been delayed beyond the end of this research contract. In an attempt to exercise the UIC Stormwater Monitoring Plan for Highway 20, our Research Coordinator, Matthew Mabey, noted the following challenges and issues:

1. If monitoring of stormwater quality is going to be a common requirement and/or ongoing need at ODOT stormwater facilities, then the facilities must be designed and constructed such that automated sampling equipment can be installed and easy and safe access to that equipment provided. The time, staff and logistics of sampling dwarfed the process of writing a monitoring plan even without the help of the templates developed as part of this research project.
2. Personnel responsible for maintenance and/or sample retrieval must participate in the establishment of standards and procedures for their design and installation.
3. Current staffing will not be able to support a system wide program of monitoring, even with automated sampling equipment. Additional staff or out-sourcing will be necessary.
4. The responsibility for the maintenance of the automated sampling equipment will need to be explicitly and completely laid out by ODOT headquarters.
5. Regulatory requirements must be quickly and clearly defined or negotiated. This must be done with a clear understanding or the land, human and fiscal resources that are being required and/or committed.
6. Targeted precipitation events seem to be overly rare events in an east-side setting.

Mr. Mabey recommended that the project team continue with the remaining tasks prior to results from the Highway 20 site, since it is unknown when monitoring will be concluded. Thus, this final report concludes the project by including an evaluation of the BMP monitoring data from the monitored Highway 26 site in the following section and a concise BMP monitoring guidance document included as Appendix A.

Evaluation of Collected Data and Monitoring Plan Implementation (Task 7)

An informal summary report was submitted by Mr. Mabey to the project team that summarized the data collected at the Highway 26 monitoring site, as well as issues and problems that arose during the monitoring plan implementation. As mentioned in that report, most of the problems encountered during monitoring were due to the physical characteristics of the site that was selected rather than procedures described in the monitoring plan. The site was found to be atypical of conventional BMPs in a number of ways, including being subjected to snow during much of the wet season and the presence of large, poorly-graded rock material used for constructing the roadside ditch and associated check dams. This coarse material was the cause of the limited surface flow and limited sediment accumulation observed at the site. Over time the pore spaces within this coarse material will likely get filled with sediments and/or organic matter and more surface flows will begin to occur. This will allow for surficial sediment accumulation, which in turn, will provide a better substrate for vegetative growth. Following an evaluation of the collected data in the next subsection some of the issues with implementing the monitoring plan will be discussed along with providing recommendations for mitigating the issues for future monitoring plans.

Evaluation of Monitoring Data and BMP Performance

As stated in the Plan, the goal of monitoring the Highway 26 sediment traps was to estimate their effectiveness at removing particulates and adsorbed pollutants from stormwater and snowmelt runoff from the highway. Determination of pollutant removal efficiencies was not a monitoring goal. This was instead a base level monitoring effort to (1) estimate the quantity and grain size distribution of fine sediment (< 1 mm) captured and bypassed by the check dams, and to (2) assess the concentrations of a selected suite of highway pollutants adsorbed to the captured sediment.

Three different types of monitoring occurred at the site: visual observations, sediment sampling, and water quality sampling. Visual observations included documenting and photographing the hydrologic and geomorphic changes at the site, such as the number of check dams containing water, activity of tributary springs, aggradation or scour of sediment, and growth of vegetation. Sediment sampling included analyzing the grain size distribution and metals concentrations of accumulated sediment on the upstream side of three different sediment traps. Water quality sampling included analyzing suspended sediment concentrations per the Monitoring Plan, as well as magnesium and chloride concentrations at the request of a Technical Advisory Committee member, at three locations along the study area. The following presents and evaluates the data obtained.

Visual Observations

During the implementation of the monitoring plan, ODOT personnel conducted a total of nine field visits. The first visit on July 31, 2003 was not an official observation event; only pictures were taken. These photos are shown in Figures 1 and 2 below. During the second visit, the 28 check dams were assigned sequential numbers beginning from the uppermost check dam and markers were installed at Check Dams 2, 15, 24, and 27, which were chosen for monitoring. Photos were taken and the Field Observations Checklist was completed. Similar activities occurred during all subsequent field visits. Photos of the sites were provided in the summary report, but the Checklists or a summary of the Checklists were not. Therefore, it is not possible at this time to evaluate these data.

Figure 1. July 31, 2003 photos looking downstream at check dams 1-7 (left) and 9-15 (right).

Figure 2. July 31, 2003 Photos looking downstream at check dams 17-21 (left) and 25-28 (right).

Photos for Check Dams 2, 15, 24, and 27 that illustrated the progression of sediment accumulation and vegetation establishment behind the check dams are presented below. Figure 3 shows the progression of sedimentation behind Check Dam 2. The accumulation of fine sediment is evident, but the quantity of sediment is difficult to ascertain from the photos, especially since the staff gage was dislodged. However, as reported in the Summary Report, Mr. Mabey estimated about 1 centimeter of sediment accumulated behind Check Dam 2 during the course of the study. Undoubtedly this does not account for the total amount of sediment removed by this check dam since some of the sediment likely migrated into the pore spaces of the ditch. The final photo on July 14, 2004 shows that vegetation is clearly taking hold. Over time it is surmised that the channel will begin to take on the characteristics of a bioswale and the pollutant removal capabilities (particularly of dissolved constituents) of the check dams will increase.

Figures 4 through 6 show the progression of sedimentation and vegetation establishment behind Check Dams 15, 24, and 27. As mentioned in the summary report, Check Dam 15 only contained water during one of the site visits (11/17/2004), which was a water quality sampling event, not a visual observations event. Consequently, none of the photos in Figure 4 show standing water behind Check Dam 15. During the December 16th event the staff gage was reinstalled, as it had been dislodged.

Check Dams 24 and 27 contained water for nearly all of the visual observation events. The primary source of the water to these lower check dams is not highway runoff however as an ephemeral spring emerges from the hillside just upstream of Check Dam 24. This supplemental water source is likely responsible for the dense vegetation that has established itself at these two locations toward the end of the sampling period.

Since the staff gages at nearly all of the monitored sites were dislodged during the winter months due to snow plowing activities, the ability to accurately estimate sedimentation rates is limited. However, Matt Mabey provided some rough estimates based on the site visits and the photos taken. The table below provides a breakdown of those estimates. Note that with estimates of the extents of the sedimentation area, an approximation of sedimentation rates could be calculated if these data were available.

Table 2. Approximate depth of accumulated sediment.

Check Dam	Approx. Depth of Sediment
2	1 cm
15	0
24	1-2 cm
27	1-2 cm

Figure 3. Check Dam 2 photos showing the progression of sedimentation.

Figure 4. Check Dam 15 photos showing the progression of sedimentation.

