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Comprehensive Clackamas County NPDES MS4 Stormwater Monitoring Plan

May 23, 2011

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Prepared for

City of Gladstone, Oregon
City of Milwaukie, Oregon
City of Oregon City, Oregon
City of West Linn, Oregon

May 23, 2011

Table of Contents

List of Figures

List of Tables

1. Introduction

As part of the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit requirements, Clackamas County co-permittees are required to develop and implement a stormwater monitoring program. Specific stormwater monitoring requirements and objectives are defined in Schedule B of the Clackamas County NPDES MS4 permit (number 101348), issued March 15, 2011.

The NPDES stormwater monitoring programs require two components. The first component is ***program monitoring***, which involves the tracking and assessment of programmatic activities, as described in the individual permittees Stormwater Management Plans (SWMPs), through the use of tracking measures. The second component is ***environmental monitoring*** which includes the actual collection and analysis of samples. The purpose of this monitoring plan is to address the environmental monitoring component of the requirements. As a result, this monitoring plan includes the following elements as required by Schedule B.2 of the NPDES MS4 permit:

- identification of how the monitoring objectives are addressed
- discussion of how the monitoring program is related to adaptive management and a long-term monitoring program strategy
- documentation and record keeping procedures
- documentation of monitoring sites, parameters, and sample collection frequency and methods
- identification of the analytical methods
- protocols for quality assurance and quality control
- discussion of data management, review, validation, and verification.

Due to the inherent wide ranging variability in stormwater data, collecting and analyzing data that will be sufficient to address the permit environmental monitoring requirements will require significant resources in order to obtain data that are sufficiently robust to be statistically valid. The Oregon Department of Environmental Quality (DEQ) itself acknowledged this issue and provided the following clause in the 2011-2016 NPDES MS4 permit (Schedule B.4) that allows for a coordinated monitoring approach:

> *"Environmental monitoring conducted to meet a permit condition in Table B-1 may be coordinated among co-permittees or conducted on behalf of a co-permittee by a third party. Each co-permittee is responsible for environmental monitoring in accordance with Schedule B requirements. The co-permittee may utilize data collected by another permittee, a third party, or in another co-permittee's jurisdiction to meet a permit condition in Table B-1 provided the co-permittee established an agreement prior to conducting coordinated environmental monitoring."*

Given the magnitude of effort associated with implementing an effective monitoring program that will adequately address permit requirements and objectives, eight Clackamas County co-permittees agreed to consolidate efforts and prepare one comprehensive stormwater monitoring plan. This coordinated approach was initiated in 2006.

Per the permit requirements identified above, this monitoring plan serves as the established agreement related to conducting a coordinated monitoring effort. The current participating co-permittees include the cities of Gladstone, Milwaukie, Oregon City, and West Linn. Monitoring activities affiliated with Clackamas County Service District #1 (CCSD#1) and the Surface Water Management Agency of Clackamas County (SWMACC) and conducted on behalf of the cities of Happy Valley and Rivergrove are included in this monitoring plan as well. However, the CCSD#1 and SWMACC monitoring activities included in this monitoring plan are consistent with those identified in the 2006 coordinated stormwater monitoring plan and have not been revised to address requirements of the 2011-2016 reissued NPDES MS4 permit. Clackamas County Water Environment Services (WES) is currently appealing elements of the 2011-2016 NPDES MS4 permit and has therefore removed themselves from participation in this monitoring plan submission until resolution of the permit appeal.

The following Stormwater Monitoring Plan is organized into the following sections:

Section 2. Objectives	Summarizes the objectives of the plan, specifically related to the six objectives listed in Schedule B of the 2011-2016 NPDES MS4 permit.
Section 3. Background	Provides background related to the development of the Comprehensive Clackamas County Monitoring Plan.
Section 4. Data Gathering	Outlines the various data gathering strategies utilized and describes how data collected will be used in the adaptive management of the individual stormwater programs and in the development of a long-term monitoring program strategy.
Section 5. Activities	Describes the various environmental monitoring activities including monitoring frequency and locations, as applicable.
Section 6. QA/QC	Provides a summary of sampling parameters, sampling procedures, and analytical methods including applicable quality control and quality assurance.
Section 7. Data Management	Summarizes the data analysis, interpretation, and management activities that will be used to evaluate the monitoring data.

2. Objectives

Schedule B.1 of the 2011-2016 NPDES MS4 permit lists six specific monitoring objectives that should be addressed with the revised monitoring program. The six objectives are listed below.

1. *Evaluate the source(s) of the 2004/2006 303(d) listed pollutants applicable to the co-permittees' permit area;*
2. *Evaluate the effectiveness of Best Management Practices (BMPs) in order to help determine BMP implementation priorities;*
3. *Characterize stormwater based on land use type, seasonality, geography or other catchment characteristics;*
4. *Evaluate status and long-term trends in receiving waters associated with MS4 stormwater discharges;*
5. *Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters; and,*
6. *Assess progress towards meeting total maximum daily load (TMDL) pollutant load reduction benchmarks.*

Each of the monitoring activities listed in Section 5 includes a narrative describing how the above monitoring objectives will be addressed through implementation of each of the proposed monitoring plan components.

3. Background Related to the Development of a Comprehensive Clackamas County Monitoring Plan

The Comprehensive Clackamas County Monitoring Plan (Plan) was originally developed in 2006 and submitted to DEQ with the November 1, 2006 NPDES Permit Annual Compliance Reports. Implementation of the Plan was initiated by participating co-permittees in July, 2007. Minor updates (editorial modifications, wording clarifications) to the Plan have been made periodically and submitted to DEQ.

Development of a coordinated monitoring effort stemmed from the inclusion of monitoring objectives in the 2004-2009 NPDES MS4 permit. Prior to development of the comprehensive monitoring program, each jurisdiction had been collecting samples independently in conjunction with the requirements outlined in Tables B-1 of the 2004-2009 NPDES MS4 permit. Given the variability in stormwater data and individual monitoring efforts, smaller jurisdictions with limited environmental monitoring requirements listed in Table B-1 (of the 2004-2009 NPDES MS4 permit) would not be able to address the monitoring objectives without substantial additional effort, and costs would be beyond what would be considered to be the "maximum extent practicable" for those communities.

The 2006 Comprehensive Clackamas County Monitoring Plan was developed by reviewing each participating co-permittee's existing monitoring efforts (through annual reports), and all monitoring activities were summarized graphically and tabularly. Following compilation of the existing monitoring activities, a meeting was held with all participating co-permittees to review the tables and maps. Discrepancies between activities reported in the tables and maps and activities most recently conducted were discussed, and the tables were modified as necessary.

Following the meeting, the tables of existing monitoring efforts were reorganized and compared to the monitoring objectives in order to identify potential gaps in the data with respect to addressing the monitoring objectives as a group effort. Monitoring activities were refined to address these potential data gaps; to minimize duplication of monitoring efforts; and to ensure data collected contained information that was sufficiently comprehensive to address the monitoring objectives. Additional meetings were held with each jurisdiction individually to further refine details with respect to monitoring recommendations and commitments (e.g., specific monitoring site locations, sample frequencies, etc.).

With the pending issuance of the 2011-2016 NPDES MS4 permit, the original 2006 Comprehensive Clackamas County Monitoring Plan was reviewed for consistency with the revised monitoring objectives (per the 2011-2016 NPDES MS4). Monitoring activities have been updated in conjunction with the revised Table B-1 (per the 2011-2016 permit). Additional information such as quality assurance procedures has also been added in conjunction with Schedule B.2. This Plan reflects the results of these review and update efforts.

4. Data Gathering Strategies

As described in Section 3.0, the development of the original 2006 Comprehensive Clackamas County Monitoring Plan applied adaptive management principals to refine co-permittees existing, individual monitoring programs and develop a coordinated approach to address the monitoring objectives from the 2005-2009 NPDES MS4 permit. Monitoring locations were selected in order to obtain water quality information throughout the participating co-permittees MS4 permit coverage area and reflect the various contributing land uses.

With the issuance of the 2011-2016 NPDES MS4 permit and revised monitoring objectives and plan requirements, the Plan has been further refined and revised. Co-permittees reviewed their monitoring locations, monitoring activities and data collection methods in conjunction with the revised monitoring objectives and provided input to DEQ during the permit negotiation process. This revised Plan reflects the results of these adaptive management efforts.

There are three primary strategies outlined in this Plan to obtain and review data and information necessary to address the six monitoring objectives of the permit. These strategies include the following:

1. Collect water quality data in conjunction with Table B-1 of the 2011-2016 NPDES MS4 permit to address the specified monitoring objectives.
2. Conduct literature reviews to track relevant technical information related to stormwater quality that is collected by others yet representative of co-permittee activities.
3. Review and evaluate the monitoring results and other information (literature and stormwater management program tracking measures) collected by the co-permittees to support decision making related to adaptively managing and refining both the stormwater management plan and future monitoring efforts.

With respect to item 1 above, monitoring locations, frequencies, and parameters established in Table B-1 have been qualified by the co-permittees as providing beneficial information for the City/jurisdiction in order to address the current monitoring objectives. Selection of such locations, frequencies, and parameters also reflect data that co-permittees have historically collected so that adequate data is available to assess trends.

With respect to item 2 above, the scientific community, public agencies, and private organizations interested in stormwater management continue to conduct research related to stormwater characterization and treatment. This research is costly and it is often beyond the means of any one co-permittee to conduct a significant study. Organizations such as the Oregon Association of Clean Water Agencies (ACWA), the Bay Area Stormwater Management Association, the Water Environment Research Foundation, state transportation departments, vendors of proprietary stormwater treatment systems, and others conduct research and examine complex stormwater-related issues that individual permittees could not accomplish on their own. By participating in these groups and following current research, co-permittees can realize greater benefits from labor and capital investment than if they were to attempt such studies on their own. As such, the co-permittees plan to utilize information garnered by these groups to address some of the more complex and costly objectives of the permit especially with respect to understanding the effectiveness of BMPs.

With respect to item 3 above, the compilation of monitoring data during the annual reporting period and the permit renewal period will allow co-permittees to ensure that the data are being collected as required and that the data are providing useful information. In conjunction with the monitoring objectives, the monitoring data can potentially provide rationale for co-permittees in making decisions related to the allocation of resources. Monitoring activities can be continually revised in order to better address needs. The intent of the monitoring program is to provide data that would support conclusions related to implementation of the co-permittee's SWMPs (e.g., what are the trends) and NPDES MS4 permit requirements and ensure that the data continue to provide value.

5. Proposed Monitoring Activities

This section describes the coordinated monitoring efforts being conducted by the participating Clackamas County co-permittees. This section is organized according to the following monitoring activities:

- instream monitoring efforts
- outfall monitoring efforts
- biological monitoring efforts
- BMP monitoring efforts.

The monitoring objectives that are addressed by each monitoring activity are listed at the beginning of each subsection.

5.1 Instream Monitoring

Instream monitoring throughout the Clackamas MS4 permit area is conducted to address NPDES MS4 objectives 4 and 5 from Schedule B.1.a. when conducted during both wet and dry weather conditions for comparison.

4. *Evaluate status and long-term trends in receiving waters associated with MS4 stormwater discharges; and*
5. *Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters.*

The following text describes the instream monitoring locations (Section 5.1.1), the instream sample collection method and processes (Section 5.1.2), and additional instream sample collection efforts (Section 5.1.3).

5.1.1 Description of Instream Monitoring Locations

Instream monitoring efforts conducted by the participating Clackamas co-permittees as part of the Comprehensive Clackamas County Monitoring plan include a total of 26 sampling locations representing 22 water bodies. Waterbodies selected for monitoring were prioritized based on those that are considered water quality impaired and have a TMDL in place or are 303(d) listed for a specific parameter. Within the Clackamas County area, the TMDL and 303(d) water bodies are listed in Table 1.

Table 1. Summary of Clackamas County TMDL and 303(d) Listed Streams

Monitored waterbody	Bacteria	Temperature	Dissolved oxygen (DO)	Phosphorus	Mercury	PCBs	PAHs	DDT	Dieldrin
TMDLs									
Willamette River (and tributaries)	X	X			X				
Johnson Creek	X	X						X	
Tualatin River	X	X	X	X					
Additional 303(d) listed streams/Parameters									
Johnson Creek						X	X		X

Instream monitoring locations were also selected based on the length of record of the data historically collected and maintaining geographic coverage of the participating co-permittees MS4 permit area. Paired instream monitoring locations were also identified, one upstream location that represents stormwater and baseflow conditions generally located outside of the co-permittee's MS4 permit boundary; and one downstream location that represents stormwater and baseflow conditions generated both outside and inside of the co-permittee's MS4 permit boundary. Figure 1 identifies the instream monitoring locations including the specific waterbody, the responsible jurisdiction, and the type of sampling method employed.

5.1.2 Sample Collection Process and Methods

Instream monitoring efforts are focused on collecting ambient water quality data during both dry weather and wet weather seasons. As instream water quality tends to vary during storm events, sample collection is conducted during storm events and during dry weather conditions in order to assess water quality impacts associated with MS4 discharges and support monitoring objectives #4 and #5.

Grab samples will be collected instream during dry weather conditions. During storm events, multiple (minimum of three) time-spaced grab samples will be collected throughout the storm event to provide a single time composite sample. A composite sample collected during a storm event allows for capture of a larger portion of the entire storm hydrograph and better represents fluctuating pollutant concentrations. As a result, use of composite sampling techniques better represents those variations during storm events. Rationale related to the use of a time-composite sampling approach is provided in Appendix A.

Instream sampling procedures applicable to this Plan are as follows:

1. Instream water quality samples will be collected during both the dry and wet weather seasons. A minimum of 50 percent of the samples shall be collected during the wet weather season *(October 1 to April 30).* For example, for Oregon City, this requires two samples to be collected during the dry season and two samples during the wet season.
2. A select (varies by jurisdiction) number of samples will be collected during storm events greater than 0.1 inches of rainfall (see Table 2). Samples collected during a storm event shall be collected as time-composite grab samples, which will require samples to be collected at a defined frequency and combined prior to analysis.
3. A minimum of 14-days shall be maintained between consecutive dry weather (ambient sampling events) or storm sampling events at a particular site, in order to avoid potential autocorrelation of samples. The 14-day minimum time frame is not applicable between a dry weather and a storm event sampling effort.

Table 2 outlines the specific instream monitoring locations, monitoring frequencies, sampling type, and responsible jurisdiction. Table 3 summarizes the instream samples collected by participating co-permittees as a whole. As shown in Table 3, approximately 154 individual samples (grab or composited) are planned for collection instream per year representing 26 sampling sites across 20 waterbodies. Approximately 62 of those samples are time-composite samples collected during storm events.

NOTE: The most resource-intensive element of water quality monitoring is the sampling during storm events. Because of the difficulty of identifying suitable storms, and then mobilizing in a timely manner to allow for characterizing the storm, storm sampling requires a large time commitment. Staff is assigned other responsibilities in addition to monitoring. To ensure that monitoring doesn't consume inordinate resources at the expense of activities that reduce pollution, the following limitations apply to the commitments made in this Plan related to storm event sample collection.

- Storms will not be sampled on major holidays, including Thanksgiving, Christmas Eve, Christmas, New Year's, President's Day, Fourth of July, Labor Day, Memorial Day, and Easter.
- Storm events shall be a minimum of 0.1 inches of rainfall and of a size that once a crew is mobilized, runoff is anticipated to occur for a minimum of two hours.
- For time-composite sample collection, the duration of time between the collection of individual grab samples will be varied as necessary to meet the goal of obtaining at least three grab samples per storm event (these three grab samples will then be combined into one composited sample for analyses). In some cases a storm may not last long enough to collect three individual grab samples. In these cases, the samples that are collected will be composited and analyzed; no minimum number of samples is specified.