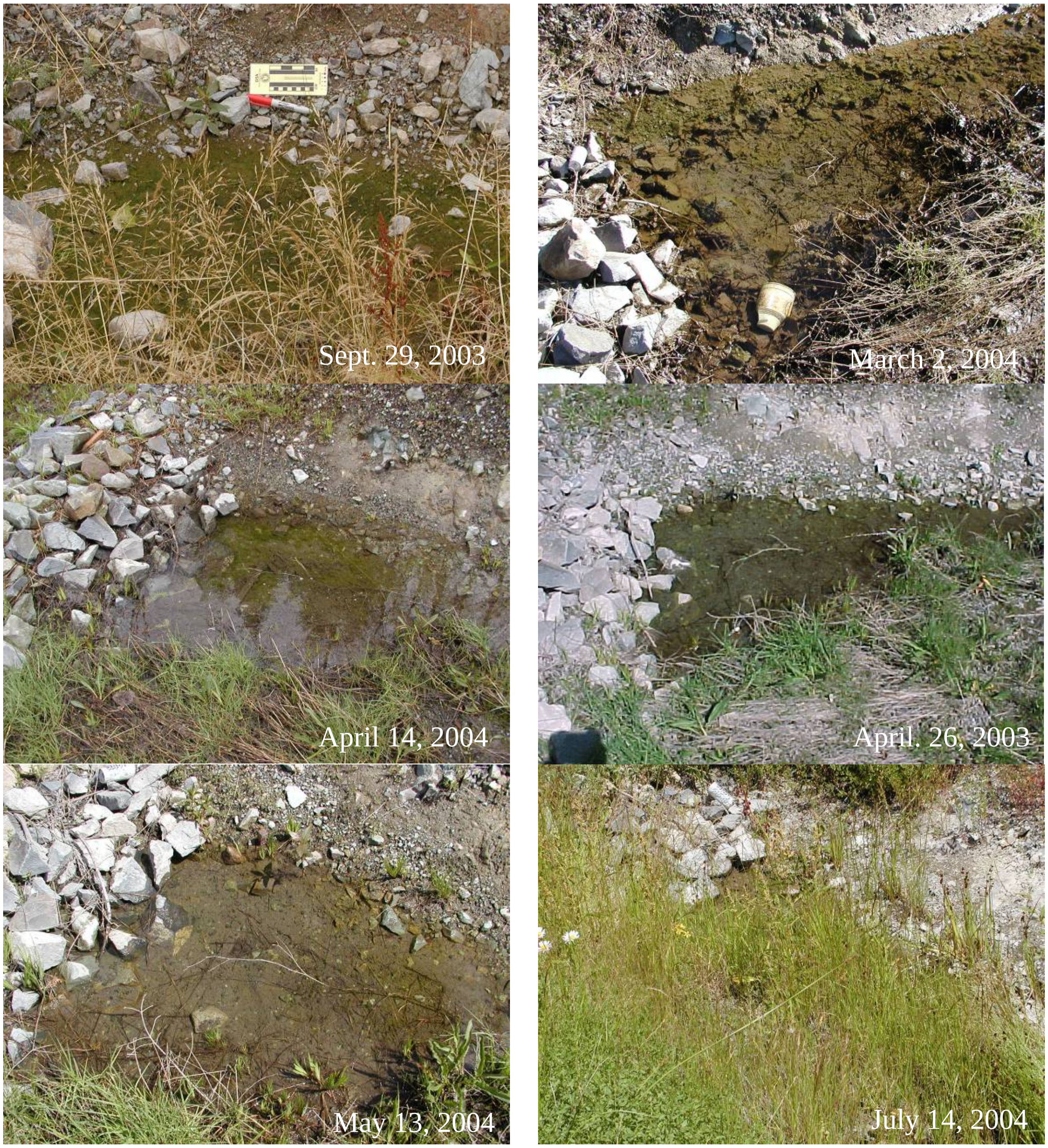

Figure 5. Check Dam 24 photos showing the progression of sedimentation and vegetation establishment.

Figure 6. Check Dam 27 photos showing the progression of sedimentation and vegetation establishment.

Sediment Sampling Data

Three different types of sediment/soil samples were taken during the study: check dam sediment, sanding material, and native material. Check dam sediment (Check Dams 2, 15, 24, and 27 only) was collected once in 2003 (September 29) and twice in 2004 (April 26 and August 25). The sanding material was sampled once on November 19, 2003 and the native material was sampled once on November 17, 2003. Per the monitoring plan, all samples were analyzed for total cadmium, copper, lead, and zinc, as well as grain size distribution. At the request of a panel member, the sanding and native materials were also analyzed for magnesium and chloride.

Average metals concentrations for each check dam are compared to the sanding and native materials in Table 3. The short time frame of the study and the small number of samples make it difficult to make a conclusive assessment of the sediment metals concentrations. Except for lead, the check dam concentrations appear to be within the range of the native and sanding materials. However, with only one sample each, the actual range of these materials is unknown. The sanding material is lower for copper and zinc than the native material. Check Dam 15 appears to have higher values for all detected metals, but considering the limited sediment and standing water at this site, the metals source is likely either natural or historic. There is a general decreasing trend in concentrations for all detected metals in the direction of flow from Check Dam 15 to 24 to 27, which indicates that pollutants associated with sediment (whether natural or anthropogenic) may be reduced prior to discharging to downstream waterbodies. However, this trend may also be due to the washing out of particles due to continuous flows from the emergent spring just upstream of Check Dam 24

Screening-level, non-regulatory thresholds for freshwater sediment are included in the table for comparison purposes. Only total lead from Check Dams 15 and 24 exceeds the probable effects level (PEL). While not statistically conclusive given the small number data points, this comparison along with the native and sanding materials concentrations may indicate an anthropogenic source for lead. It should be noted that PELs are Canadian Guidelines that have not been adopted in the US or Oregon, so these comparisons are for informational purposes only.

Table 3. Average sediment concentrations in sampled sediment.

	Copper (mg/kg)	Lead (mg/kg)	Zinc (mg/kg)	Cadmium (mg/kg)
Check Dam 2	14.8	12.1	45.2	ND
Check Dam 15	94.5	105.1	235.0	ND
Check Dam 24	43.5	47.5	113.2	ND
Check Dam 27	36.7	28.5	71.8	ND
Sanding Material	32.9	9.78	67.1	ND
Native Material	66.4	46.1	133.0	ND
PEL	35.7	35.0	123.1	3.53

ND - Not detected
PEL - Probable Effects Level*
* Note these are non-regulatory screening values for freshwater sediment
(source: http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html)

In addition to sediment quality analysis, the sediment samples were also analyzed for grain size distribution. Grain size distributions provide information on the size of particles being trapped by the check dams. Since sedimentation is a function of hydraulic retention time, it is expected that check dams consistently observed with standing water would settle a higher proportion of fine sediment provided that a significant source of fine sediment exists.

Figure 7 shows the particle size distribution by weight for sediment samples collected behind each of the monitored check dams. Note that only a sieve analysis was conducted for the second sampling event. Therefore, size fractions of the fine particles less than the #200 sieve (75 microns) were determined only for the first and final sampling events. Notice lower proportions of small particles during the August 24, 2004 sampling event than the other two sampling events for all of the check dams except Check Dam 15. This is very evident for Check Dam 27 where about 60% of the sample had particles greater than 4750 microns. One possible reason for this difference is over an inch of rain fell before August 24, which may have flushed out the finer particles.

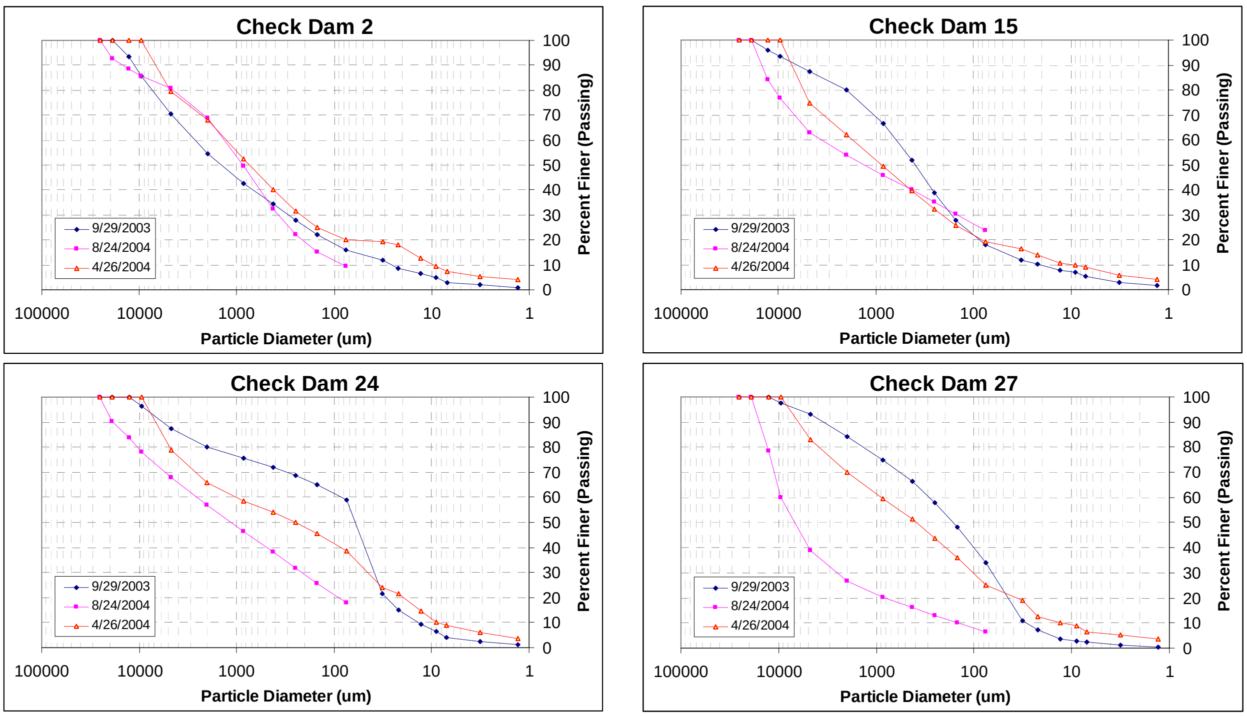

Figure 7. Particle size distributions by weight for sediment samples collected behind each monitored check dam.

Since the percentages shown in the figure above are based on the entire sample, the relative quantities for each particle size are not accurately depicted because large rocks can skew the particle size distributions. By normalizing these data by medium sand-sized particles (~ 850 microns; #20 sieve) a more useful analysis of fine particles can be conducted. Figure 8 shows the distribution of particles less than 850 microns.
As shown in the figure, all of the sediment samples show a larger proportion of fine sediment from the April 26, 2004 monitoring event, which indicates an accumulation of fine sediment in all of the check dams.