Number	Jurisdiction	Sampling Method	Site Description	Stream Name
1	CCSD #1/ USGS	Automated	S. Fork Water Intake	Clackamas River
2	CCSD #1	Grab and Composite	SE 120th and Carpenter Dr. (manhole)	Carli Creek
3	CCSD #1	Grab and Composite	Hwy 212/224	Sieben Creek
4	CCSD #1	Grab and Composite	South of Hwy 212/224	Rock Creek
5	CCSD #1	Grab and Composite	84th Ave. and Sunnybrook	Phillips Creek
6	CCSD #1	Grab and Composite	North Clackamas Park	Mt. Scott Creek
7	CCSD #1	Grab and Composite	At SE Rusk Rd.	Kellogg Creek
8	CCSD #1	Grab and Composite	Kellogg Ck at Hwy 99E	Kellogg Creek
9	CCSD #1	Grab and Composite	SE Last Rd.	Cow Creek
10	Milwaukie	Grab and Composite	Box Culvert at Lake Rd.	Minthorn Creek
11	Milwaukie / USGS	Automated	At Milport Rd. Bridge	Johnson Creek
12	Oregon City	Grab and Composite	At Holly Lane Bridge	Abernethy Creek
13	Oregon City	Grab and Composite	SE 17th Street at railroad tressel	Abernethy Creek
14	Oregon City	Grab and Composite	Outfall at Willamette	Coffee Creek
15	Oregon City	Grab and Composite	Behind 13530 Redland Rd	Park Place Creek
16	Oregon City	Grab and Composite	At N. end of Singer Cr Park	Singer Creek
17	Oregon City	Grab and Composite	At 7th Street (manhole)	Singer Creek
18	SWMACC	Automated	Tualatin River at RM 1.8	Tualatin River
19	SWMACC	Grab and Composite	SW Long farm Rd	Wilson Creek
20	SWMACC	Grab and Composite	SW Mossy Brae Rd	Pecan Creek
21	SWMACC	Grab and Composite	SW Shadow Wood Drive	Shipley Creek
22	SWMACC	Grab and Composite	SW Ribera Lane	Unnamed Tributary
23	West Linn	Grab and Composite	At Imperial Drive	Tanner Creek
24	West Linn	Grab and Composite	At Caloroga Rd	Trillium Creek
25	West Linn	Grab and Composite	Johnson Rd. at Ryan Ct.	Summerlinn Creek
26	Gladstone	Grab and Composite	Outfall at Risley Rd.	Rinearson Creek

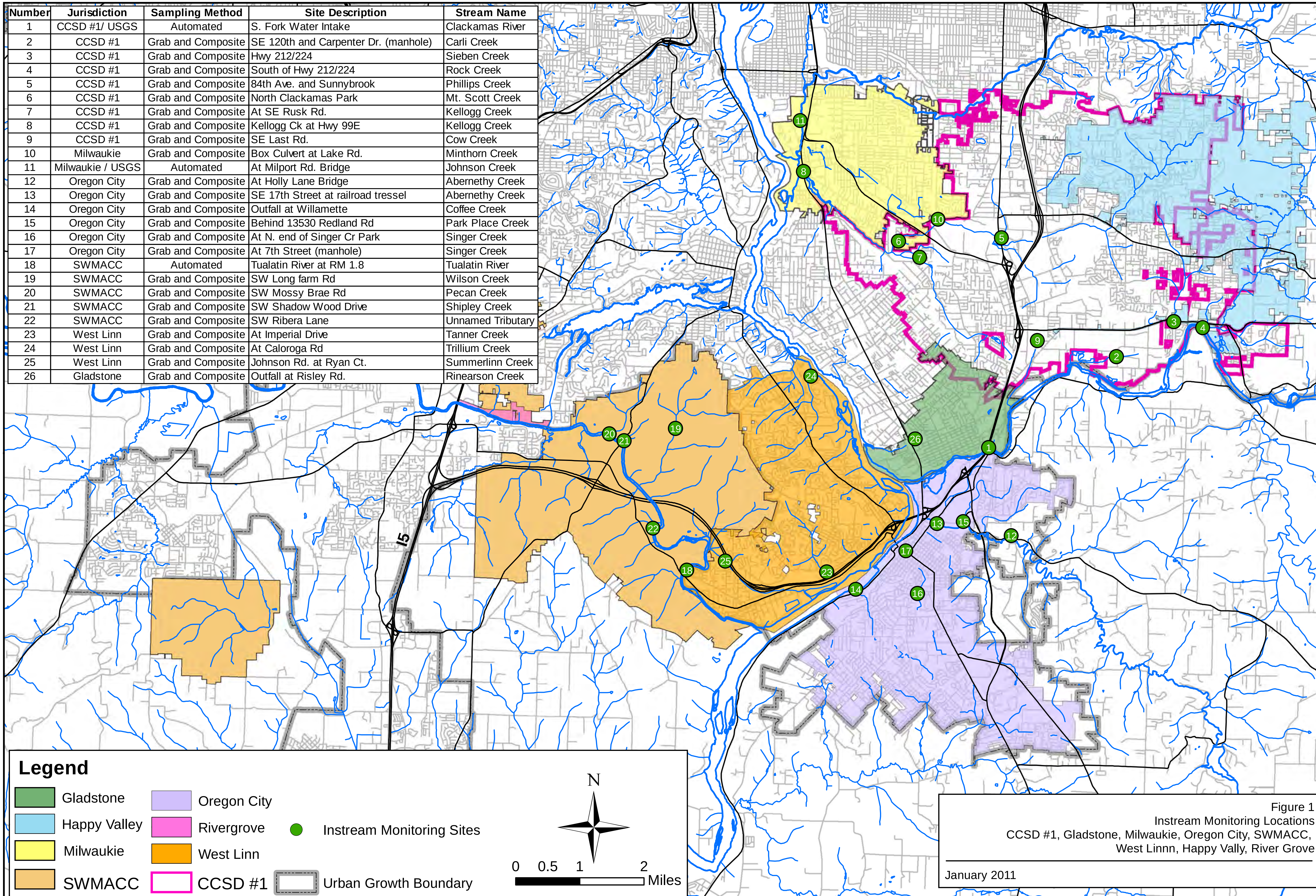

Figure 1
Instream Monitoring Locations
CCSD #1, Gladstone, Milwaukie, Oregon City, SWMACC,
West Linnn, Happy Vally, River Grove

January 2011

Table 2. Comprehensive Clackamas County Monitoring Plan - Instream Monitoring						
Monitored waterbody	Responsible party	Number of locations	Type of sample	Sampling frequency	Parameters monitored (Field/Lab)*	Storm event monitoring (Y/N)
Carli Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
	CCSD#1/USGS	1	Automated	Continuous	Field	Y
Cow Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Kellogg Creek	CCSD#1	2	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Mt Scott Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Phillips Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Rock Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Sieben Creek	CCSD#1	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Minthorn Creek	Milwaukie	1	Grabs and composites	4/year	Field and Lab	Y (2 of 4)
Johnson Creek	Milwaukie (via USGS)	1	Automated	Continuous	Field	Y
Abernethy Creek	Oregon City	2	Grabs and composites	4/year	Field and Lab	Y (2 of 4)
Coffee Creek	Oregon City	1	Grabs and composites	4/year	Field and Lab	Y (2 of 4)
Park Place Creek	Oregon City	1	Grabs and composites	4/year	Field and Lab	Y (2 of 4)
Singer Creek	Oregon City	2	Grabs and composites	4/year	Field and Lab	Y (2 of 4)
Pecan Creek	SWMACC	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Shipley Creek	SWMACC	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Tualatin River	SWMACC/USGS	1	Automated	Continuous	Field	Y
Unnamed Creek at Riberia Lane	SWMACC	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Wilson Creek	SWMACC	1	Grabs and composites	9/year	Field and Lab	Y (3 of 9)
Summerlinn Creek	West Linn	1	Grabs and composites	5/year	Field and Lab	Y (3 of 5)
Tanner Creek	West Linn	1	Grabs and composites	5/year	Field and Lab	Y (3 of 5)
Trillium Creek	West Linn	1	Grabs and composites	5/year	Field and Lab	Y (3 of 5)
Rinearson Creek	Gladstone	1	Grabs and composites	3/year	Field and Lab	Y (3 of 3)

* *The term “Field” indicates samples that are analyzed using meters in the field–typically for temperature, conductivity, DO, total dissolved solids, and pH.*

Table 3. Summary of the Clackamas County Co-permittee Instream Monitoring Efforts

Jurisdiction	Total number of grab/ composite sampling sites	Total number of sampling events per year (number of storm sampling events in parenthesis)	Automated continuous sampling sites	Total number of sampling sites
CCSD #1	8	72 (24)	1	9
SWMACC	4	36 (12)	1	5
Milwaukie	1	4 (2)	1	2
Oregon City	6	24 (12)	0	6
West Linn	3	15(9)	0	3
Gladstone	1	3 (3)	0	1
Total	23	154 (62)	3	26

5.1.3 Additional Instream Monitoring Efforts

Continuous flow data, collected as part of the instream monitoring effort, are collected at three instream monitoring sites (Table 2). Generally, water quality data collected at these sites includes temperature and pH, although some sites are also sampled for DO.

5.2 Outfall Monitoring Efforts

Stormwater monitoring throughout the Clackamas MS4 permit area is conducted to address NPDES MS4 objectives 1, 3, 5, and 6 from Schedule B.1.a. when conducted during wet weather conditions.

1. *Evaluate the source(s) of the 2004/2006 303(d) listed pollutants applicable to the co-permittees' permit area;*
3. *Characterize stormwater based on land use type, seasonality, geography or other catchment characteristics;*
5. *Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters; and*
6. *Assess progress towards meeting TMDL pollutant load reduction benchmarks.*

The following text describes outfall monitoring locations (Section 5.2.1), provides a description of the sample collection methods and processes (Section 5.2.2), and summarizes additional outfall monitoring activities with respect to the new mercury monitoring requirements (Section 5.2.3).

5.2.1 Description of Stormwater Monitoring Locations

Stormwater monitoring efforts conducted by the participating Clackamas co-permittees as part of the Comprehensive Clackamas County Monitoring Plan represent a total of ten sampling locations and five land use categories. Stormwater monitoring locations were identified based on the distribution and consistency of the upstream land use type or category (i.e., residential, commercial, industrial, and rural residential). Classification of stormwater quality by land use allows for estimation and evaluation of the sources of specific pollutants. Additionally, the classification of stormwater quality based on land use can be used for pollutant load modeling efforts, and the identification and application of specific best management practices to address specific pollutant loading from a particular land use.

Monitoring locations were also selected based on whether baseflow was present. Samples collected during a storm event from locations with significant baseflow would not be entirely representative of MS4 discharge. Therefore, sites with baseflow were avoided. Finally, monitoring locations were selected that were easily accessible and where access is relatively unrestricted considering that sampling events could occur during evenings or weekends. Stormwater monitoring locations are shown on Figure 2.

Number	Juristiction	Site Description	Associated Land Use	Sampling Frequency
1	CCSD #1	Outfall #19 SE Webster Rd at Kellogg Cr	Residential	3 / Year
2	CCSD #1	Outfall #12 at Pheasant Ct	Mixed Use	3 / Year
3	CCSD #1	Outfall #26 SE Tolbert Rd & 94th Ave.	Mixed Use	3 / Year
4	CCSD #1	SE Oregon Trail Dr. near SE Sieben Park Way	Commercial	3 / Year
5	Milwaukie	Outfall #23003 at Roswell Street	Residential	3 / Year
6	Oregon City	OC Shopping Center	Commercial	3 / Year
7	Oregon City	Clackamette Cove	Industrial	3 / Year
8	SWMACC	12" Outfall - SW Terry Ave	Residential	3 / Year
9	SWMACC	SW Brookman Rd	Rural Residential	3 / Year
10	West Linn	Storm Manhole- River Heights Cir	Residential	3 / Year

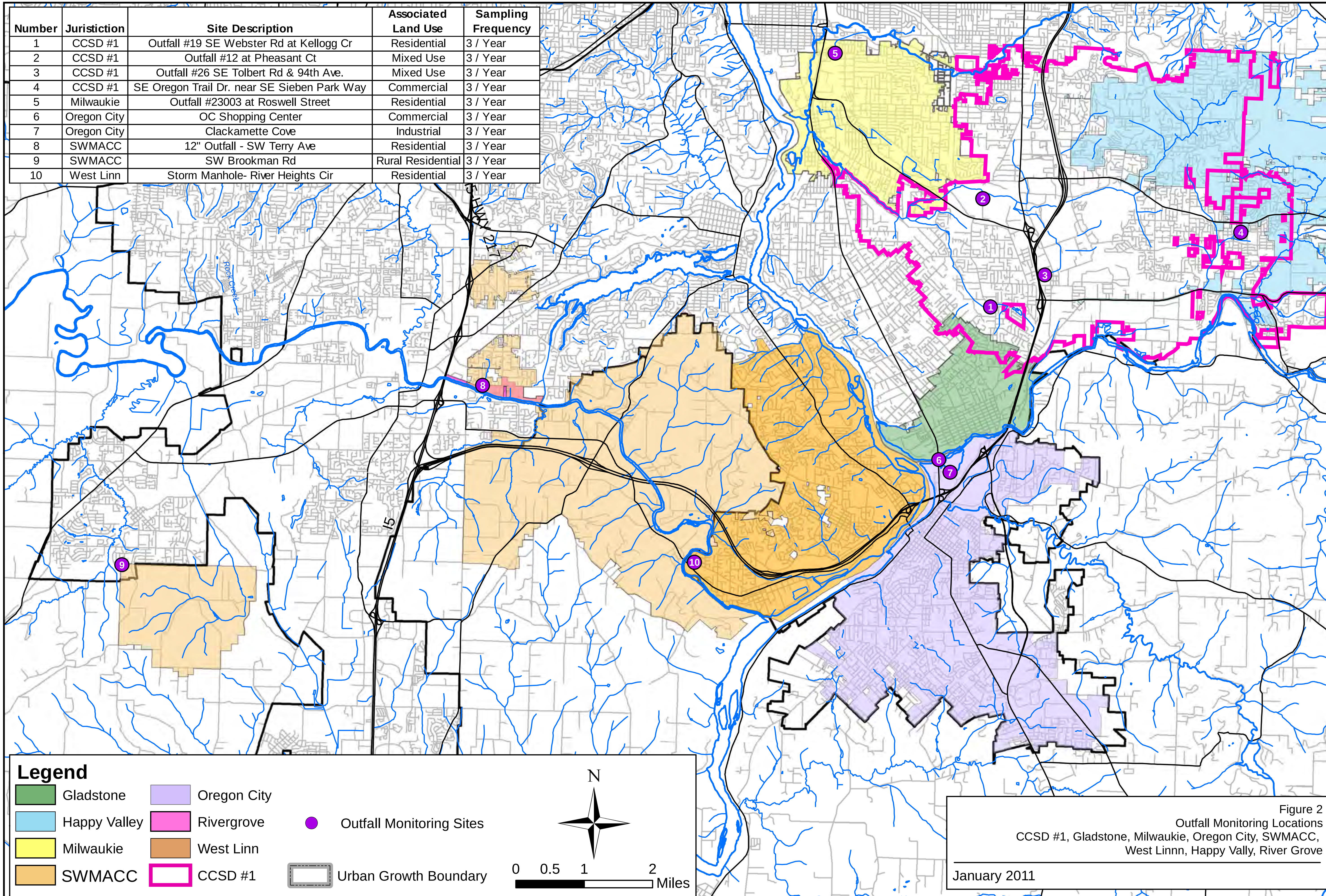

Figure 2
Outfall Monitoring Locations
CCSD #1, Gladstone, Milwaukie, Oregon City, SWMACC,
West Linnn, Happy Vally, River Grove

January 2011

5.2.2 Sample Collection Process and Methods

Stormwater monitoring efforts are focused on capturing storm specific data from select outfall locations representing drainage from various land use categories. In conjunction with the monitoring objectives, collection of stormwater samples allows for the identification of pollutant sources, the characterization of stormwater (based on land use), and assessment of the effects that stormwater runoff may have on in-stream water quality.