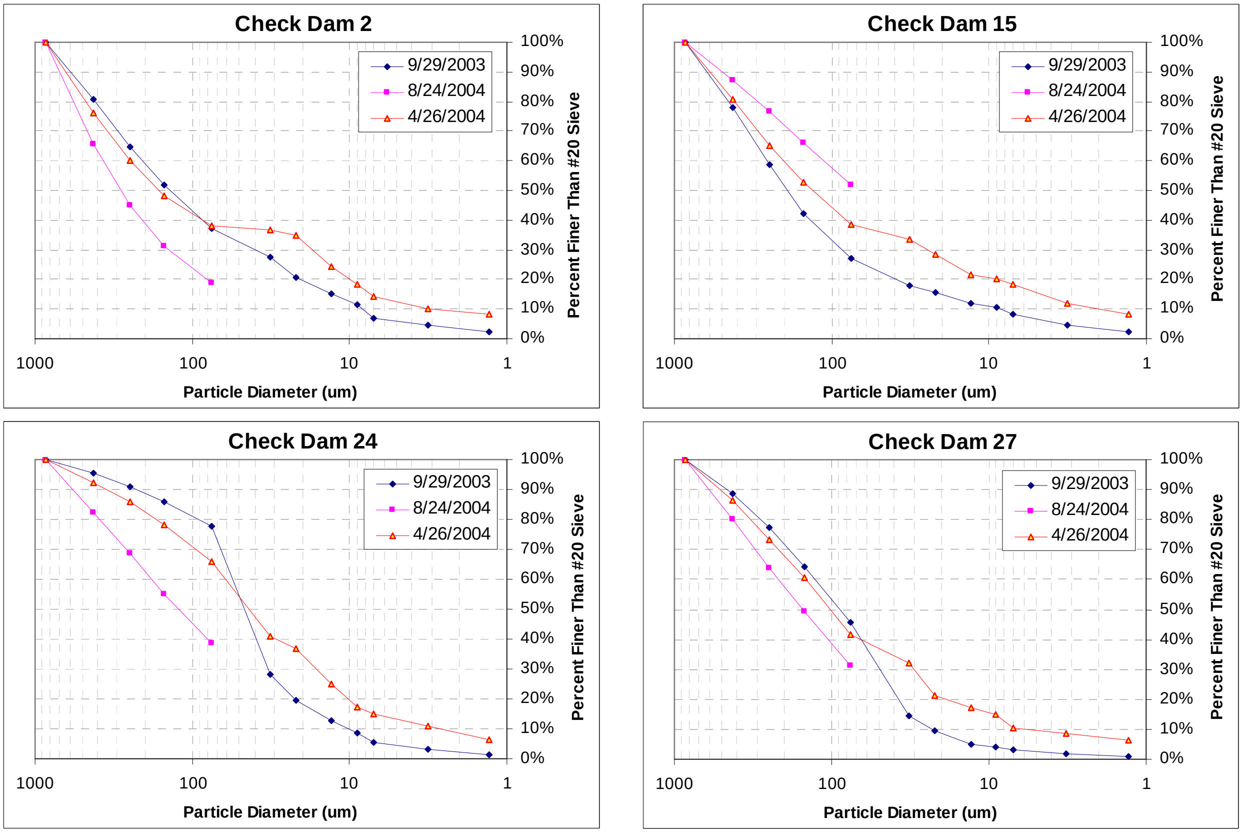

Figure 8. Particle size distributions by weight for particles less than a #20 sieve (850 microns) for sediment samples collected behind each monitored check dam.

To analyze the spatial variation in sediment sizes, Figure 9 shows the average particle size distribution for particles less than 850 microns for the four monitored check dams. Notice that the percentages of fine sediment for each of the check dams begin to approach each other with decreasing particle sizes. Check Dam 24 has a much higher percentage of sand-sized particles, which may indicate that the finer particles are either being deposited upstream, are settling below the surface or are being flushed through or out during storm events.

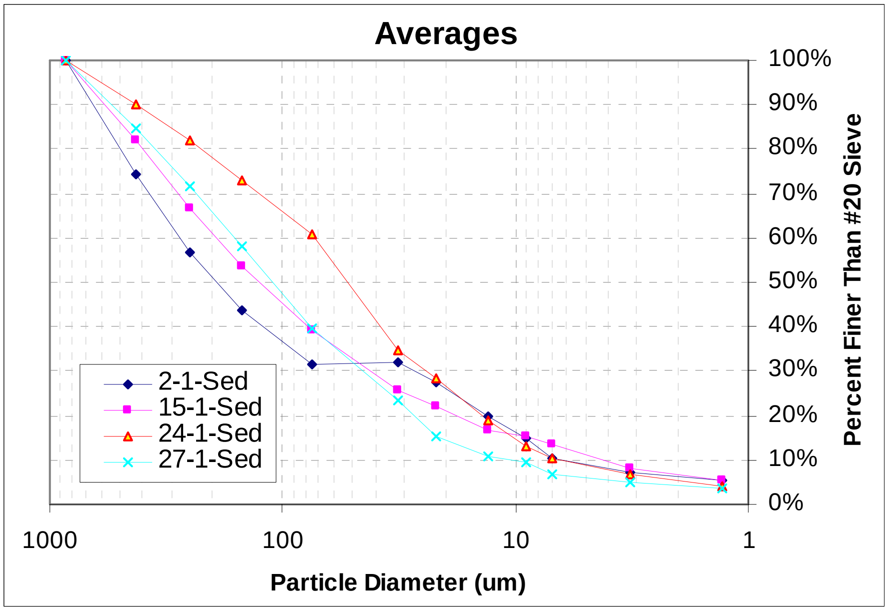

Figure 9. Average particle size distribution by weight of captured sediment less than a #20 sieve (850 microns).

Water Quality Sampling

As stated in the monitoring plan, time-weighted composite water quality samples were to be collected during one to three storm events per year at three locations along the check dams, including the effluent. Time-weighted composite sampling requires samples to be collected about every 30 to 60 minutes for the entire duration of the storm event. As noted in the Summary Report, there were problems with accurately predicting and mobilizing for storm events (discussed in next subsection). Consequently, only single grab samples from behind Check Dams 2, 15, and 24 were collected. In accordance with the monitoring plan, samples were analyzed for total suspended sediment, and at the request of a Committee member, they were also analyzed for magnesium and chloride.

Water quality samples were collected on November 17, 2003, March 25, 2004, and April 14, 2004. Only on November 17, 2003 was enough water behind Check Dam 15 to collect a sample. Table 4 shows the depth of rainfall of the monitored storm events as well as the previous 10-day accumulation of rainfall. Clearly, the November 2003 sampling event occurred after a much wetter time period.

Table 4. Precipitation summary of monitored storm event (inches).

Date	11/17/2003	3/25/2004	4/14/04
Storm Depth	0.69	0.93	0.59
Previous 10-day Accumulation	3.66	1.03	0.36

Table 5 summarizes the water quality data collected from the site. Note that the lab used a detection limit of 10 mg/liter for the first TSS analysis and 1 mg/liter for all subsequent analyses. Therefore, the non-detects shown for all of the check dams on 11/17/03 have a different meaning than the non-detect shown for Check Dam 24 on 3/25/04. Nonetheless, the data do indicate a reduction in TSS in the direction of flow. This reduction is likely due to both a combination of sedimentation behind the check dams, as well as mixing of clean water from the hillside seep above Check Dam 24. A similar trend is shown for magnesium and chloride. The higher concentrations during the last two monitoring events for Check Dam 2 indicate an upstream source for these two ions. The lower concentrations observed at Check Dam 2 during the 11/17/2003 event are likely due to the flushing of these ions during the previous week of rainfall.

Table 5. Water quality sampling results for Check Dams 2, 15, and 24.

	Total Suspended Solids (mg/L)			Magnesium (mg/L)			Chloride (mg/L)		
Site	11/17/03 (0.69 in)	3/25/04 (0.93 in)	4/14/04 (0.59 in)	11/17/03	3/25/04	4/14/04	11/17/03	3/25/04	4/14/04
2	nd	37.3	6	2.78	14.1	24.6	18	48.1	99.9
15	nd	ns	ns	2.81	ns	ns	17.9	ns	ns
24	nd	nd	3	3.06	3.88	3.86	18.6	18.2	17.9

nd - not detected at the analytical detection limit
ns - not sampled

Summary and Conclusions of Highway 26 Monitoring

While there were some significant issues with implementing the monitoring plan and more data are needed, the information collected does provide a preliminary indication of the performance of the check dams at the Highway 26 site. The most general conclusion is that the check dams are efficient at capturing sand-sized particles and associated pollutants. Suspended sediment appears to be reduced, but the results are inconclusive with only two data points, neither of which are event mean concentrations (EMCs). It is surmised that small particles are captured during snow melt and small rainfall events, but are resuspended during large runoff events. For some of the check dams, the migration of small particles and associated pollutants into the rocky substrate is also suspected, especially for Check Dam 15 where there is no apparent accumulation of sediment. Infiltration of runoff undoubtedly reduces the total load of sediment that would otherwise be discharged downstream. Subsurface flows play an important role at the site and a more advanced monitoring program that includes subsurface sediment and pore water sampling may be required to adequately characterize the performance of the check dams. Since snowmelt is a significant contributor to runoff at the site, roadside snow sampling may have aided in the characterization of inflows to the check dams. An automated sampler with a flow gage at the outlet of the check dams could also provide additional data useful for comparing the snow samples with the ultimate effluent quality of the check dams.