Samples will be collected as time-composite grab samples. Given the number of stormwater monitoring sites and the geographic coverage of sites, a time composite sampling method is preferred for participants in the Comprehensive Clackamas County Monitoring Program as opposed to flow composite sampling. Composite samples (either time or flow composited samples) collected during storm events allow for capture of a larger portion of the entire storm hydrograph. As fluctuations of pollutant concentrations could vary widely throughout a storm event, use of composite sampling techniques would better represent those variations during storm events. Rationale related to the use of time-composite sampling techniques is provided in Appendix A.

Stormwater sampling procedures are as follows:

1. Qualifying stormwater monitoring events must be associated with a storm event resulting in greater than 0.1 inches of rainfall.
2. As possible, qualifying stormwater monitoring events shall occur after a minimum 24 hour antecedent dry period. During sample collection activities, an intra event dry period must not exceed 6 hours.
3. Stormwater samples will be collected during three storm events per year per location.
4. For each sampling event, a minimum of three time-spaced grab samples will be collected throughout the storm event. As possible, based on the number and location of stormwater monitoring sites, sample collection will be initiated towards the beginning of the storm event and individual grab samples will be taken no more frequently than one sample per hour.
5. The time-spaced grab samples collected will be combined into a single time-composite sample in accordance with the field collection methods outlined in Appendix B.
6. The Notes on page 6 regarding limitations on the commitments for storm event sampling related to instream monitoring efforts are also applicable to stormwater monitoring efforts.
7. For each monitored storm event, the contributing stormwater runoff volume or storm event rainfall depth will be estimated.

Each stormwater monitoring location is listed in Table 4, along with a reference regarding the sampling frequency and parameters monitored. A more condensed summary of stormwater monitoring is provided in Table 5.

Table 4. Comprehensive Clackamas County Monitoring Plan–Stormwater Monitoring

Upstream land use	Outfall description	Responsible party	Sampling frequency	Parameters monitored (field/lab)
Residential	Outfall #19– SE Webster Rd. at Kellogg Creek	CCSD#1	3/year	Field and Lab
Mixed use (industrial, highway, commercial, residential)	Outfall #12– SE Pheasant Court	CCSD#1	3/year	Field and Lab
Mixed use (industrial, school, commercial, residential)	Outfall #26– SE Tolbert Rd. and 94th Avenue	CCSD#1	3/year	Field and Lab
Commercial	SE Oregon Trail Drive near SE Sieben Park Way	CCSD#1	3/year	Field and Lab
Residential	Outfall #23003 at Roswell Street	Milwaukie	3/year	Field and Lab

Table 4. Comprehensive Clackamas County Monitoring Plan–Stormwater Monitoring				
Upstream land use	Outfall description	Responsible party	Sampling frequency	Parameters monitored (field/lab)
Commercial	Clackamas River outfall at Oregon City Shopping Center	Oregon City	3/year	Field and Lab
Industrial	Clackamas River outfall at Clackamette Cove	Oregon City	3/year	Field and Lab
Residential	12-inch outfall – SW Terry Avenue and Childs Road	SWMACC	3/year	Field and Lab
Rural residential	Outfall at SW Brookman Road near Sherwood	SWMACC	3/year	Field and Lab
Residential	Outfall to the Tualatin River at River Heights Circle	West Linn	3/year	Field and Lab

Table 5. Summary of the Clackamas County Co-permittee Stormwater Monitoring Efforts		
Upstream land use	Number of outfalls monitored	Total number of samples collected per year
Residential	4	12
Commercial	2	6
Mixed use	2	6
Industrial	1	3
Rural residential	1	3
Total	10	30

5.2.3 Additional Outfall Monitoring Efforts

Stormwater mercury monitoring is required for the cities of West Linn, Oregon City, and Milwaukie per guidelines outlined in Table B-1 and Schedule B.4 of the NPDES MS4 permit and as described in DEQ's "Mercury Monitoring Requirements for Willamette Basin Permittees" memorandum dated December 23, 2010.

Stormwater mercury monitoring procedures are as follows:

1. Qualifications for a stormwater mercury monitoring event are consistent with those for a stormwater monitoring event.
2. Each city is responsible for sample collection from one location.
3. Each city is required to collect two storm events over a two year period (at their selected monitoring location). One storm event must collected during the dry-weather season (May 1 to September 30) and one storm event must be collected during the wet-weather season (October 1 to April 30).
4. Co-permittees must collectively coordinate the stormwater mercury monitoring to ensure a minimum of four storm events are collected during the wet-weather season and four storm events are collected during the dry-weather season between July 1, 2011 and June 30, 2012. Four storm events during the dry-weather season and four storm events during the wet-weather season must also be collected between July 1, 2012 and June 30, 2013.

As a result of the required coordination that is reflected in the Clackamas NPDES MS4 permit language (Schedule B.4), the cities of West Linn, Oregon City, and Milwaukie, along with the cities of Lake Oswego and Wilsonville who are also required to conduct stormwater mercury monitoring, developed a coordinated approach to address the requirements. Each city identified a stormwater mercury monitoring location that considers upstream land use characteristics. Stormwater mercury monitoring locations were identified consistent with locations of existing outfall monitoring activities. The selected stormwater mercury monitoring locations are provided in Table 6 and shown graphically in Figure 3.

Number	Jurisdiction	Site Description	Associated Land Use	Sampling Frequency
1	Milwaukie	Outfall #23003 at Roswell Street	Residential	1/Year
2	Oregon City	Clackamette Cove	Industrial	1/Year
3	West Linn	Storm Manhole - River Heights Circle	Residential	1/Year
4	Lake Oswego	Outfall to Carter Creek	Commercial	1/Year
5	Wilsonville	Library Detention Pond Inlet at Memorial Park	Mixed Use	1/Year

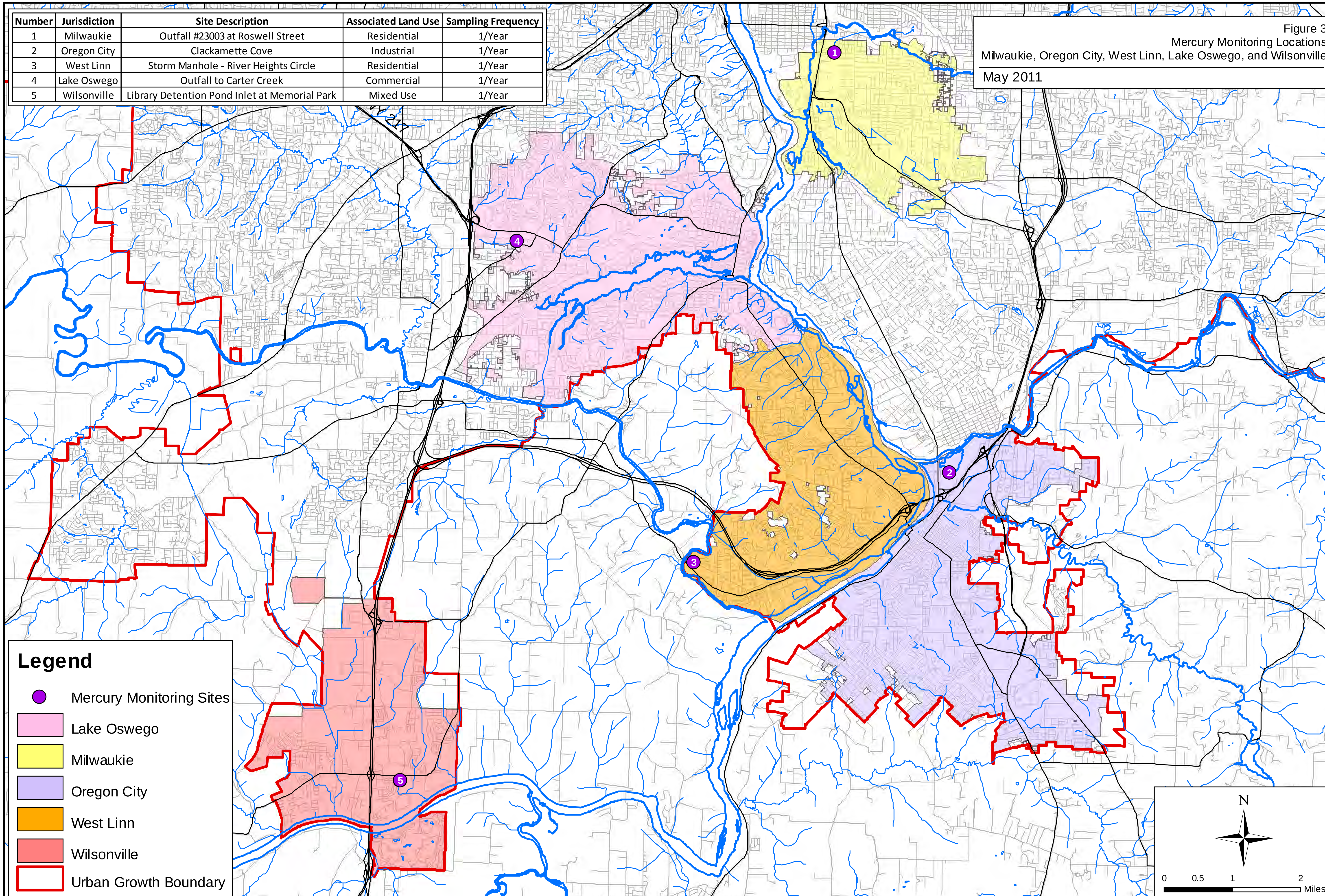

Table 6. Comprehensive Clackamas County Monitoring Plan–Stormwater Mercury Monitoring				
Upstream land use	Outfall description	Responsible party	Sampling frequency	Parameter
Residential	Outfall #23003 at Roswell Street	Milwaukie	1/year	Total/ Dissolved Mercury and Methyl Mercury
Industrial	Clackamas River outfall at Clackamette Cove	Oregon City	1/year	Total/ Dissolved Mercury and Methyl Mercury
Commercial	Outfall to Carter Creek	Lake Oswego	1/year	Total/ Dissolved Mercury and Methyl Mercury
Mixed Use	Inlet to the Library Detection Pond	Wilsonville	1/year	Total/ Dissolved Mercury and Methyl Mercury
Residential	Outfall to the Tualatin River at River Heights Circle	West Linn	1/year	Total/ Dissolved Mercury and Methyl Mercury

To ensure that an equal number of samples are collected during the dry-weather and wet-weather season each year, monitoring locations will be classified into one of two groups (East group and West group) based on geography and accessibility. Each group will be responsible for sample collection during either the wet-weather season or the dry-weather season in any given year. Such classification is in progress and will depend on the final number of co-permittees subject to the stormwater mercury monitoring requirement (i.e., outcome from the Clackamas WES NPDES MS4 permit appeal). Final classification will be determined prior to the start of stormwater mercury monitoring activities. A jurisdictional point of contact will be established for each group.

Staff scheduled to conduct sampling will attend training on EPA Method 1669 prior to the start of monitoring activities. Additional detail related to the sample collection and analytical methods for stormwater mercury sampling is provided in Section 6 and Appendix B.

5.3 Biological Monitoring Efforts

Biological monitoring throughout the Clackamas MS4 permit area will be conducted during the 2011-2016 NPDES MS4 permit term to address NPDES MS4 objectives 4 and 5 from Schedule B.1.a.

4. *Evaluate status and long-term trends in receiving waters associated with MS4 stormwater discharges; and*
5. *Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters.*

Biological monitoring activities are also required in accordance with Table B-1 in the permit.

The cities of Gladstone, Milwaukie, Oregon City, and West Linn will investigate the value and identify goals for conducting biological monitoring activities both regionally and specifically within their cities. By July 1, 2012, the cities will identify a biological monitoring approach to be implemented during the 2011-2016 permit term. Results of this investigation and the identified biological monitoring approach will be outlined in the 2012 NPDES MS4 annual report. Such monitoring locations may correspond to existing water quality monitoring locations, if feasible, in order to attempt to correlate results of the biological monitoring activities with water quality sampling.

5.4 BMP Monitoring Efforts

Monitoring to analyze the effectiveness of BMPs will be conducted to address NPDES MS4 monitoring objective 2 from Schedule B.1.a.

2. *Evaluate the effectiveness of BMPs in order to help determine BMP implementation priorities.*

BMPs is a broad term that can be used to describe practices ranging from structural water quality facilities to source control/programmatic activities (as reported in the co-permittees SWMPs) that are implemented to achieve a net water quality benefit. The monitoring of a structural BMP facility (detention and retention ponds, swales, constructed wetlands, proprietary systems) would represent an environmental monitoring effort, while monitoring of source control/ programmatic activities or BMPs (erosion and sediment control, stormwater conveyance system cleaning and maintenance, industrial and business inspection programs and public education and outreach) would represent a program monitoring effort. Although this monitoring plan is intended to focus on environmental monitoring efforts, programmatic monitoring of source control activities would help address permit monitoring objective #2.

The evaluation of BMP effectiveness also helps to indirectly address monitoring objective #6: Assess progress towards meeting applicable pollutant load reduction benchmarks. BMP effectiveness data are used in pollutant load modeling and the development of pollutant load reduction estimates in order to meet requirements for TMDL compliance. Continually evaluating BMP effectiveness allows for refinement of these effectiveness values used in the model and allows for the pollutant load modeling to more accurately reflect current conditions.

The following text describes BMP monitoring efforts pertaining to environmental monitoring (Section 5.4.1) and BMP monitoring efforts pertaining to program monitoring (Section 5.4.2).

5.4.1 BMP Monitoring (Environmental)

Limited environmental monitoring is currently being conducted by Clackamas co-permittees associated with the performance of structural BMPs. Structural BMP monitoring can be a very time and cost intensive activity, while the BMP monitoring results only apply to the specific characteristics of the sampled BMP. As stormwater management and stormwater treatment are continually changing and evolving fields, extensive literature regarding the monitoring of various treatment technologies (structural BMPs) is being generated by researchers, public entities, and private companies to meet both regulatory and non-regulatory needs. Regionally, there are a number of local jurisdictions that are actively collecting effectiveness information for various structural controls. Review and application of the results from these studies will provide a cost effective means of addressing the permit's monitoring objective #2.

A description of the environmental BMP monitoring efforts is provided below.

5.4.1.1 Structural BMP Monitoring

CCSD#1, SWMACC, and the City of Milwaukie are currently involved in an ongoing monitoring program related to underground injection controls (UIC). Coordination of this program is the result of UIC permit requirements, not MS4 permit requirements, and the monitoring program is expected to continue on an annual basis. UICs are not considered to be part of the MS4 system, as they convey stormwater to the subsurface rather than through an MS4 conveyance system into surface water bodies. However, results of the UIC monitoring program will be beneficial to the MS4 program because the monitoring that is being conducted for this program is evaluating the effluent from structural BMPs prior to its discharge into a UIC. There are seven BMPs that are currently being evaluated including sedimentation manholes, catchbasin inserts, a Stormceptor, an oil-water separator, a StormFilter, and sumped catchbasins. Sampling of these facilities is conducted on a storm basis only. Review of these monitoring results will help address monitoring objective #2. With the pending issuance of individual UIC permits, continuation of this study may not occur during the entire MS4 NPDES permit term.

5.4.1.2 Literature Review Activities

By collecting literature and tracking local monitoring efforts, Clackamas County co-permittees will gain information that will aid their individual stormwater management efforts and possibly influence future decision-making regarding appropriate levels of treatment technology to require for new development and redevelopment. Specifically, Clackamas County co-permittees will track available data related to the performance and cost effectiveness of both structural and source control BMPs. Actively tracking and reviewing literature will also allow the co-permittees to effectively keep up with current innovations and technological advances.

A number of Clackamas County co-permittees are actively involved in ACWA, which provides an open forum for stormwater management discussions and provides additional educational opportunities for local officials regarding stormwater quality and treatment. Participation in ACWA will continue to support literature tracking efforts.

5.4.2 BMP Monitoring (Programmatic)

Clackamas County co-permittees currently conduct a variety of program monitoring efforts, generally related to implementation of their SWMPs. Currently, quantitative effectiveness data for the programmatic elements outlined in the SWMP does not readily exist. Instead, qualitative information is collected in the form of tracking measures. These tracking measures provide qualitative but valuable information to assist in the assessment of BMPs. Examples of BMP categories that are assessed for effectiveness through the use of tracking measures include the following:

- Illicit discharge detection and elimination
- Industrial controls
- Erosion controls
- Public education
- Development standards
- Municipal operations and maintenance activities
- Maintenance of structural controls

Specific tracking measures for these BMP categories are described in each of the co-permittees SWMPs.

6. Sampling Parameters, Analytical Methods, and Quality Assurance and Quality Control

This section includes a summary of sampling parameters and analytical methods (Section 6.1) and a summary of quality assurance and quality control procedures (Section 6.2).

6.1 Sampling Parameters and Analytical Methods

As the purpose of both the instream and stormwater outfall monitoring efforts is to assess the degree to which ambient water quality is impacted by stormwater runoff, consistent pollutant parameters are monitored for both instream and outfall (stormwater) sampling locations. Pollutant parameters have been identified by DEQ (see Table B-1 of the Clackamas County 2011-2016 NPDES MS4 permit). A summary of the pollutant parameters required for analysis is included in Table 7.

The applicable analytical methods are also identified in Table 7. Provisions of the 2011-2016 NPDES MS4 monitoring plan require the use of EPA approved methods listed in the most recent publication of 40 CFR 136. Such identified analytical methods in Table 7 include both EPA and Standard Methods and are consistent with provisions of 40 CFR 136 (dated May 2011).

In addition to parameters provided in Table 7, the 2011-2016 NPDES MS4 permit requires the Clackamas co-permittees to conduct or contribute to pesticide stormwater characterization monitoring or an instream pesticide monitoring project or task. Pesticides to consider in such study are outlined in Table B-1 of the NPDES MS4 permit. During the 2011-2016 permit period, Clackamas County co-permittees (including those participating in the Comprehensive Clackamas County Monitoring Plan) have committed to developing a coordinated pesticide monitoring approach during permit year 1 and implementing said approach during permit years 2 and 3. Participating jurisdictions will likely conduct this monitoring jointly in a single coordinated study. Jurisdictions have currently developed a proposal for pesticide monitoring in conjunction with USGS and anticipate refining this proposal during permit year 1.

6.2 Quality Assurance and Quality Control Procedures

For purposes of this Plan, quality assurance and quality control (QA/QC) procedures are identified for field analysis and laboratory analysis. Field QA/QC procedures are outlined in combination with sample handling and custody procedures (see Appendix B). ACWA developed detailed QA/QC procedures for stormwater data collection and sample handling and custody as part of the ACWA UIC Monitoring Study. Provisions from this ACWA study have been incorporated into the field QA/ QC procedures in Appendix B as appropriate. Appendix B also provides Standard Operating Procedures (SOPs) for tasks associated with field sample collection, chain of custody, and sample handling and transportation.

Co-permittees will use laboratories that have comprehensive Quality Assurance Programs and are DEQ-approved.. The Water Environment Services (WES) water quality laboratory, which currently conducts laboratory analysis for samples (excluding macroinvertebrate samples, pesticides, and mercury) collected under this Plan, operates under the WES Water Quality Assurance Manual (May 17, 2007). This Manual outlines pertinent test methods, validation and reporting limits; equipment calibration and maintenance procedures; sample handling and storage procedures; sample acceptance and results reporting procedures; and data qualification and validation procedures. This Manual is available by request from the WES Water Quality Laboratory.

Mercury analyses will be conducted at a NELAC-certified analytical laboratory in accordance with DEQ's "Mercury Monitoring Requirements for Willamette Basin Permittees" memorandum dated December 23, 2010. A partial list of analytical laboratories that are able conduct testing in accordance with the specified analytical method in Table 7 and able to achieve the required quantitation limit are also included in the memorandum. Proposals from the three laboratories identified in the memorandum will be solicited for purposes of conducting the mercury analyses. As such laboratories were identified by DEQ, the laboratories are presumed to have quality assurance protocols that meet the permit requirements.

The development and determination of future monitoring activities for mercury, macroinvertebrates, and pesticides will confirm compliance with the field and laboratory quality assurance standards outlined in the NPDES MS4 permit.

Table 7. Pollutant Parameters and Analytical Methods for the Comprehensive Clackamas County Monitoring Plan							
Type (field or laboratory)	Analyte	Sample type (Grab or time-spaced composite)	Unit	Analytical method	Estimated MDL	Notes	Analyzed in-house* versus send-out
Field	Specific conductivity	Grab	µmhos/cm	SM 2510 B	1	Method assumes use of probe	
Field	pH	Grab	Std units	SM-4500-H B	0.1	Method assumes use of probe	
Field	Temperature	Grab	Deg Celsius	SM 2550-B	0.1	Method assumes use of probe	
Field	DO	Grab	mg/L	EPA 360.1	0.1	Method assumes use of probe	
Lab	Copper, total	Composite	µg/L	EPA 200.8	0.1		In-house
Lab	Copper, dissolved	Composite	µg/L	EPA 200.8	0.1		In-house
Lab	*E. coli*	Grab	MPN/ 100 mL	SM 9223 B	1.0		In-house
Lab	Biochemical Oxygen Demand (BOD_5)	Composite	mg/L	SM 5210B	2		In-house
Lab	Total hardness	Composite	mg $CaCO_3$/L	SM 2340 C	5		In-house
Lab	Lead, total	Composite	µg/L	EPA 200.8	0.01		In-house
Lab	Lead, dissolved	Composite	µg/L	EPA 200.8	0.01		In-house
Lab	Mercury, total and dissolved	Grab	ng/L	EPA 1631 E	0.5		Send-out
Lab	Methyl Mercury, total and dissolved	Grab	ng/L	EPA 1630	0.05		Send-out
Lab	Nitrogen–ammonia	Composite	mg/L	SM 4500 NH_3G	0.05		In-house
Lab	Nitrogen–nitrate	Composite	mg/L	EPA 353.2	0.045		In-house
Lab	Phosphorus, total	Composite	mg/L	SM 4500-P B&F	0.04		In-house
Lab	Phosphorus, ortho-phosphate	Composite	mg/L	SM 4500-P F	0.01		In-house
Lab	Solids–Total suspended	Composite	mg/L	SM 2540 D	1.0		In-house
Lab	Solids–Total dissolved	Composite	mg/L	SM 2540 C	1		In-house
Lab	Solids–Total volatile	Composite	mg/L	SM 2540 B	1		In-house
Lab	Zinc, total	Composite	µg/L	EPA 200.8	1		In-house
Lab	Zinc, dissolved	Composite	µg/L	EPA 200.8	1		In-house

* *In-house refers to the Water Environment Services laboratory*

7. Monitoring Data Management and Monitoring Plan Modifications

This section includes a summary of data management procedures (Section 7.1) and procedures for modifying this plan (Section 7.2).

7.1 Data Management

Participants in the Comprehensive Clackamas County Monitoring Plan individually (or through an intergovernmental agreement) collect samples and are responsible for the quality control of their samples prior to delivery at the laboratory. Field sample collection procedures are outlined in Appendix B. Sample validation and verification is conducted at the laboratory and, following analysis, the monitoring results are provided to the responsible jurisdiction to validate and verify that the findings are consistent with their expectations. Questionable monitoring results will be flagged for further review and possible follow up in the field. If data quality indicators suggest that contamination or corruption of the sample occurred, data may be discarded and re-sampling may occur, and the cause of the failure will be evaluated. If the cause is found to be equipment failure, calibration and/or maintenance techniques will be assessed and improved; if the cause is found to be with the sample collection process, field techniques will be assessed, revised, and retrained as appropriate.

Individual jurisdictions will be responsible for the compilation of monitoring data in database format. Monitoring data shall be compiled by monitoring location and monitoring event, and data shall include times, concentrations, and indication of whether a sample represents a grab or time composite sample. Statistics (i.e., mean, maximum, minimum) may be calculated on the data by an individual jurisdiction for their own use. The compiled monitoring data will be provided to DEQ with submittal of the individual jurisdiction's NPDES MS4 annual reports. Monitoring data provided to DEQ annually shall be in a usable digital format in accordance with requirements of the 2011-2016 NPDES MS4 annual report.

For the fourth year annual report (due date: November 1, 2014), a water quality trends analysis is required based on the monitoring data obtained. The benefit of a coordinated monitoring program is that resources can be distributed more widely to produce data that will provide comprehensive information for the County as a whole. As a result, data analyses will be conducted specific to each waterbody, but assessment and interpretation associated with this requirement will be conducted for each individual jurisdiction. As part of the water quality trends analysis effort, previously collected monitoring data specific to the waterbody would be reviewed. Although most of the previously collected data have already been analyzed, wet weather and dry weather data may not have been segregated and the comparison of dry weather to wet weather data may provide further insights into the extent to which runoff is impacting streams for various parameters.

7.2 Monitoring Plan Modifications

Modifications to monitoring locations and frequency as outlined in this Plan are permissible as long as the number of monitoring data points (the product of monitoring location, frequency, and permit term) is maintained. Additionally, if on an annual basis a participating co-permittee is not able to collect the required samples due to climatic conditions, sampling conditions, equipment malfunction, monitoring location inaccessibility, etc, such inability is not directly reflective of a need to modify the monitoring plan.

If a modification is required to the monitoring plan, such need must be provided to DEQ in the form of a 30-day notice of proposed monitoring plan modification. As provided in Schedule B.2.e., written approval must be received from DEQ before such modification can take place. If DEQ does not respond within 30 days, the proposed modification is deemed to be approved without written approval.

Appendix A:

Rationale for Conducting Time-Composite Sampling

Brown AND Caldwell

Memorandum

6500 SW Macadam Avenue, Suite 200
Portland, Oregon 97239
Tel: 503-244-7005
Fax: 503-244-9095

Date: November 19, 2010

Subject: Request to Conduct Time-Composite versus Flow-Weighted Composite Sampling Program for MS4 Communities

To: Benjamin Benninghoff, Oregon Department of Environmental Quality

From: City of Gladstone,
City of Happy Valley,
City of Lake Oswego,
City of Milwaukie,
City of Oregon City,
City of West Linn,
City of Wilsonville,
Clackamas County Service District #1,
SWMACC

CONTENTS

1. SUMMARY

Phase I jurisdictions in Oregon are currently in negotiations with the Oregon Department of Environmental Quality (DEQ) related to provisions of their Phase I Municipal Separate Storm Sewer (MS4) National Pollutant Discharge Elimination System (NPDES) permit. The public review draft permit was received October 8, 2010, which outlines requirements for their stormwater management programs including monitoring activities. In accordance with the October 8, 2010 draft MS4 NPDES permit template, jurisdictions are required to conduct flow-weighted composite sampling to meet their stormwater monitoring requirements unless the jurisdiction "*identifies the infeasibility of the flow-weighted composite sampling method or flow-weighted composite sampling is scientifically unwarranted…*". .

Many Phase I jurisdictions currently collect grab samples at timed intervals and composite these samples into a single time-composite sample to fulfill their stormwater monitoring requirements. As a result, jurisdictions who want to continue using this sampling technique must outline their rationale for the use of this method.

This memorandum outlines the rationale for our requested continued use and acceptance of time-composite sample collection for stormwater monitoring in accordance with the Phase I MS4 NPDES permit. Specifically, we request DEQ's approval of continued collection of time-composite samples for the following reasons:

1. Time and resource limitations, especially for the smaller, Phase I Clackamas County jurisdictions;
2. Documented difficulties in obtaining robust data sets using automated samplers and flow meters;
3. Need for consistency with past/current sample collection methods in order to evaluate trends over time; and
4. Consideration that time-composite mean concentrations may result in more conservative concentration estimates than flow-weighted composite event mean concentrations (EMCs), if/when first flush characteristics are present.

This memorandum is organized in accordance with the following topics, in order to provide information to support our request for the use of a time-composite sampling method:

1. Background information including a description of flow-weighted composite and time-composite sampling.
2. Summary of the difficulties, feasibility, and applicability of results related to the use of flow-weighted composite sampling methods and equipment as compared to current time - composite sampling activities.
3. Analysis and comparison (via case study) of time-composite sampling versus flow-weighted composite sampling results for equivalent storm events, parameters, and drainage areas.
4. Recommendations and Conclusions
5. Proposed methodology for collecting time-composite samples in accordance with requirements outlined in the draft MS4 NPDES permit (dated October 8, 2010).

2. BACKGROUND

Flow-weighted composite sampling has been cited in multiple technical publications as providing the most representative means for characterizing stormwater runoff data (National Research Council, 2008 and CalTrans, 2005). The benefits of flow-weighted composite sampling are generally well-understood and documented. Specifically, if samples are collected for the duration of a storm event, a flow-weighted composite sampling regime provides the ability to calculate a mass load discharged for a specific storm event and is therefore expected to provide a more robust estimate of the average pollutant concentration over a storm event (including a pollutant first flush if applicable).

However, the application of flow-weighted composite sampling methods to stormwater and the rationale related to its benefits are generally documented in academic or research articles and technical publications as opposed to being documented in the realm of MS4 permit compliance. Monitoring objectives, as outlined in the draft MS4 NPDES permit template, focus on the evaluation of trends in order to characterize stormwater, determine MS4 effects on receiving waters, and evaluate status and trends in receiving waters. Thus, flow-weighted composite sampling methods would not be necessary to address the objectives as outlined in the draft MS4 NPDES permit template. Additionally, the technical abilities and resources of a municipality to conduct flow-weighted composite sampling for their MS4 NPDES permit compliance is often more limited than for an academic or research institution with more extensive personnel and financial resources that can focus on a more involved method of stormwater data collection.

Flow-weighted composite sampling involves the use of an automated flow meter and water quality sampler. Runoff volumes must be estimated for each station based on predicted rainfall amounts, catchment areas, and estimated catchment runoff volumes, and the automated sampler is then programmed to collect a runoff sample at a specified, incremental flow. As a result, multiple samples are collected for each storm, representing runoff conditions from the overall storm hydrograph. The samples are composited to provide an event mean concentration (EMC).

Time-composite sampling involves the collection of single, discrete grab samples at regular time intervals during a runoff event. Like flow-weighted composite sampling, the samples represent runoff conditions throughout a storm event and are composited to provide a mean concentration. The difference is that a greater number of samples are collected as a part of flow-weighted composite sampling when more flow is occurring. Therefore, the mean concentration is weighted based on the amount of flow that occurred. Regardless of the amount of flow that occurs, time-composites represent more-regular sampling intervals throughout the storm event. Time-composite sampling requires less planning, technical assumptions, equipment, and operational knowledge when compared to flow-weighted composite sampling, which is a benefit for resource-limited municipalities.

3. LIMITATIONS ASSOCIATED WITH FLOW-WEIGHTED COMPOSITE SAMPLING

Significant Time and Resources Required

Application and implementation of a stormwater monitoring program using flow-weighted composite sampling would be a difficult undertaking for many Oregon Phase I municipalities. Specific to MS4 NPDES permit compliance, municipalities typically implement their stormwater programs by relying on the multi-tasking of maintenance and public works staff. The limited staff and funds available for implementation of an overall stormwater management program are divided between monitoring, program implementation, facility operations and maintenance, reporting, and the completion of special studies and assessments. Therefore, additional resources directed at stormwater monitoring would result in reduced resources directed at program implementation and hence water quality improvements.

Given that automated flow monitoring equipment can cost an average of $10,000 per site (Personal Communication with John Hedrick, May 13, 2010), and given that significant training is required to properly operate and maintain the equipment, smaller jurisdictions have been able to maximize data results obtained by conducting time-composite sampling. Using the time-composite method, it is likely that approximately two to four times as many sites can be sampled for the same resources it would take to operate one site using flow-weighted composite sampling methods (Burton and Pitt, pp. 285). Also, as mentioned above, due to the limited staff and funds allocated for implementation of the overall stormwater program, diverting additional resources to monitoring would reduce resources available for implementation of the actual activities that would have an impact of stormwater pollutant generation such as inspections, maintenance, outreach, and enforcement.

Difficulties with Data Collection

Assuming that a community has the personnel and equipment available to conduct flow-weighted composite sampling for stormwater, there are a number of difficulties and issues associated with the collection of flow-weighted composite samples across the entire range of the storm hydrograph.