Issues Raised with Monitoring Plan Implementation

As stated in the Summary Report, there were a number of issues raised with regard to implementing the monitoring plan. Most of these were due to the uniqueness of the Highway 26 monitoring site; however, others point to some deficiencies in the monitoring plan that should be addressed**.** Table 6 summarizes the issues raised in the Summary Report including an explanation and/or suggestion for mitigating the issue in future monitoring plans.

Table 6. List of observed issues during monitoring plan implementation.

Issue Item	Description	Explanation / Potential Fix
Check dam markers	Visibility and durability	Use large, stout permanent markers. The Summary Report provides an illustration and concept for such markers.
Field observations check list	1. Some data requested are not field observations 2. Some data requests are not explicit enough to illicit useful information	1. Either make additional check list or specify that some information should be acquired prior to going out into the field. 2. Check list should be more explicit and reference a section of the monitoring plan with more information on the subject. Some observations are best described qualitatively.
Random sampling approach	Sediment accumulation confined to small areas, so random approach could not be easily applied	Could specify minimum sedimentation area needed to apply random sampling and if this minimum is not met then subjectively choose the approximate middle of the sedimentation area for a single sample
Teflon scoop	Teflon coated scoop difficult to obtain and insufficiently durable	Plastic scoop could be used as long as petroleum compounds are not sampled. This could be stated in the monitoring plan template, but sediment sampling was not addressed in the template.
Sediment reporting limits	Reporting limits were for aqueous samples not sediment samples	This was simply an oversight and should be corrected. Reporting limits should be at least below the probable effects levels (PELs) listed in the NOAA SQuiRT tables. During monitoring plan preparation, the contract laboratory should be contacted to ensure these limits can be met.
Gallon jars	Laboratory considered this request unusual	Gallon jars were specified for time-weighted composites. Since only single grab samples were collected smaller jars would have sufficed. As an alternative, could have the laboratory composite individual storm samples.

Issue Item	Description	Explanation / Potential Fix
Laboratory terminology	Laboratory analyzed first water quality sample using a 10 mg/L detection limit rather than the specified 1 mg/L because the lab uses different terminology for lower detection limits, namely, "Lower Limit Total Suspended Solids"	Communication with the laboratory is crucial. Recommend reviewing monitoring plan with lab prior to sampling and provide explicit instruction on COC form.
Snow melt hydrology	The monitoring plan does not mention snow.	The monitoring plan does mention that the site is impacted by snow melt, but this was intended to be a low-tech study. Snow melt hydrology is complicated and difficult to predict. Without automated sampling equipment, accurately sampling snow melt events would be difficult. One alternative would be to sample the snow bank. This would not be a good indicator of effluent TSS concentrations, but could provide pollutant source data.
Logistics	Sampling team mobilized from Salem, so timing with respect to precipitation was crude.	As suggested in the Summary Report, recommend a maximum travel time of one hour for storm event monitoring events.
Rock fall hazard	An apparent rock fall hazard existed at the site, but was not mentioned in the Monitoring Plan.	The rock fall hazard is valid and should have been included in Section 7 of the Monitoring Plan. However, a separate Health and Safety Plan (HASP) should also be prepared and attached to the monitoring plan. A HASP was not prepared by the project team due to liability issues in doing so. It is up to the primary monitoring contractor to prepare the HASP.

Conclusion and Recommendations

The Highway 26 site provided a preliminary indication of the performance of the Rockfall Checkdams at removing particulate solids. With more water quality data, especially time-weighted composite storm event data, a more statistically defensible estimate of performance could be provided. As the check dams continue to fill in with sediment, the ability to detect differences between background concentrations and deposited sediment metals concentrations may increase, but it currently appears that there is limited supply of deposited material behind the check dams to collect representative samples of deposited sediment without inadvertently collecting native material. The sampling of roadside snow banks may have provided additional information on the quality of sediment and runoff delivered to the check dams. Future monitoring of ODOT BMPs near areas with snow should consider the collection of snow samples.

The unsuccessful attempt to exercise the UIC Stormwater Monitoring Plan developed for Highway 20 from MP 1.11 to 2.31 in eastern Bend, Oregon is unfortunate, but valuable lessons were learned, and the importance of considering monitoring in the early planning and design stages of BMPs was highlighted. The key lessons learned from the effort are as follows:

- Manholes and outfalls that require regular access for water quality monitoring need to be located and designed with monitoring access in mind.
- Staffing resources need to be made available for monitoring, including monitoring plan preparation, implementation, and data reporting and analysis.
- Adequate funding for monitoring is essential for a monitoring plan to be successful, and the available budget must be explicitly known before a monitoring plan is developed.
- Explicit delegation of responsibility for monitoring will have to come from ODOT Headquarters.
- Automated sample collection should be considered for stormwater monitoring, especially if samples are to be collected at multiple sites over multiple storms over several years.
- Design and construction must include maintenance, monitoring, and safety as parameters.
- Outsourcing may be necessary.
- Regulatory requirements must be clear and drive the monitoring plans.

For both of these sites, it is important to note that the monitoring plans were developed in an attempt to highly minimize the costs of monitoring and the technical difficulty due to early indications of very limited funding and expertise for sample collection and analysis by ODOT. If additional funding and expertise were available, more elaborate and technically advanced monitoring plans would have been developed for the chosen sites or other BMPs specifically designed for monitoring (e.g., Sunnybrook Swales). For instance, automated samplers that collected flow-weighted composite samples rather than manual time-weighted composite samples would have been recommended. Telemeters would also have been recommended so the samplers could be monitored and programmed in real-time. These devices require expertise to install and operate successfully and they likely would require additional design and construction (e.g., flumes may need to be installed to accurately monitor flow rates). Also, these devices significantly increase the capital costs of monitoring. If the intention was to continue monitoring at the two sites for multiple years, then automated equipment would be a more cost effective solution than manual sampling.

References

Caltrans (2000). “Guidance Manual: Stormwater Monitoring Protocols.” Prepared by Larry Walker and Associates. [Online Available, September 2002] http://www.dot.ca.gov/hq/env/stormwater/special/index.htm

FHWA (2000). “Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring” FHWA Office of Natural Environment. FHWA-EP-00-002. Prepared by Tetra Tech, Inc.