Based on the stormwater monitoring results documented in the *City of Portland Event History Data between May 1994 and March 1995* (City of Portland, May 1995), a variety of issues associated with the collection of flow-weighted composite samples for municipal stormwater monitoring were identified. Such issues are outlined and described below:

- **Difficulties in estimating the expected rainfall depth (rainfall volume)**. In order to program the automated sampler to collect samples at a specified flow increment throughout the storm event, an estimate of the depth of rainfall expected is necessary. However, prediction of rainfall depth is limited to available weather forecasts, and such forecasts frequently over or under predict the rainfall depth expected. Additionally, depending on the size of the catchment area, spatial rainfall variation over the catchment area may occur.

  Per the *City of Portland Event History Data between May 1994 and March 1995*, samples from a total of four storm events were collected at three monitoring locations. For three of these events, the forecasted rainfall depth differed significantly from the rainfall depth measured at the gages used to represent each monitoring location. An incorrect prediction of rainfall results in either too few samples being collected, or the collection of too many samples such that staff may not have sufficient time to change out the sample bottles once full and hence bypass a portion of a storm event. Table 1 outlines the range in forecasted and measured rainfall.

Table 1. Forecasted and Measured Rainfall (City of Portland, May 1995)

Storm event	Forecasted rainfall depth, inches	Measured rainfall depth (range based on monitoring location), inches
#1	0.25	0.20 – 0.25
#2	0.30	0.17 – 0.22
#3	0.80	2.78 – 3.45
#4 (first hydrograph)	0.25	0.26 – 0.57

- **Difficulties in approximating the equivalent runoff volume associated with a particular rainfall depth (rainfall volume).** In order to program the automated sampler to collect samples at a specified flow increment throughout the storm event, an estimate of the volume of runoff expected is also necessary. The estimated volume of runoff is calculated based on the rainfall (described above) and an estimated runoff coefficient for the catchment area. The runoff coefficient is estimated based on the impervious characteristics of the catchment and is considered an indication of the proportion of rainfall that will result in runoff. Based on antecedent dry period, rainfall depth, and rainfall intensity, the runoff coefficient can be highly variable at an individual site, but it is required in order to convert rainfall depth into a runoff volume for programming the automated samplers. As with rainfall, the values estimated for a runoff coefficient can frequently result in over and under predicting the stormwater runoff expected for an event.

Per the *City of Portland Event History Data between May 1994 and March 1995*, samples from a total of four storm events were collected at three monitoring locations. At all locations, the forecasted runoff coefficient and the measured runoff coefficients varied for each storm event. This resulted in either too few or too many samples collected based on the forecasted runoff volume, and an inability of staff to schedule and change out full bottles with empty bottles. Table 2 outlines the range in forecasted and measured runoff coefficients at each location.

Table 2. Forecasted and Measured Runoff Coefficient (City of Portland, May 1995)

Monitoring location	Forecasted runoff coefficient	Measured runoff coefficient (range based on storm event)
M1 – mixed land use (91 acres)	0.60	0.62 – 0.65
R1 – residential land use (1,426 acres)	0.10	0.02 – 0.30
C2 – commercial land use (75 acres)	0.70	0.35 – 0.57

- **Difficulties in approximating the start time of an anticipated storm event.** Programming and set up of the automated samplers is required prior to the anticipated storm event. Scheduling the set up, start time, and anticipated duration of sample collection is necessary in conjunction with the anticipated start of the storm event, as one hopes to catch the entire storm event hydrograph while not prematurely setting up the equipment such that batteries could wear down or equipment could get contaminated.

  Per the *City of Portland Event History Data between May 1994 and March 1995*, an earlier than expected arrival of rainfall occurred during storm event #1, which resulted in a late set up and the automated samplers missing the first part of the storm hydrograph.

- **Mechanical Difficulties.** A variety of mechanical difficulties can occur with use of the automated samplers because staff is typically not present throughout the duration of sample collection. After set-up, staff generally only visits the samplers to either collect the sample bottles following the storm event or to replace the bottles during the storm event. At such time, staff may observe a variety of problems that may negate or result in questionable monitoring results.

  Per the *City of Portland Event History Data between May 1994 and March 1995*, observed mechanical issues included tubing that had become disconnected, lines that had become clogged, and cracks in the tubing. Observed mechanical issues resulted in inconsistent sample collection or an inability to collect samples at all.

- **User/Operator Error.** Human error can also result in problems obtaining representative samples via an automated sampler. This is especially problematic during storm sampling as events are often unscheduled and occur during the evening and in the dark when staff are tired. Such errors may include forgetting to power the samplers, forgetting to remove the lids from the bottles upon bottle installation and an inability (due to timing or resources) to replace bottles during a storm event in accordance with the programmed flow rate. Any of these activities would result in skewed, missing, or flawed sample collection.

Even when sampling is conducted and thought to be representative of the entire storm hydrograph, the monitoring results, when plotted against the storm hydrograph may indicate the difficulty in obtaining truly representative samples. Figures 1 and 2 show how actual sample collection using an automated sampler compares with the representative hyetograph and hydrograph for the various storm events.

The example in Figure 1 shows the delay in sample collection at the beginning of the rainfall event, as a result of the difficulty in estimating the storm event start time. Samples from the first flush of the storm event were not collected because sampling was initiated approximately two to three hours following the start of the rainfall event.

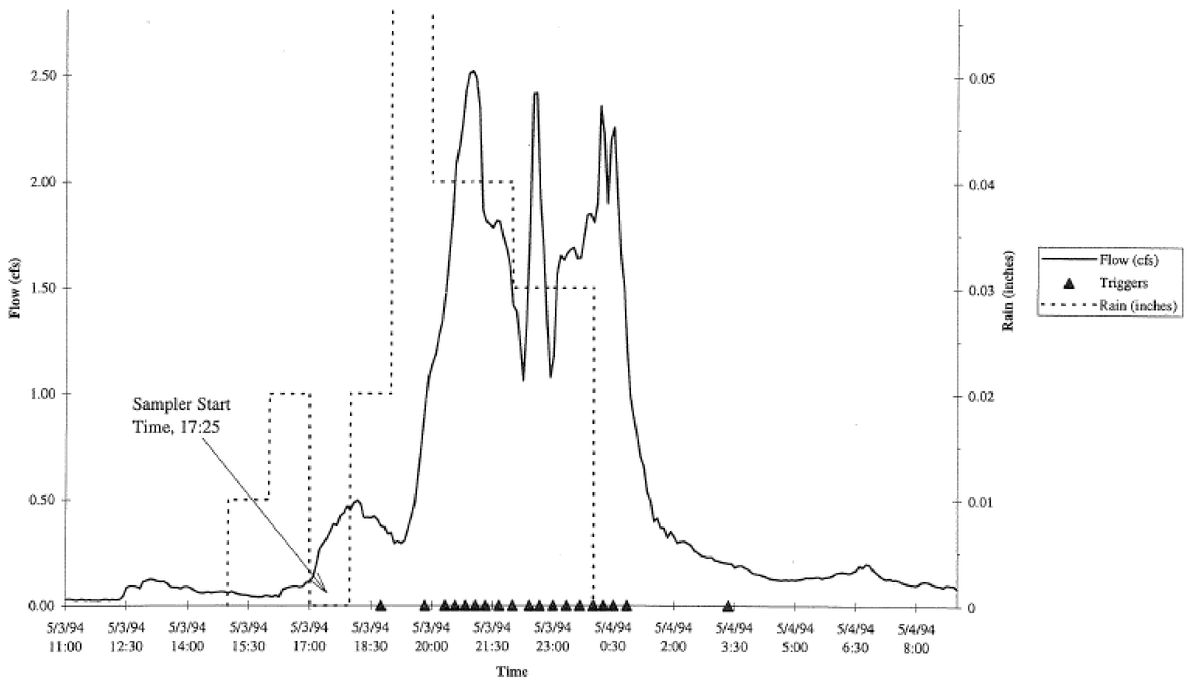

Figure 1. Storm Hydrograph and Sample Collection for Event #1 (City of Portland, May 1995)

The example in Figure 2 shows that as a result of an inability to accurately predict the rainfall and runoff volume from the site (required to establish a sampling frequency for the automated sampler) and an inability of staff to change out the sample bottles, the end of the storm event was not sampled.

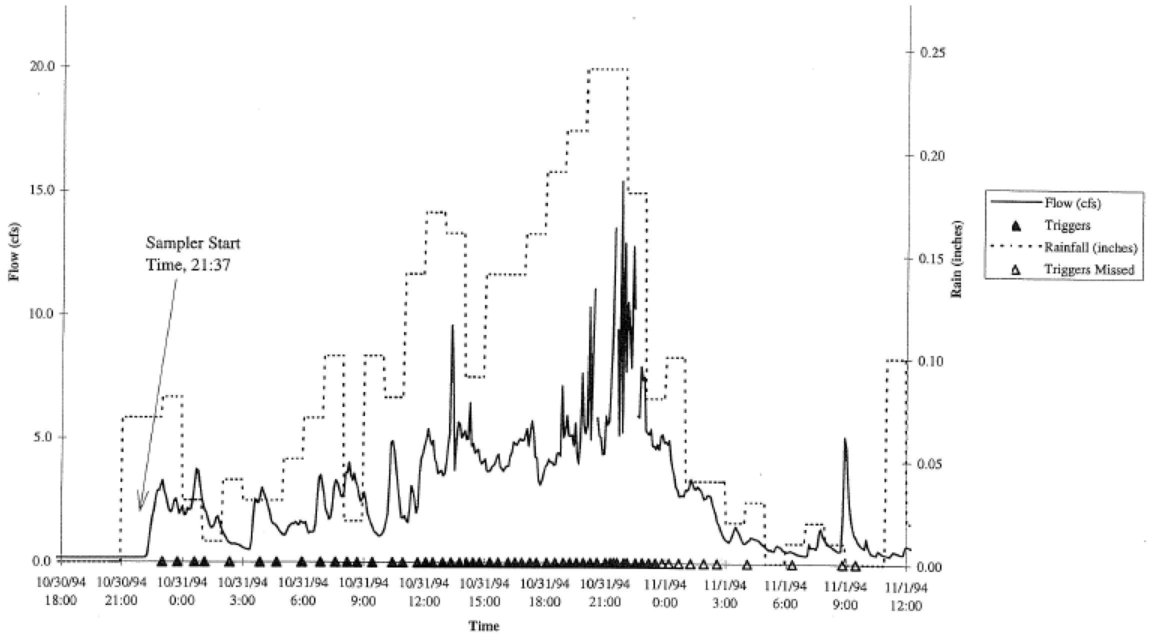

Figure 2. Storm Hydrograph and Sample Collection for Event #3 (City of Portland, May 1995)

Inconsistent Data Collection Methods

Clackamas jurisdictions have generally been employing time-composite sample collection methods for their MS4 NPDES permit compliance since the late 1990s. In order to ensure collection of a statistically significant data set, many monitoring locations have not been changed. As a result, even though relatively few samples are collected on an annual basis, collection of samples over the last 10-15+ years has allowed jurisdictions to analyze long-term trends related to their stormwater discharge.

As described in the Stormwater Effects Handbook (Burton and Pitt, pp. 286), time-composite sampling more readily detects intermittent discharges and other short-term, high concentration flows. This is due to the fact that flow-weighted composite sampling may allow very long periods to be unrepresented in the sample. As a result, flow-weighted composite sampling may result in a less conservative estimate of mean pollutant concentration when compared to time-composite sampling. Therefore, adjusting the monitoring method from a time-composite approach to a flow-weighted composite approach now could potentially skew the long-term monitoring record, making comparison between past and present monitoring results more difficult. Also, if the newly acquired flow-weighted composite monitoring data is used in conjunction with previously collected monitoring data to establish and evaluate trends, given that the flow-weighted composite monitoring results may not be as conservative as the time-composite monitoring results, the comprehensive monitoring results may incorrectly indicate improving trends. To ensure the most robust data set, consistency in monitoring methods should be employed.

4. CASE STUDY TO COMPARE DIFFERENCES IN FLOW-WEIGHTED AND TIME-COMPOSITE SAMPLING RESULTS

In order to estimate the difference between a flow-weighted composite EMC and a time-composite mean concentration for a variety of stormwater parameters, the raw data from the *City of Portland Event History Data between May 1994 and March 1995* (City of Portland, May 1995) were revisited and assessed. Both individual sample concentrations and associated flow data were available for the same drainage areas, parameters, and storm events. As a result, flow-weighted composite EMCs could be directly compared to the individual sample concentrations and hence a simulated time-composite concentration, in order to estimate differences between the two data sets.

A description of the original *City of Portland Event History Data between May 1994 and March 1995* study is provided below, in addition to detail related to the analysis conducted as part of the flow-weighted composite versus time-composite comparison.

Background

The *City of Portland Event History Data between May 1994 and March 1995* study was originally conducted to evaluate the presence of first-flush conditions, specifically to evaluate the types of parameters that exhibit first flush characteristics and the storm event variables (intensity, duration, antecedent dry period) that relate to an observed pollutant first flush. Four storm events were monitored over a nine month period at three site locations throughout the City of Portland. Each catchment area represented a different land use classification: residential, commercial, and mixed-use. To evaluate first flush characteristics, individual samples were collected at discrete intervals during a storm event

Results of the *City of Portland Event History Data between May 1994 and March 1995* study indicate that first flush characteristics are dependent on the parameter monitored and the storm characteristics. Total/particulate phase pollutants sometimes exhibited a first flush. When a first flush was observed, these total phase pollutants (with the exception of bacteria) generally displayed the first flush effect when the storm events had a relatively long antecedent dry period. First flush effects were generally not observed for dissolved parameters, regardless of the antecedent dry period. For both total/particulate and dissolved phase pollutants, an increase in pollutant concentrations was often noted in association with the highest intensity rainfall, regardless of whether the high intensity occurred during the beginning, middle, or end of the storm event.

Other referenced studies indicate that first flush characteristics may also be related to the overall size of the catchment or watershed and the relative impervious surface of the site (CalTrans, 2005). Specifically, for the smaller, more impervious catchment areas, it has been suggested that the first flush effect would be increasingly observed.

Analysis

Both the pollutant concentration and flow data from the *City of Portland Event History Data between May 1994 and March 1995* study were revisited in order to 1) calculate a flow-weighted composite EMC for each available storm event and monitoring location and 2) calculate time-composite mean concentrations using select individual samples (representing timed grabs). The flow-weighted composite EMC and time-composite mean concentrations were compared in order to estimate the relative difference in value based on the sampling methodology employed.

Only stations and storm events with qualified data were included in the analysis. Because samples collected representing the residential land use location were collected from an instream site instead of an outfall location, the residential location was excluded from the analysis.

Flow-weighted composite EMCs were not calculated as part of the original study because the focus of the study was solely to evaluate the presence of a first flush. Therefore, for this analysis, the individual flow-weighted samples were used to calculate a flow-weighted composite EMC for the following pollutants: total suspended solids (TSS), total phosphorus, ortho-phosphorus, nitrate, total Kjeldahl nitrogen (TKN), total lead, dissolved lead, and fecal coliform.

To calculate a time-composite mean concentration based on individual samples, individual samples were selected from the raw data, and the mean concentration calculated. Conclusions related to first flush characteristics from the original *City of Portland Event History Data between May 1994 and March 1995* study were used to appropriately select representative, individual samples that would be used to calculate a time-composite mean concentration. Three individual samples were collected to represent a time-composite mean concentration, consistent with terms and methods outlined in the Comprehensive Clackamas County Monitoring Plan (dated 2006 and updated in 2008).

Multiple scenarios of time-composite mean concentrations were calculated for each storm event and parameter, depending on the number and timing of individual samples selected. Individual samples for each scenario were selected to represent sample collection towards the beginning of the storm event and sample collection throughout the storm event. In all, between two and four (depending on the length of the storm and the availability of individual sample data) time-composite mean concentrations were calculated to represent time-composite sample data collection that would target the beginning of a storm event (time-composite sample scenarios). Between two and four time-composite mean concentrations were calculated to represent time-composite sample data collection that would include the entire storm event (time-composite sample scenarios), for comparison. All time-composite mean concentrations were compared to the event and parameter-specific flow-weighted composite EMCs that were calculated. A detailed summary of the data analysis is provided in Attachment 1.

Results and Conclusions. Results from the comparison of flow-weighted composite EMCs and time-composite mean concentrations indicate that the time-composite mean concentrations were typically more conservative (i.e., higher) than flow-weighted composite EMCs. Table 3 summarizes the results of the analysis by event and sampling location. The range of time-composited mean concentrations is based on the various combinations of individual samples.

The difference between the time-composite mean concentration and the flow-weighted composite EMC appears to be based on the first flush characteristics if a first flush was present. As a result, combinations of individual samples collected towards the beginning of a storm event tended to result in a higher time-composite mean concentration than combinations of individual samples collected during the entire storm event. Based on the raw data for storm events #1 and #2, an obvious first flush was observed for all analyzed parameters for each monitoring location with the exception of nitrate, dissolved lead, and bacteria. Additionally, both storms had a fairly long antecedent dry period (more than six days) and similar peak intensity. In comparison, a first flush amongst any of the parameters was not readily observed for storm event #3. Storm event #3 had the shortest antecedent dry period amongst all storm events (less than one day) and the longest duration storm.

As a result, the following conclusions can be drawn from the flow-weighted composite EMC and time-composite mean concentration comparison.

1. Time-composite mean concentrations were typically higher for total phase pollutants than flow-weighted composite EMCs if samples were collected during the beginning of a storm event where first flush conditions were observed. This result is based on sampling that captures the beginning of a storm event following a longer antecedent dry period.
2. A time-composite mean concentration appeared to be a relatively consistent estimate for dissolved phase pollutants when compared to a flow-weighted composite EMC, as dissolved pollutants did not show first flush characteristics as part of this study.

Table 3. Summary of Flow-Weighted Composite EMCs and Time-Composite Mean Concentration (by location and storm event)

Storm event	Monitoring station (by land use)	Monitored parameters											
		TSS (mg/L)			Total phosphorus (mg/L)			Ortho-phosphorus (mg/L)			Nitrate (mg/L)		
		Flow-weighted composite EMC	Time-composite mean concentration (assuming sample collection towards the beginning of the storm event)[1]	Time-composite mean concentration (assuming sample collection throughout the duration of the storm event)[2]	Flow-weighted composite EMC	Time-composite mean concentration (assuming sample collection towards the beginning of the storm event)[1]	Time-composite mean concentration (assuming sample collection throughout the duration of the storm event)[2]	Flow-weighted composite EMC	Time-composite mean concentration (assuming sample collection towards the beginning of the storm event)[1]	Time-composite mean concentration (assuming sample collection throughout the duration of the storm event)[2]	Flow-weighted composite EMC	Time-composite mean concentration (assuming sample collection towards the beginning of the storm event)[1]	Time-composite mean concentration (assuming sample collection throughout the duration of the storm event)[2]
1	*Mixed-Use*	813	1434 - 1480	90 - 1480	0.37	0.41 – 0.46	0.29 – 0.46	0.13	0.18 – 0.19	0.06 – 0.19	0.33	0.48 – 0.49	0.16 – 0.49
	Commercial	83	84 - 94	75 - 94	0.19	0.19 – 0.22	0.19 – 0.26	0.04	0.02 - 0.03	0.02 – 0.08	0.24	0.19 – 0.22	0.19 – 0.28
2	*Mixed-Use*	744	837 - 937	657 - 947	3.23	1.79 – 4.79	0.61 – 4.79	0.12	0.11 – 0.12	0.11 – 0.12	0.72	0.60 – 0.86	0.51 – 0.94
	Commercial[(3)]												
3	*Mixed-Use*	155	37 - 72	37 - 233	1.01	0.18 – 0.37	0.18 – 1.41	0.10	0.05 – 0.06	0.05 – 0.12	0.11	0.14 – 0.18	0.09 – 0.18
	Commercial	47	27 - 61	27- 95	0.18	0.17 – 0.23	0.17 – 0.24	0.03	0.03 – 0.04	0.02 – 0.04	0.12	0.13 – 0.16	0.09 – 0.16
4	*Mixed-Use*[3]												
	Commercial	284	291 - 500	172 - 500	0.38	0.52 – 0.92	0.21 – 0.92	0.07	0.05 – 0.07	0.05 – 0.07	0.23	0.29 – 0.43	0.18 – 0.43
Storm event		TKN (mg/L)			Total lead (mg/L)			Dissolved lead (mg/L)			Fecal coliform (number/100 mL)		
1	*Mixed-Use*	3.94	4.57 – 5.50	2.27 – 5.50	0.10	0.16 – 0.17	0.02 – 0.17	0.001	0.001	0.001	1.3×10^4	$0.9 \times 10^4 – 1.9 \times 10^4$	$0.7 \times 10^4 – 1.9 \times 10^4$
	Commercial	3.28	3.13 – 3.50	2.50 – 3.50	0.06	0.06 – 0.07	0.06 – 0.07	0.007	0.006 – 0.009	0.006 – 0.009	1.2×10^4	$0.6 \times 10^4 – 1.2 \times 10^4$	$0.6 \times 10^4 – 1.9 \times 10^4$
2	*Mixed-Use*[(3)]	5.63	5.87 – 6.73	5.00 – 6.73	0.07	0.08	0.06 – 0.08				7.5×10^4	$3.1 \times 10^4 – 4.6 \times 10^4$	$3.1 \times 10^4 – 9.9 \times 10^4$
	Commercial[(3)]												
3	*Mixed-Use*	1.82	0.87 – 1.93	0.87 – 2.23	0.03	0.01 – 0.02	0.01 – 0.03	0.0002	0 – 0.0003	0 – 0.0003	1.1×10^4	$0.8 \times 10^4 – 2.0 \times 10^4$	$0.8 \times 10^4 – 2.0 \times 10^4$
	Commercial	1.75	1.37 – 2.53	1.37 – 2.53	0.02	0.02 – 0.03	0.02 – 0.03	0.004	0.004 – 0.005	0.003 – 0.005	1.8×10^4	$0.7 \times 10^4 – 1.0 \times 10^4$	$0.6 \times 10^4 – 1.0 \times 10^4$
4	*Mixed-Use*[3]												
	Commercial[3]	1.32	1.83 – 3.23	1.50 – 4.10	0.05	0.05 – 0.08	0.03 – 0.08	0.007	0.004 – 0.014	0.004 – 0.015			

[1] *The range of time-composite mean concentrations were calculated for multiple sampling scenarios, assuming that the individual samples were collected towards the beginning of the storm event such that: 1) the first flush of the storm event was captured, and 2) samples were collected over an average duration of approximately three hours.*

[2] *The range of time-composite mean concentrations were calculated for multiple sampling scenarios, assuming that the individual samples for each scenario were collected throughout the duration of the storm event.*

[3] *Empty cells indicate either a parameter or location that was not analyzed for the particular storm event or a storm event when the automated sampler/ flow meter encountered issues which prevented the collection of data.*

5. CONCLUSIONS AND RECOMMENDATIONS

Both time-composite sampling and flow-weighted composite sampling appear to be viable data collection methods for conducting stormwater monitoring given the monitoring objectives of characterizing runoff and evaluating trends. Although some technical publications (National Research Council, 2008 and CalTrans, 2005) tend to support flow-weighted composite sampling as a more robust and accurate sampling technique, other publications support the use of time-composite sampling as opposed to flow-weighted composite sampling, due to its simplicity, low-cost, and good comparison to flow-weighted composite sampling (Burton and Pitt, pp. 285). In addition, there is more guarantee of success with time-composite sampling given all the potential failures that can occur with automated equipment.

Grab sampling methods (as used to develop a time-composite sample) are less expensive and more easily employed by municipal employees conducting monitoring as part of their MS4 NPDES permit compliance. Specific to the Phase I Clackamas County municipalities, the limited staff and resources responsible for MS4 NPDES program implementation is divided between various operations and maintenance, program tracking, monitoring, and public education activities. In some cases, program implementation is even the direct responsibility of the City Administrator as opposed to a technical staff person. Modifying the monitoring requirement from a time-composite method to a flow-weighted composite method would draw from resources that would otherwise be used for stormwater pollutant source control and stormwater pollutant removal activities. On average, time-composite sampling costs about ¼ of the cost of flow-weighted composite sampling (Burton and Pitt, pp. 285). Therefore, if flow-composite sampling were explicitly required, it is likely that only 25-50% of the existing sites could be sampled, given that jurisdictions are already operating at their resource limits to reduce pollutants to the maximum extent practicable.

Review of the raw data from the *City of Portland Event History Data between May 1994 and March 1995* study was conducted to compare calculated flow-weighted composite EMCs and time-composite mean concentrations for consistent parameters, drainage areas, and storm events. Results from this comparison support the conclusions made in the Burton and Pitt (2002) that time-composite sampling compares well with flow-weighted composite sampling. Based on the review, the differences between the flow-weighted composite EMC and time-composite mean concentration were primarily a function of whether first flush characteristics were exhibited by a particular parameter and during a particular storm event. A pollutant first flush is more readily apparent for total versus dissolved phase parameters after a longer antecedent dry period (City of Portland, 1995). In accordance with this conclusion from the original study, the time-composite mean concentrations calculated for total phase pollutants sampled after a more significant antecedent dry period typically resulted in a more conservative pollutant concentration estimate than the corresponding flow-weighted composite EMC. The flow-weighted composite EMC and time-composite mean concentrations for dissolved constituents were generally consistent. Although differences were observed, the magnitude of such differences did not appear significant; given the expected variability in the data and the intent of such monitoring activities (see Table 3).

Conclusions from the comparison of flow-weighted EMCs and time-composite mean concentrations were used to outline an appropriate time-composite sampling protocol (see Section 6). Conclusions from the comparison include the following:

1. Continuing with a time-composite sampling approach will help ensure consistency with long-term sampling methods. The collection of multiple (e.g., minimum three) grab samples composited appears to allow for a similar representation as would be provided by a flow-weighted EMC. See Attachment 1.
2. Maintaining a consistent monitoring approach using the same sampling procedures as past efforts would better indicate trends and allow for comparison between past and present/ future monitoring results.

3. Time-composite sampling appears more likely to result in a conservative estimate of a mean concentration when compared to flow-weighted composite sampling for parameters and storm events displaying first flush characteristics. First flush characteristics are typically displayed for total (as opposed to dissolved) parameters and after a long, antecedent dry period. As described previously, time-composite sampling more readily detects intermittent discharges and other short-term, high concentration flows (Burton and Pitt, pp. 286). As a result, time-composite sampling, when initiated towards the beginning of a storm event would ensure the first flush is accounted for and results in a more conservative mean concentration estimate.

4. Given the difficulties and limitations with collecting flow-weighted composite samples and the limited differences in the results between time and flow-weighted composite monitoring results, time-composited samples are assumed adequate to address the monitoring objectives of characterizing the chemical characteristics of stormwater runoff and overall assessment of trends.

5. Given the high cost and resource requirements of collecting flow-weighted composite samples, more data and hence more value can be obtained by applying available monitoring resources to the collection of time-composite samples.

Finally, recently publicized language related to anticipated modifications to the DEQ 1200-Z NPDES permit language proposes use of time-composite sampling. Given similar applications (i.e., wet weather monitoring, consistent pollutant parameters), collection of time-composite sampling should continue to be permissible for stormwater monitoring for MS4 NPDES permit compliance as well.

6. PROPOSED TIME-COMPOSITE SAMPLING METHODOLOGY

In accordance with the conclusions summarized in this memorandum related to time-composite sampling, the following guidelines are proposed for approval by DEQ for jurisdictions that intend to conduct time-composite sampling as opposed to flow-weighted sampling.

1. A time-composite sampling approach would continue to be used for storm-based monitoring activities (i.e., instream and stormwater or outfall monitoring).

2. A qualifying storm event must be greater than 0.1 inches.

3. When possible, the minimum antecedent dry period is 24 hours.

4. A minimum of three grab samples would be collected to represent a single time-composite sample for specified parameters.

5. When possible, sample collection would be initiated during the beginning of a storm event, in order to capture collection of samples representing a first flush concentration.

7. REFERENCES

Burton, G.A. Jr., and R. Pitt. Stormwater Effects Handbook: A Tool Box for Watershed Managers, Scientists, and Engineers. CRC Press, Inc., Boca Raton, FL. 2002. 911 pages.

Stenstrom, Michael and Masoud Kayhanian, First Flush Phenomenon Characterization. Prepared for the California Department of Transportation, Division of Environmental Analysis, August 2005.

National Research Council, Urban Stormwater Management in the United States. National Academies Press, Washington D.C. 2008.

Pedrick, John. Contech Stormwater Solutions. Personal communication. May 14, 2010.

Wildensee, Frank. City of Portland Bureau of Environmental Services. Personal communication. April 16, 2010 and May 9, 2010.

Woodward Clyde Consultants, Event History Data from Storms Monitored between May 1994 and March 1995, Attachment No. 1 to the Final Report. Prepared for City of Portland Bureau of Environmental Services, May 1995.

Attachment 1: Data Analysis Related to Case Study
(per the City of Portland Event History Data from Storms Monitored between May 1994 and March 1995)

EVENT 1

Station M-1

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
8:20:00 PM	6233	4100	1584	0.61	0.236	0.40	0.155	1.1	0.425	10	3.864	0.43	0.166	0.0008	0.00031	2.50E+04	4.41E+10
9:05:00 PM	5996	280	104	0.61	0.227	0.10	0.037	0.18	0.067	2.9	1.078	0.06	0.022	0.001	0.00037	0	0.00E+00
10:00:00 PM	5905	140	51	0.48	0.176	0.09	0.033	0.17	0.062	1.1	0.403	0.032	0.012	0.001	0.00037	0	0.00E+00
11:00:00 PM	5658	62	22	0.15	0.053	0.06	0.021	0.19	0.067	2.6	0.912	0.017	0.006	0.0008	0.00028	1.42E+03	2.28E+09
12:00:00 AM	6127	83	32	0.24	0.091	0.05	0.019	0.16	0.061	5.4	2.051	0.03	0.011	0.0013	0.00049	30800	5.34E+10
12:50:00 AM	5730	46	16	0.14	0.050	0.05	0.018	0.16	0.057	1.3	0.462	0.012	0.004	0.0008	0.00028	20600	3.34E+10
Total:	**35649**		**1809.395414**		**0.83175914**		**0.28250796**		**0.73851734**		**8.770489**		**0.221815292**		**0.0021057**		**1.33262E+11**

Flow Composite EMC	**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
	813.031	0.374	0.127	0.332	3.941	0.100	0.001	13201.183

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 3, 5	1441.00	0.44	0.18	0.48	5.50	0.16	0.0010	18600
	Samples 1, 2, 4	1480.67	0.46	0.19	0.49	5.17	0.17	0.0009	8807
	Samples 1, 3, 4	1434.00	0.41	0.18	0.49	4.57	0.16	0.0009	8807
3 aliquots over min 3 hours (anytime during storm)	Samples 1, 4, 6	1402.67	0.30	0.17	0.48	4.63	0.15	0.0008	15673
	Samples 2, 4, 6	129.33	0.30	0.07	0.18	2.27	0.03	0.0009	7340
	Samples 3, 5, 6	89.67	0.29	0.06	0.16	2.60	0.02	0.0010	17133