FHWA (2001). “Guidance Manual for Monitoring Highway Runoff Water Quality.” *U.S. Department of Transportation Federal Highway Administration* FHWA-EP-01-022. Prepared by URS Group, Inc.

USEPA/ASCE (2002). “Urban Stormwater BMP Performance Monitoring – A Guidance Manual for Meeting the National Stormwater BMP Database Requirements.” Prepared by GeoSyntec Consultants and Urban Drainage and Flood Control District [Online Available, September 2002] http://www.bmpdatabase.org/docs.html

APPENDIX A

ODOT BMP Monitoring Plan Guidance

This guidance document discusses only the recommended minimum requirements of an ODOT BMP monitoring study, and provides reference material for the user interested in finding more information. The guidance focuses on BMPs with monitoring goals that are achievable with a relatively low-level of technical sophistication (i.e., Base-Level Monitoring). Those who wish to conduct a more technical study will be directed to seek information contained in the referenced materials.

1 Primary Regulations Affecting ODOT's Stormwater Management Activities

While there are numerous environmental regulations affecting highway projects, such as fish passage and wetland mitigation, this discussion is limited to regulations specifically related to water quality management activities. A summary of laws and regulations affecting DOT water quality management are as follows:

- **The National Environmental Policy Act (NEPA)** The National Environmental Policy Act (NEPA) establishes judicially enforceable obligations that require all federal agencies to identify the environmental impacts of their planned activities. The NEPA legislation and its requirements provide the framework under which environmental impacts of all substantial federal projects are evaluated, and have been the starting point from which many other environmental regulations are applied and enforced. Any major effort that involves federal funding, oversight, or permits, such as highway operations and projects, is subject to the NEPA process to ensure environmental concerns are considered and documented in an environmental impact statement (EIS) before implementation.
- **The Clean Water Act (CWA) of 1972, as amended.** The EPA regulates water quality under the Clean Water Act (CWA). CWA requires that the discharge of pollutants to waters of the United States from any point source be effectively prohibited, unless the discharge is in compliance with a National Pollutant Discharge Elimination System (NPDES) permit (discussed below). Stormwater runoff discharged from a storm drain to a receiving water body is considered a point source. Section 303(d) of the CWA requires identification and listing of water-quality limited or "impaired" waterbodies where water quality standards and/or receiving water beneficial uses are not met. Once a waterbody is listed as "impaired," total maximum daily loads (TMDLs) must be established for the pollutants or flows causing the impairment (33 U.S.C. §1313(d)(c)).
- **The National Pollutant Discharge Elimination System (NPDES).** This program requires discharge permits for industrial and municipal effluents containing pollutants. Effluent regulations include characterization of stormwater runoff, possibly originating directly from highways and the construction and maintenance of the highway systems. An NPDES permit requires dischargers to comply with technology-based pollution limitations (generally according to the "best available technology economically achievable," or "BAT" standard). 33 U.S.C. § 1311(b)(2)(A).

- **The Nonpoint Source (NPS) Management Programs, Title 3, Section 319**. This program also promotes the implementation of best management practices regarding highway runoff, as a potential nonpoint pollutant source of surface and ground water.
- **Federal Antidegradation Policy (40 CFR §131.12).** Requires states to develop statewide antidegradation policies and identify methods for implementing them. Pursuant to the CFR, state antidegradation policies and implementation methods shall, at a minimum, protect and maintain: (1) existing in-stream water uses; (2) existing water quality where the quality of the waters exceeds levels necessary to support existing beneficial uses, unless the State finds that allowing lower water quality is necessary to accommodate economic and social development in the area; and (3) water quality in waters considered an outstanding national resource.
- **The Department of Transportation (DOT) National Transportation Policy (NTP), the Federal Highway Administration (FHWA) Environmental Policy Statement (EPS), and the Intermodal Surface Transportation Efficiency Act (ISTEA).** These policies and acts specify increased environmental responsibilities for policies and programs developed by federal and state transportation agencies.
- **The Coastal Zone Reauthorization Amendment (CZRA).** This amendment regulates highway-runoff water quality and its environmental impacts in coastal areas.
- **Oregon Administrative Rule 340-41-26(3)(a)(D), Surface Water Temperature Management Plan**. As part of their NPDES permit, ODOT must develop and implement a surface water temperature management plan. If it is determined that storm water discharges in a particular basin are impacting a Total Maximum Daily Load for temperature, then permittees in this basin will be required to implement additional management practices to reduce the temperature of the discharges. These practices include, but are not limited to, increased vegetation to provide for shading, underground conveyance systems or detention vaults, and filter treatment systems to reduce temperatures.
- **Oregon Nonpoint Source Control Program Plan (NPS Plan)**. Originally established in 1978, the NPS Plan was revised in 1991 and updated every year in the Intended Use Document 319-proposal submittal to EPA. The program was established to address non-discreet pollutant discharges to surface waters not otherwise regulated by Federal or State point source control programs. The goal of the program has been broadened to safeguard groundwater resources as well as surface water.
- **Underground Injection Control Rules OAR 340-044 (UIC Rules)**. Provides requirements to limit and control injection of wastes, including stormwater, into the subsurface to protect existing groundwater quality for current and future beneficial uses including use as a source for drinking water. Prior to construction, maintenance, and operation of a UIC facility, a permit must be obtained from the ODEQ.

2 Identifying the Limitations of the Study BMP

2.1 Choosing a Study Site

The choice of whether to study a particular BMP or not should be based on the following:

- **Need for Information**. Prior to initiating a BMP performance study, the value of the information that will be collected should be assessed to ensure that knowledge gained through performing the study will be useful for water quality management planning and decision making purposes.

- **Representativeness.** To maximize the usefulness of the collected data, the site should be representative of other facilities owned and operated by ODOT, both in design and tributary drainage area. An exception to this would be when information is needed or required from a critically important site.

- **Safety.** The safety of the public and monitoring personnel should be of utmost concern in the selection of a BMP to monitor. Reconsider any site that cannot be safely accessed without extensive traffic control or safety equipment.