Station C-2

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
8:15:00 PM	8133	170	86	0.31	0.156	0.02	0.010	0.16	0.081	3.7	1.866	0.11	0.055	0.0043	0.002	1.17E+04	2.69E+10
8:35:00 PM	5404	200	67	0.33	0.111	ND	0.000	0.09	0.030	3.3	1.106	0.12	0.040	0.0045	0.002	25900	3.96E+10
9:05:00 PM	5604	71	25	0.17	0.059	0.02	0.007	0.18	0.063	2.6	0.903	0.055	0.019	0.0063	0.002	0	0.00E+00
9:50:00 PM	5830	40	14	ND	0.000	0.02	0.007	0.23	0.080	1.9	0.660	0.04	0.014	0.013	0.005	3.90E+03	6.44E+09
10:50:00 PM	6047	41	15	0.1	0.037	0.03	0.010	0.26	0.090	4.2	1.459	0.042	0.015	0.008	0.003	6300	1.08E+10
12:15:00 AM	5687	16	6	0.2	0.071	0.06	0.021	0.37	0.129	2.3	0.799	0.025	0.009	0.0095	0.003	27800	4.48E+10
2:15:00 AM	5482	16	5	0.18	0.061	0.12	0.042	0.49	0.170	5.3	1.841	0.014	0.005	0.0045	0.002	12700	1.97E+10
Total:	**42187**		**218.30975**		**0.49513758**		**0.09694692**		**0.64242912**		**8.634771**		**0.156823668**		**0.018025576**		**1.48288E+11**

Flow Composite EMC	**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
	82.893	0.188	0.037	0.244	3.279	0.060	0.007	12413.132

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 3, 5	94.0	0.193	0.023	0.200	3.500	0.069	0.006	6000.0
	Samples 2, 4, 5	93.7	0.215	0.025	0.193	3.133	0.067	0.009	12033.3
	Samples 1, 4, 5	83.7	0.205	0.023	0.217	3.267	0.064	0.008	7300.0
3 aliquots over min 3 hours (anytime during storm)	Samples 1, 4, 6	75.3	0.255	0.033	0.253	2.633	0.058	0.009	14466.7
	Samples 2, 4, 6	85.3	0.265	0.040	0.230	2.500	0.062	0.009	19200.0
	Samples 2, 5, 7	85.7	0.203	0.075	0.280	4.267	0.059	0.006	14966.7

EVENT 2
Station M-1

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
10:55:00 PM	8439	1700	889.471	0.55	0.288	0.11	0.058	0.39	0.204	7.5	3.924	0.093	0.049	ND	0.000	1.15E+04	2.75E+10
11:20:00 PM	7955	640	315.654	4	1.973	0.12	0.059	1.2	0.592	6.3	3.107	0.055	0.027	ND	0.000	1170	2.64E+09
12:00:00 AM	6990	310	134.348	13	5.634	0.11	0.048	0.41	0.178	3.7	1.604	0.05	0.022	ND	0.000	<10	0.00E+00
12:35:00 AM	6119	500	189.689	0.81	0.307	0.12	0.046	0.99	0.376	6.4	2.428	0.084	0.032	ND	0.000	8.10E+04	1.40E+11
4:35:00 AM	5761	210	75.008	0.48	0.171	0.13	0.046	0.73	0.261	3.8	1.357	0.04	0.014	ND	0.000	187000	3.05E+11
6:20:00 AM	6817	830	350.803	0.24	0.101	0.11	0.046	0.64	0.270	5.6	2.367	0.11	0.046	ND	0.000	216000	4.17E+11
Total:	**42081**		**1954.9728**		**8.4747304**		**0.30286194**		**1.88041846**		**14.7870372**		**0.1901018**		**0**		**8.92483E+11**

		TSS (mg/L)	TP (mg/L)	OP (mg/L)	Nitrate (mg/L)	TKN (mg/L)	T Pb (mg/L)	D Pb (mg/L)	Fecal (Number/ 100mL)
Flow Composite EMC		744.176	3.226	0.115	0.716	5.629	0.072	0.000	74897.789

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 2, 4	946.667	1.787	0.117	0.860	6.733	0.077		31223.333
	Samples 1, 3, 4	836.667	4.787	0.113	0.597	5.867	0.076		46250.000
3 aliquots over min 3 hours (anytime during storm)	Samples 1, 3, 5	740.000	4.677	0.117	0.510	5.000	0.061		99250.000
	Samples 2, 4, 6	656.667	1.683	0.117	0.943	6.100	0.083		99390.000
	Samples 1, 4, 5	803.333	0.613	0.120	0.703	5.900	0.072		93166.667

Event 3

Station M-1

Time	Incremental Volume (cf)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
11:40:00 PM	17329	98	105.291	0.48	0.516	ND	0.000	0.23	0.247	4	4.298	0.025	0.027	0	0.000	<10	0.00E+00
12:50:00 AM	16780	46	47.857	0.21	0.218	0.05	0.052	0.16	0.166	0.8	0.832	0.009	0.009	0	0.000	8800	4.18E+10
2:10:00 AM	17035	46	48.584	0.17	0.180	0.05	0.053	0.13	0.137	0.7	0.739	0.012	0.013	0	0.000	32000	1.54E+11
7:15:00 AM	32999	20	40.919	0.16	0.327	0.05	0.102	0.17	0.348	1.1	2.251	0.009	0.018	0	0.000	6.40E+03	5.98E+10
10:25:00 AM	34571	76	162.899	0.33	0.707	0.05	0.107	0.14	0.300	1	2.143	0.021	0.045	0.001	0.002	8000	7.83E+10
1:30:00 PM	51294	120	381.627	0.63	2.004	0.08	0.254	0.11	0.350	1.2	3.816	0.029	0.092	0	0.000	8800	1.28E+11
3:25:00 PM	50997	330	1043.399	1.4	4.427	0.12	0.379	0.11	0.348	2.4	7.588	0.05	0.158	0	0.000	11200	1.62E+11
5:25:00 PM	52487	130	423.045	1	3.254	0.12	0.391	0.1	0.325	0.8	2.603	0.029	0.094	0	0.000	7800	1.16E+11
7:40:00 PM	58622	120	436.148	0.83	3.017	0.11	0.400	0.08	0.291	2.5	9.086	0.022	0.080	0	0.000	13200	2.19E+11
9:05:00 PM	52492	250	813.626	2	6.509	0.13	0.423	0.09	0.293	1.8	5.858	0.032	0.104	0	0.000	10900	1.62E+11
8:20:00 PM	52713	220	719.005	2	6.536	0.14	0.458	0.09	0.294	3.2	10.458	0.026	0.085	0.001	0.003	13100	1.96E+11
Total:	**437319**		**4222.398896**		**27.69479364**		**2.6190691**		**3.09961002**		**49.6738916**		**0.72608894**		**0.00541161**		**1.31645E+12**

Flow Composite EMC		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
		154.661	1.014	0.096	0.114	1.819	0.027	0.00020	10630.710

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 2, 3	63.33	0.29	0.05	0.17	1.83	0.02	0.0000	20400.0000
	Samples 2, 3, 4	37.33	0.18	0.05	0.15	0.87	0.01	0.0000	15733.3333
	Samples 4, 5, 6	72.00	0.37	0.06	0.14	1.10	0.02	0.0003	7733.3333
	Samples 1, 3, 4	54.67	0.27	0.05	0.18	1.93	0.02	0.0000	19200.0000
3 aliquots over min 3 hours (anytime during storm)	Samples 2, 4, 5	47.33	0.23	0.05	0.16	0.97	0.01	0.0003	7733.3333
	Samples 2, 4, 6	62.00	0.33	0.06	0.15	1.03	0.02	0.0000	8000.0000
	Samples 4, 6, 8	90.00	0.60	0.08	0.13	1.03	0.02	0.0000	7666.6667
	Samples 7, 9, 10	233.33	1.41	0.12	0.09	2.23	0.03	0.0000	11766.6667

Station C-2

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
12:35:00 PM	19802	26	31.921	0.16	0.196	0.04	0.049	0.16	0.196	1.5	1.842	0.035	0.043	0.007	0.009	2.70E+03	1.51E+10
3:50:00 AM	17810	16	17.668	0.18	0.199	0.04	0.044	0.19	0.210	4.6	5.079	0.019	0.021	0.005	0.006	1990	1.00E+10
8:40:00 AM	38232	38	90.075	0.16	0.379	0.03	0.071	0.12	0.284	1.1	2.607	0.022	0.052	0.004	0.009	15000	1.62E+11
12:25:00 PM	37217	46	106.143	0.21	0.485	0.02	0.046	0.08	0.185	1.9	4.384	0.032	0.074	0.005	0.012	4.50E+03	4.74E+10
3:15:00 PM	47975	98	291.496	0.31	0.922	0.03	0.089	0.2	0.595	1.1	3.272	0.033	0.098	0.003	0.009	11000	1.49E+11
5:35:00 PM	38016	38	89.566	0.17	0.401	0.02	0.047	0.07	0.165	1.6	3.771	0.027	0.064	0.004	0.009	7800	8.40E+10
6:55:00 PM	20132	150	187.228	0.24	0.300	0.02	0.025	0.12	0.150	2.4	2.996	0.027	0.034	0.002	0.002	7000	3.99E+10
9:00:00 PM	42202	30	78.496	0.15	0.392	0.03	0.078	0.09	0.235	3.4	8.896	0.02	0.052	0.003	0.008	78000	9.32E+11
11:30:00 PM	65674	16	65.149	0.11	0.448	0.03	0.122	0.1	0.407	0.7	2.850	0.011	0.045	0.002	0.008	12700	2.36E+11
Total:	**327060**		**957.739544**		**3.7217298**		**0.57252474**		**2.42760752**		**35.69774**		**0.48255425**		**0.07197481**		**1.6766E+12**

Flow Composite EMC		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
		46.907	0.182	0.028	0.119	1.748	0.024	0.004	18103.264

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 2, 3	26.667	0.167	0.037	0.157	2.400	0.025	0.005	6563.333
	Samples 2, 3, 4	33.333	0.183	0.030	0.130	2.533	0.024	0.005	7163.333
	Samples 3, 4, 5	60.667	0.227	0.027	0.133	1.367	0.029	0.004	10166.667
3 aliquots over min 3 hours (anytime during storm)	Samples 2, 4, 5	53.333	0.233	0.030	0.157	2.533	0.028	0.004	5830.000
	Samples 4, 5, 6	60.667	0.230	0.023	0.117	1.533	0.031	0.004	7766.667
	Samples 4, 6, 7	78.000	0.207	0.020	0.090	1.967	0.029	0.004	6433.333
	Samples 5, 6, 7	95.333	0.240	0.023	0.130	1.700	0.029	0.003	8600.000

Event 4

Station M-1

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)	Fecal (Number/ 100mL)	Total Counts
6:30:00 AM	6688	1600	663.450	2	0.829	0.01	0.004	0.81	0.336	3.5	1.451	0.14	0.058	0.008	0.003	NA	0.00E+00
9:30:00 PM	10038	600	373.414	0.67	0.417	0.03	0.019	0.15	0.093	1.5	0.934	0.07	0.044	0.003	0.002	NA	0.00E+00
Total:	**16726**		**1036.8632**		**1.246291**		**0.0228172**		**0.42922476**		**2.38483**		**0.10161676**		**0.00518432**		**0**

Flow Composite EMC	**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
	993.002	1.194	0.022	0.411	2.284	0.097	0.005	0.000

Time Weighted Conc.	Not enough aliquots for specific analysis	**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**	**Fecal (Number/ 100mL)**
	Sample 1	1600	2	0.01	0.81	3.5	0.14	0.008	NA
	Sample 2	600	0.67	0.03	0.15	1.5	0.07	0.003	NA
	Samples 1 and 2	1100	1.335	0.02	0.48	2.5	0.105	0.0055	

Station C-2

Time	Incremental Volume (cft)	TSS (mg/L)	Load (lbs)	TP (mg/L)	Load (lbs)	OP (mg/L)	Load (lbs)	Nitrate (mg/L)	Load (lbs)	TKN (mg/L)	Load (lbs)	T Pb (mg/L)	Load (lbs)	D Pb (mg/L)	Load (lbs)
4:50:00 AM	6501	65	26.199	1.4	0.564	0.04	0.016	0.28	0.113	1.4	0.564	0.01	0.004	0.005	0.002
6:00:00 AM	7626	980	463.356	0.69	0.326	0.02	0.009	0.72	0.340	7.1	3.357	0.16	0.076	0.03	0.014
6:30:00 AM	27282	690	1167.124	0.23	0.389	0.07	0.118	0.31	0.524	3	5.074	0.11	0.186	0.002	0.003
7:30:00 AM	13993	120	104.108	0.68	0.590	0.1	0.087	0.29	0.252	1.1	0.954	0.02	0.017	0.006	0.005
8:55:00 PM	29788	400	738.742	0.2	0.369	0.04	0.074	0.21	0.388	1.5	2.770	0.05	0.092	0.004	0.007
12:50:00 AM	13646	24	20.305	0.29	0.245	0.1	0.085	0.19	0.161	ND	0.000	0.014	0.012	0.008	0.007
5:20:00 AM	29658	93	171.008	0.2	0.368	0.05	0.092	0.15	0.276	ND	0.000	0.02	0.037	0.01	0.018
12:30:00 PM	13329	1	0.826	0.16	0.132	0.05	0.041	0.18	0.149	ND	0.000	0.003	0.002	0.002	0.002
10:30:00 PM	13067	62	50.230	0.87	0.705	0.16	0.130	0.06	0.049	ND	0.000	0.017	0.014	0.007	0.006
Total:	**154890**		**2741.8983**		**3.689056**		**0.652103**		**2.2510061**		**12.7203106**		**0.44031036**		**0.06465571**

Flow Composite EMC	**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**
	283.562	0.382	0.067	0.233	1.316	0.046	0.007

Time Weighted Conc.		**TSS (mg/L)**	**TP (mg/L)**	**OP (mg/L)**	**Nitrate (mg/L)**	**TKN (mg/L)**	**T Pb (mg/L)**	**D Pb (mg/L)**
3 aliquots over min 3 hours (start of storm)	Samples 1, 3, 4	291.667	0.770	0.070	0.293	1.833	0.047	0.004
	Samples 1, 2, 4	388.333	0.923	0.053	0.430	3.200	0.063	0.014
	Samples 2, 4, 5	500.000	0.523	0.053	0.407	3.233	0.077	0.013
3 aliquots over min 3 hours (anytime during storm)	Samples 2, 4, 6	374.667	0.553	0.073	0.400	4.100	0.065	0.015
	Samples 3, 5, 6	394.333	0.210	0.053	0.223	2.250	0.060	0.005
	Samples 5, 6, 7	172.333	0.230	0.063	0.183	1.500	0.028	0.007

Appendix B:

Field QA/QC Procedures

Appendix B:

Field Quality Assurance and Control Procedures for Sample Collection, Handling, and Custody

SOP B-1: Field Sample Collection Procedures

SOP B-2: Monitoring Field Data Sheets and Chain of Custody Records

SOP B-3: Transporting, Packaging, and Shipping of Samples from Field to Lab

SOP B-4: Sampling Procedures for Parameters Analyzed in the Field

SOP B-1: Field Sample Collection Procedures

Field crews are responsible for sample collection, recording information, and transferring collected samples.

Prior to sample collection, field crews are to verify that adequate sample collection bottles and sample storage equipment is obtained. Sample collection bottles shall be of adequate size and appropriate material, per requirements of the applicable analytical method. Preserving agents will be added to samples at the laboratory if necessary.

Upon arrival at the site, field crews are to establish a safety zone for sample collection if necessary (this may include the placement of traffic cones, etc.). Site conditions and other sampling notes shall be recorded in a monitoring log and/or on the Monitoring Field Data Sheet.

Procedures for conducting grab sampling and composite sampling are as follows:

<u>Grab Sampling Procedures</u>
Grab sample collection methods are employed for all dry weather, instream water quality monitoring activities and for wet weather instream and stormwater (outfall) monitoring activities for select parameters.

Bottle Preparation:

1. Obtain clean ½ pint, pint, quart, or half gallon sample bottles from the laboratory conducting the water quality analyses. Each monitoring site would require a minimum number of sample bottles such that a separate sample bottle is obtained for each analytical test method to be employed by the laboratory. Bottles are pre-labeled by the laboratory with the site number and monitoring parameter.
2. Based on the number of sampling sites, obtain additional sample bottles for the collection of grab sample duplicates and travel blanks. Bottles for duplicate sampling and travel blanks are also obtained from the laboratory conducting the water quality analyses as required. Based on the number of analytical test methods to be employed, the appropriate number of bottles should be obtained for the collection of duplicate samples and travel blanks at a site. Bottles are pre-labeled with the designated duplicate site number and monitoring parameter.

   Procedures related to the collection of grab sample duplicates and travel blanks are outlined under SOP B-1, QA/QC Procedures.

Grab Sampling Technique:

Depending on the site characteristics, samples can be obtained by hand or with the aid of a grab pole.

1. For sample collection from a (flowing) surface water body, the sample should be collected from the middle of the flow stream (if possible). Care must be taken to avoid collecting particulates that are resuspended as result of bumping the bottle on the streambed. To sample with a hand-held bottle/container, stand downstream of the bottle while it is being filled.
2. If sampling at a surface water outfall, the sample should be collected, if possible, at the point where the flow leaves the pipe.
3. When no sample is collected because of lack of flow or any other circumstances beyond the sampler's control, Not Enough Flow or NEF should be noted in the appropriate entry point on the Monitoring Field Data Sheet.
4. Once the bottle is filled to the proper level, replace the lid on the sample bottle and complete the Monitoring Field Data Sheet with appropriate information related to sample collection (i.e., time, sampling conditions, date, etc).
5. Samples should be stored for transport to the laboratory in an "iced" cooler.
6. If a grab sample duplicate is to be obtained at a particular sampling site, the duplicate samples will be obtained by completing the normal grab sampling procedures and documenting information of the Monitoring Field Data Sheet consistent with collection of an actual sample so that the lab is blind to the collection of duplicate samples.
7. For samples that are collected for the analysis of bacteria, samples must be transported to the lab within 6 hours of sample collection.
8. Ensure all elements of the Monitoring Field Data Sheet are complete prior to relinquishing the samples to the laboratory.

Mercury Sampling Procedures

Mercury sampling will be conducted in accordance with the ultra-clean procedures outlined in EPA Method 1669. An abbreviated summary of EPA Method 1669 with respect to bottle preparation and sampling techniques is as follows. Please note that the complete EPA Method 1669 should be adhered to for the actual sample collection.

Bottle Preparation:

1. Obtain clean ½ pint, pint, quart, or half gallon sample bottles from the laboratory conducting the water quality analyses. The laboratory is responsible for cleaning and preparation of the sample bottles and generating acceptable equipment blanks to demonstrate that the sampling equipment and containers are free from trace metals contamination before shipment. Each monitoring site would require a minimum number of sample bottles such that a separate sample bottle is obtained for each sample, the field blank sample, and the duplicate sample.
2. Obtain a carboy or other appropriate clean container filled with reagent water from the laboratory for use with the collection of field blanks during sampling activities. A minimum of one field blank is required for each site.

Grab Sampling Technique:

1. A minimum two-person sampling team is required for sample collection. One member of the team is designated as the "dirty hands" and one member as the "clean hands". All operations involving contact with the sample bottle and transfer of the sample from the sample collection device to the sample bottle are handled by the "clean hands" team member; preparation of the sampler, operation of any machinery, and all other activities that do not involve direct contact with the sample are performed by the "dirty hands" team member.
2. Sampling personnel are required to wear clean, nontalc gloves at the time of sampling (to be provided by the laboratory). Additionally, an unlined, long sleeved wind suit is required to prevent sample contamination when specifically monitoring for mercury.
3. Mercury samples shall be collected as a single grab sample.
4. The collection of samples should occur in accordance with Section 8.2.5 or 8.2.6 of EPA Method 1669.
5. Samples must be shipped within 24 hours of collection and processed at the analytical laboratory within 48 hours of collection. Samples must be chilled to 4 degrees Celsius in the field and for transport to the laboratory. Preservation agents will be added and filtering will occur at the laboratory

   Procedures related to the collection of mercury sample duplicates and travel blanks are outlined under SOP B-1, QA/QC Procedures.

Composite Sampling Procedures

Composite sample collection methods are employed for wet weather instream and stormwater (outfall) monitoring activities for all parameters (with the exception of bacteria and other specific analytes) as outlined in Table 6 of the Comprehensive Clackamas County Monitoring Plan.

Bottle Preparation:

1. A minimum of three (3), clean half gallon sample bottles will be needed for the collection of individual samples. At the end of the event, the individual samples should be combined into one carboy (i.e., large glass or plastic vessel)., A separate sample bottle is required for each analytical test method to be employed by the laboratory. These sample bottles are pre-labeled with the site number and monitoring parameter. The composited sample from the carboy is then distributed into these additional, clean ½ pint, pint, quart or half gallon sample bottles (a bottle for each analytical parameter) for transfer of samples to the laboratory. All bottles are obtained from the laboratory conducting the water quality analyses.
2. Based on the number of sampling sites, obtain the same number of sample bottles as outlined in Step 1 above for the collection of a composite duplicate sample and travel blank samples. Bottles for duplicate sampling and travel blanks are also obtained from the laboratory conducting the water quality analyses as required.

Procedures related to the collection of composite sample duplicates are outlined under SOP B-1, QA/QC Procedures.

Composite Sampling Technique:

Depending on site conditions, samples can be obtained by hand or with the aid of a grab pole.

Grab sample collection methods, steps 1-5 as documented above should be employed for each of the minimum three individual grab samples to be combined into a composite sample. Composite samples are generally collected at timed intervals and/or on a sampling rotation. Following collection of the minimum three individual grab samples that will comprise the composited sample, the following procedures should be conducted:

1. Pour equal portions from each of the minimum three half gallon bottles representing individual grab samples into the pre-labeled carboy.
2. Properly mix the composited sample and pour a sufficient quantity of water into each pre-labeled sample bottle that is to be relinquished to the lab for analysis.
3. Update the Monitoring Field Data Sheet to document completion of the composite sample collection efforts.

Please note the following:

1. If a composite sample duplicate is to be obtained at a particular sampling site to test the accuracy of the analytical procedures, the duplicate sample will be obtained by completing the normal grab sampling procedures, compositing as indicated above, and transferring the composited sample into the pre-labeled sample collection bottles for the laboratory. The bottles will be pre-labeled as an additional sample with a fictitious site name so that the lab is blind to the duplicate sample.

QA/QC Sampling Procedures

The use of travel blanks and grab and composite sample duplicates will help to identify potential sources of error in the stormwater sampling process, specifically those associated with sample collection, transportation, and analytical procedures.

For grab and composite samples for parameters not including mercury, travel blanks and grab or composite duplicates shall be collected at a minimum of 10% of the total number of monitoring locations for a single event. For example, if samples are to be collected at 10 sites or less for one monitoring event, then one travel blank and one duplicate sample shall be obtained for that monitoring event. If individual grab samples are to be collected at 12 sites for one monitoring event, then two travel blanks and two grab sample duplicates shall be obtained for that monitoring event. A minimum of one travel blank and one duplicate shall be obtained for a single monitoring event.

For mercury samples, a minimum of one travel blank and one duplicate sample is required at each monitoring location for a single event. If more than 10 samples are collected at a single monitoring location, then the number of field blanks and duplicate samples would have to equal 10% of the total number of samples collected. For example, if 10 samples are to be collected at a one monitoring location site for a single monitoring event, then one travel blank and one duplicate shall be obtained for that location.   If 12 samples are to be collected at an individual site for one monitoring event, then two travel blanks and two duplicates shall be obtained.

Guidelines related to the collection of a travel blank and duplicate sample are outlined below:

1. Procedures for collecting the travel blank sample should follow the appropriate grab, composite, or mercury sampling procedures with the exception that the analyte bottle (in the case of grab sample collection) or ½ gallon sample bottles (in the case of composite sample collection) are instead filled with deionized (DI) water as provided by the lab. The travel blanks shall be transported to all sampling sites associated with a monitoring event in the storage containers with other sample bottles. This will assist with identifying any potential contamination that may occur with the collection and transportation of samples.
2. Procedures for collecting the duplicate sample should follow the appropriate grab, composite, or mercury sample procedures. The duplicate sample bottles are pre-labeled, similar to the actual sample bottles to result in unbiased analysis results. These duplicate samples will assist with identifying any potential contamination that may occur with sample collection or analytical procedures.

SOP B-2: Field Data Sheets and Chain of Custody Records

Monitoring Field Data Sheets are completed by staff conducting the monitoring activities and are completed during sample collection activities and maintained with the samples during transport to the water quality laboratory.

A chain of custody record (COC) is a legal document generated based on information contained in the Monitoring Field Data Sheet. The COC is prepared at the laboratory upon delivery of the samples and tracks the transportation of the sample and identifies the person(s) responsible for the sample bottles during all elements of monitoring activity.

Both forms shall be maintained for each sample collected.

The procedures for filling out these forms are as follows:

Prior to and during sample collection

Prior to sample collection activities, field staff shall document the following general information on a Monitoring Field Data Sheet including:

- Source/Location
- Site Code or ID
- Person(s) sampling
- Type of sample (instream dry season, instream wet season, instream storm, or outfall stormwater runoff)
- Date of sample collection
- Time of sample collection
- Number of sample (if applicable). Pertains to collection of multiple individual grab samples to compile as a time-composite sample.
- Parameters desired for analysis.

During sample collection, the Monitoring Field Data Sheet should remain with the sample bottles. During sampling, staff should add to the Monitoring Field Data Sheet for each individual grab sample to document the time and date that the sample was collected.

The Monitoring Field Data Sheets should remain with the samples for the duration of sampling.

After sample collection

If composite sampling methods are being used, the Monitoring Field Data Sheet should be updated to include the time and date with which the sample was composited. If a separate Monitoring Field Data Sheet is completed for the composite sample, any Monitoring Field Data Sheets associated with individual grab samples used to generate the composite sample should be maintained (e.g., stapled to the back) of the composite sample Monitoring Field Data Sheet.

At the Laboratory

The person responsible for completion of the Monitoring Field Data Sheets should be the one to relinquish this paperwork to laboratory personnel or other staff as necessary. At the time of transfer, information contained on the Monitoring Field Data Sheets is entered into the Clackamas Water Environment Services Labworks program or other relevant laboratory tracking database. In addition to information contained on the Monitoring Field Data Sheets, any special instructions and information related to the transfer of responsibility is also documented.

Using the Labworks program, the COC and labels for each individual sample bottle are generated. Labels are placed on the individual sample bottles and the samples are analyzed.

SOP B-3: Transporting, Packaging, and Shipping Samples from Field to Lab

Procedures for handling and transportation of samples to the applicable water quality laboratory are as follows. This process may be expanded upon for the collection of mercury samples per EPA Method 1669.

- Keep the Monitoring Field Data Sheet with the samples at all times.
- Pack samples well within ice chest to prevent breakage or leakage.
- As was stated previously, samples should be packed in ice or an ice substitute to maintain a sample temperature of four degrees Celsius during transport. Acquire more ice as necessary.
- Samples must be delivered to the water quality laboratory within 6 hours (standard for bacteria sample analysis).
- Samples will be preserved by staff or laboratory personnel upon arrival.

SOP B-4: Sampling Procedures for Parameters Analyzed in the Field

Sampling procedures for field parameters (i.e., dissolved oxygen/ temperature, conductivity, and pH) are outlined below.

Field Dissolved Oxygen/ Temperature Procedure

Meter Preparation (Meter: HACH HQ 10)

1. Check the meter and probe for damage.
2. Check and replenish the field supply of DI water.
3. Calibrate DO meter (refer to current manufactures calibration instructions in the appendix). Record calibration in a Calibration Log Book. As necessary, have experienced personnel (i.e., Tri-City Lab Analyst) calibrate DO meter prior to field sampling event.
4. Verify the DO meter temperature reading to a NIST thermometer. The temperature reading should be within ± 0.5°C. Record the temperature verification in a Calibration Log Book.

Analysis Time Line

1. All D.O. samples are obtained in the field.
2. Samples must be obtained in fresh glass or plastic bottles.
3. Sample analysis is performed on-site.

Technique

1. Pre-rinse the beaker bottle with sample water prior to obtaining the actual sample.
2. Collect a 200 ml sample (minimum).
3. Immerse the probe in the sample. The DO probe is not to be moved around in the sample.
4. Record the DO and temperature readings on the Monitoring Field Data Sheet.
5. Remove the probe from the sample and rinse with DI water prior to storage or analysis of the next sample.

QA/QC

1. To verify DO concentrations obtained in the field, the Winkler Titration Method will be employed. A separate grab sample will be collected in a 300 mL BOD bottle, analyzed at the laboratory, and results compared to the instrument analysis from the same location. The two D.O. readings must be within ±0.2 mg/L of each other to have "A" Data Quality Level.
2. In accordance with the rationale outlined in SOP B-1, duplicate samples shall be collected.

3. Monitoring Field Data Sheets are completed during field sample collection and during grab sample collection (for purposes of conducting the Winkler test).
4. The field collection method and the analysis is described in the DEQ Water Quality Monitoring Guidebook, Dissolved Oxygen Protocol, Version 2.0, pages 7-3, 4.

Field pH Procedure

Meter Preparation

1. Set-up the field pH meter(s).
2. Check the meter and probe for damage.
3. Check and replenish the field supply of buffer solution (4 - 7 -10), and DI water.
4. Calibrate pH meter(s) using at least two pH buffers (4-7) and document (refer to current manufactures calibration instructions in the appendix) and be sure to remove the probe's filling solution vent plug before making any pH measurements.

Analysis Time Line

1. All pH samples are obtained in the field as grab samples.
2. Samples must be obtained in fresh glass or plastic bottles.
3. Sample analysis is performed on-site within 15 minutes of grab time.

Technique

1. Remove probe from the field storage solution. (Do not remove probe from storage solution until water sample is ready for analysis)
2. Pre-rinse the sample bottle with sample water prior to obtaining the actual sample.
3. Collect a 500 ml sample (minimum).
4. Thoroughly rinse the probe tip with DI water and put the probe into sample.
5. Once the probe is immersed in the sample, slowly rotate in a circular pattern until the reading stabilizes (30 seconds).
6. Record the pH (to nearest 0.1 units).
7. Enter the pH data on the Monitoring Field Data Sheet.
8. Remove the probe from the sample and rinse with DI water prior to storage or analysis of the next sample.

QA/QC

1. Monitoring Field Data Sheets are completed in the field as the samples are collected.
2. After the completion of each day's sampling, meter calibration(s) must be verified and checked for accuracy. The verified pH readings shall be recorded in the pH Calibration Log Book. The pH readings must be within +/-0.2 S.U. of the calibrated unit to have "A" Data Quality Level. Probes should be cleaned with DI water and stored in the correct probe storage solution for that probe.
3. The field collection method and the analysis is same as described in the DEQ Water Quality Monitoring Guidebook, pH Protocol, Version 2.0, pages 8-3,4.
4. A low ionic strength pH probe and an ATC probe should be used (i.e. pH probe Orion 815600 & ATC probe 917005).

Field Conductivity Procedure

Meter Preparation

1. Set-up the field conductivity meter.
2. Check the meter and probe for damage.
3. Calibrate meter according to current manufacturer's calibration instructions
4. Check and replenish the field supply of DI water.

Analysis Time Line

1. All conductivity samples are obtained in the field as grab samples.
2. Samples must be obtained in fresh glass or plastic bottles.
3. Sample analysis is performed on-site within 15 minutes of grab time.

Technique

1. Pre-rinse the sample bottle with sample water prior to obtaining the actual sample.
2. Collect 200 ml sample (minimum).
3. Ensure that the conductivity meters reading is in conductivity mode.
4. Rinse probe with DI water.
5. Immerse the probe in the sample and do not allow the probe to touch the bottom of the container or any solid object.
6. Enter the conductivity data on the Monitoring Field Data Sheet.
7. Remove the probe from the sample and rinse with DI water prior to storage or the next analysis.

QA/QC

1. Monitoring Field Data Sheets are completed in the field as the samples are collected.
2. After the completion of each day's sampling, meter calibration(s) must be verified and checked for accuracy as shown in the DEQ Water Quality Monitoring Guide book, Conductivity Protocol, Version 2.0, Chapter 9, page 1.
3. Probes should then be cleaned with DI water and stored appropriately.