2.2 Selecting Monitoring Parameters

The selection of monitoring parameters should be based on the following:

- **Permit requirements (if any)**. Monitoring to comply with a permit may specify which parameters must be measured in stormwater discharges. However, it is common practice to include some conventional parameters for monitoring (TSS, nutrients, copper, lead, zinc, TDS etc) for additional parameters to provide a basis for comparison with other studies provided that the lab costs are not prohibitive.
- **Existing water quality data (if any) for the catchment area**. Existing water quality data can be helpful in refining the parameter list. However, if there is uncertainty about the monitoring methods and/or analytical data quality, or if the existing data pertain to baseflow conditions or only one or two storms, caution should be used in ruling out potential pollutants. For example, an earlier study may have used outdated analytical methods that had higher detection limits than current methods.
- **Beneficial uses of the receiving water**. Information on water quality within a stormwater drainage system often is used to indicate whether discharges from the system are likely to adversely affect the receiving water body. For example, if a stormwater system discharges to a lake, consider analyzing for nitrogen and phosphorus because those constituents may promote eutrophication.
- **Usefulness of parameter for other areas**. If it is desired to estimate the concentration of a water quality parameter at a particular area or project (e.g., in support of an environmental impact assessment, for example), then monitoring for that parameter at another site already set up for monitoring should be considered if that site is representative of the area of interest.
- **Overall program objectives and resources** (see Section 2.4). The parameter list should be adjusted to match resources (personnel, funds, time). If program objectives require assessing a large number of parameters (based on prior monitoring data, receiving water status, etc.), consider a screening approach where samples collected during the first one or two storms are analyzed for a broad range of parameters of potential concern. Parameters that are not detected, or are measured at levels well below concern, can then be dropped from some or all subsequent monitoring events. To increase the probability of detecting the full range of pollutants, the initial screening samples should be collected from storms that occur after prolonged dry periods.

See Section 3.2.3 of the ASCE/USEPA Urban Stormwater BMP Performance Monitoring Guidance manual for more information on constituent selection.

2.3 Classifying the Study BMP

Stormwater Best Management Practices (BMPs) can be divided into four types for the purposes of monitoring:

Type I	BMPs with well-defined inlets and outlets (e.g., detention basins, vegetated swales, catch basin inserts).
Type II	BMPs with well-defined inlets, but not outlets (e.g., infiltration basins, infiltration trenches)
Type III	BMPs with well-defined outlets, but not inlets (e.g., grass swales where inflow is overland flow along the length of the swale, buffer strips where the overland flow can be funneled into a collection vessel).
Type IV	BMPs without any well-defined inlets or outlets and/or institutional BMPs (e.g., buffer strips, catch basin retrofits, education programs, source control programs).

The monitoring approach for each type of BMP could be very different depending on specific monitoring goals.

2.4 Defining the Goals of the BMP Monitoring Study

BMP monitoring can be divided into four broad categories according to typical monitoring goals and levels of technical sophistication: base level effluent monitoring, treatment monitoring, systems monitoring, and drainage basin monitoring.

Base level effluent monitoring is the most basic and therefore the least expensive type of BMP monitoring. The purpose of effluent monitoring is to determine if the BMP meets a predetermined goal, such as effluent quality limitation or maximum flood attenuation. For example, to determine whether a BMP meets numeric water quality limits as required by a TMDL, then monitoring of only the effluent is necessary to determine if the BMP is effective at meeting that limit. Effluent monitoring can be useful in a number of ways such as to:

- indicate whether or not a BMP, on average, is achieving water quality objectives/standards,
- estimate the exceedance frequency of water quality objectives/standards,
- estimate annual discharge loading from a BMP,
- identify areas where water quality improvement is needed (add another or improve an existing BMP),
- help identify which types of BMPs work,
- identify BMP sites for more detailed investigation (e.g., efficiency or performance study), or
- compare effluent to achievable levels for similar BMPs (USEPA/ASCE Database).

Hydrologic observational monitoring is the most basic approach for monitoring the performance of Type II BMPs. The purpose of this type of monitoring is to observe the hydraulic performance of infiltration-type BMPs during and after several storm events and document via photographs and notes of how quickly and efficiently stormwater is infiltrated. The time it takes for a facility to drain at the end of a storm event, either completely or at various stages, may also be recorded to estimate the average infiltration rate, and if conducted over several storms may provide information on the loss of infiltration capacity of the facility. To obtain more quantitative information, this approach could be combined with a base level monitoring of flows that enter and bypass the infiltration facility. Hydrologic observational monitoring can be useful for:

- determining whether a BMP is actually infiltrating water quality sized storm events
- estimating the infiltration rate and how the infiltration capacity may be changing over time
- documenting the progression of sediment accumulation and vegetation establishment of a BMP for estimating maintenance frequencies

Treatment monitoring requires more information than effluent monitoring. Only BMP Type I can be assessed using this approach. The purpose of this type of monitoring is to determine not only that the BMP is working, but also how well it works. Treatment monitoring traditionally refers to the pollutant removal effectiveness or efficiency of the BMP. Historically, BMP efficiency has been used synonymously with "percent removal", which alone is not a valid measure of functional efficiency (Strecker et al., 2000). Efficiency used in the context herein refers to a measure of how well a BMP or BMP system meets a predetermined goal. For example, if the goal of a BMP is to reduce pollutant concentrations to receiving waters, both the influent and effluent concentrations must be measured (or estimated) to first determine if the BMP has an effect on water quality, and then if desired, determine the level of reduction. There are a number of different approaches to quantifying efficiency. The recommended approach in the USEPA/ASCE 2002 document is the effluent probability approach, where the influent and effluent event mean concentrations (EMCs) are first checked to see if they are statistically different from one another. If so, the median EMC is used as the estimate of performance. As can be deduced from the discussion above, treatment monitoring can be complicated and expensive. However, it provides much more information to the investigator than effluent monitoring. Some monitoring goals that treatment monitoring can be used to meet include:

- determining if a BMP is actually improving water quality,
- determining if a BMP is functioning as intended in its design,
- determining how efficiency varies between different pollutants,
- estimating the potential exceedance frequency of water quality criteria, and
- estimating the degree of pollution control provided by a BMP under typical operating conditions, and comparing the efficiency of the study BMP to the efficiency of other BMPs.

Systems monitoring is similar, but more comprehensive (and therefore more complicated) than treatment monitoring, in that it requires an engineering systems analysis or optimization approach. Any type of BMP can be evaluated using this approach. However, the data requirements of monitoring of this level of sophistication require a good knowledge of the governing treatment processes of the stormwater BMP, information on environmental and economic constraints, and a well-defined objective, such as maximizing treatment while minimizing costs. The purpose of systems monitoring is to determine how well a BMP meets a predetermined goal within stipulated constraints and objectives. Some of the monitoring goals that are addressed using this approach include:

- estimating how a BMP responds to changing influent conditions,
- estimating the value of water quality improvements,
- determining long-term trends in BMP performance,
- determining which design variables affect performance,
- determining how maintenance practices affect performance,
- determining how storm characteristics such as rainfall amount, rainfall intensity, and antecedent weather conditions affect performance, and
- numerically evaluating the "maximum extent practical" treatment criterion.

Drainage basin monitoring is primarily for BMP Types III and IV. This type of monitoring approach is not very complicated; however, it may require a substantial amount of information and sampled storm events to obtain meaningful data. There are three different methods for conducting a drainage basin monitoring study: upstream-downstream, before and after, and reference drainage area, all of which have their advantages and disadvantages. The reference drainage area approach was used in an herbicide impacts investigation conducted by the United States Geological Survey in cooperation with ODOT (Wood, 2001). Some of the monitoring goals addressed with the drainage basin monitoring approach include:

- estimating the effectiveness of source control programs, such as street sweeping and public education and outreach,
- estimating the pollutant reduction of infiltration facilities, and
- evaluating the effectiveness of roadside properties at removing pollutants.

It should be noted that as the drainage area of interest increases in size so does the number of unknown variables. These unknowns can significantly contribute to "noisy" data, sometimes requiring several years of monitoring data to identify and eliminate "background" conditions.

2.5 Identifying the Minimum Requirements

The minimum requirements for base-level monitoring of the four different BMP types are summarized in Table 1 and Table 2 below. Guidance on more technical monitoring approaches can be obtained from the primary guidance documents provided in Section 3.

Table 1. Minimum requirements for Type I or III BMP.

BMP Effluent Monitoring	Minimum Requirements for BMP Monitoring Study																			
	Monitoring Equipment						Sampling Methods				BMP design information			Comparative Information				Data Analysis and Reporting		
Objectives of Study	Field Probe	Flow Measurement Device	Automated Sampler	Sample Bottles	Cooler	Chain of Custody Forms	Sample Location	Sample collection method	Number of samples per event	Number of events for study	Watershed characteristics (a)	Hydrologic analysis (b)	BMP sizing criteria (c)	Water quality objectives/standards	Information on comparative BMPs design	Average effluent concentration from comparative BMPs	Variability of effluent concentrations of comparative BMP	Basic Descriptive Statistics (d)	Exceedance Probabilities (e)	Statistical Test Parameters (f)
Determine if average effluent quality meets water quality standards	✓			✓	✓	✓	EF	TWCG	4	5		✓		✓				✓		
Estimate the exceedance frequency of water quality standards	✓			✓	✓	✓	EF	TWCG	16	20		✓		✓				✓	✓	✓
Estimate discharge loading	✓	✓	✓	✓	✓	✓	EF	FWCA	16	20		✓						✓		
Compare average effluent quality to the average effluent quality of other BMPs	✓			✓	✓	✓	EF	TWCG	4	5	✓	✓	✓		✓	✓		✓		

EF = Effluent; all outfalls should be sampled and analyzed separately, however if samples can be taken simultaneously then they can be combined before analysis
TWCG = Time-Weighted Composite Grab sample
FWCA = Flow-Weighted Composite Automated sample

(a) General description of watershed size, land use, and % imperviousness for identifying comparative studies
(b) Basic hydrologic analysis to estimate statistical distribution of storm event depths and intensities
(c) Gross estimate of BMP sizing criteria (e.g., detention time, capacity) for identifying comparative studies
(d) Mean, median, minimum, maximum, coefficient of variation, and number of events
(e) The probability of exceeding water quality standards during a single storm event based on the suspected distribution of effluent quality
(f) Statistical tests include normality testing and hypothesis testing

Table 2. Minimum requirements for Type II or IV BMP.

BMP Effluent Monitoring	Minimum Requirements for BMP Monitoring Study																			
	Monitoring Equipment						Sampling Methods				BMP design information			Comparative Information				Data Analysis and Reporting		
Objectives of Study	Sheet Flow Sample Box (Type IV)	Lysimeter or other subsurface sampling device (Type II)	Automated Sampler (if infiltrated waters leave via underdrain (Type II)	Sample Bottles	Cooler	Chain of Custody Forms	Sample Location	Sample collection method	Number of samples per event	Number of events for study	Watershed characteristics (a)	Hydrologic analysis (b)	BMP sizing criteria (c)	Water quality objectives/standards	Information on comparative BMPs design	Average effluent concentration from comparative BMPs	Variability of effluent concentrations of comparative BMP	Basic Descriptive Statistics (d)	Exceedance Probabilities (e)	Statistical Test Parameters (f)
Determine if average effluent quality meets water quality standards	✓	✓	✓	✓	✓	✓	EF	TWCG	4	5		✓		✓				✓		
Estimate the exceedance frequency of water quality standards	✓	✓	✓	✓	✓	✓	EF	TWCG	16	20		✓		✓				✓	✓	✓
Compare average effluent quality to the average effluent quality of other BMPs	✓	✓	✓	✓	✓	✓	EF	TWCG	4	5	✓	✓	✓		✓	✓		✓		
Determine if the effluent quality is statistically different than the effluent quality of other BMPs	✓	✓	✓	✓	✓	✓	EF	TWCG	16	20	✓	✓	✓		✓	✓	✓	✓		✓

EF = Effluent; all outfalls should be sampled and analyzed separately, however if samples can be taken simultaneously then they can be combined before analysis
TWCG = Time-Weighted Composite Grab sample

- (g) General description of watershed size, land use, and % imperviousness for identifying comparative studies
- (h) Basic hydrologic analysis to estimate statistical distribution of storm event depths and intensities
- (i) Gross estimate of BMP sizing criteria (e.g., detention time, capacity) for identifying comparative studies
- (j) Mean, median, minimum, maximum, coefficient of variation, and number of events
- (k) The probability of exceeding water quality standards during a single storm event based on the suspected distribution of effluent quality
- (l) Statistical tests include normality testing and hypothesis testing

3 Obtaining More Information

The primary guidance documents recommended for obtaining information on monitoring water quality and stormwater BMPs include:

Caltrans (2000). “Guidance Manual: Stormwater Monitoring Protocols.” Prepared by Larry Walker and Associates. [Online Available, September 2002] http://www.dot.ca.gov/hq/env/stormwater/special/index.htm

FHWA (2000). “Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring” FHWA Office of Natural Environment. FHWA-EP-00-002. Prepared by Tetra Tech, Inc.

FHWA (2001). “Guidance Manual for Monitoring Highway Runoff Water Quality.” *U.S. Department of Transportation Federal Highway Administration* FHWA-EP-01-022. Prepared by URS Group, Inc.

USEPA/ASCE (2002). “Urban Stormwater BMP Performance Monitoring – A Guidance Manual for Meeting the National Stormwater BMP Database Requirements.” Prepared by GeoSyntec Consultants and Urban Drainage and Flood Control District
[Online Available, September 2002] http://www.bmpdatabase.org/docs.html

Muthukrishnan, S., Madge, B., Selvakumar, A., Field, R., Sullivan, D. (2004). "The Use of Best Management Practices (BMPs) in Urban Watersheds." Final report to U.S. EPA, EPA 600/R-04/184.