Comprehensive Clackamas County NPDES MS4 Stormwater Monitoring Plan

September 1, 2012

Updated: June 30, 2013

Comprehensive Clackamas County NPDES MS4 Stormwater Monitoring Plan

Prepared for

Clackamas County
City of Gladstone, Oregon
City of Milwaukie, Oregon
City of Oregon City, Oregon
City of West Linn, Oregon
City of Happy Valley, Oregon
City of Rivergrove, Oregon
Clackamas County Service District #1 (CCSD #1)
Surface Water Management Agency of Clackamas County (SWMACC)

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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 16, 2012.

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 wide ranging variability in stormwater data, collecting and analyzing sufficient data to address the permit's environmental monitoring requirements will require significant resources in order to obtain statistically valid and robust data sets. The Oregon Department of Environmental Quality (DEQ) itself acknowledged this issue and provided the following clause in the 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 establishes an agreement prior to conducting coordinated environmental monitoring."*

Given the effort associated with implementing an effective monitoring program that will adequately address permit requirements and objectives, nine Clackamas County co-permittees agreed to consolidate efforts and prepare one comprehensive stormwater monitoring plan. This coordinated approach was initiated in 2006. See Section 3 for additional background on the process to develop this coordinated approach.

Per the permit requirement (Schedule B.4) 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, Clackamas County Service District #1 (CCSD #1) and the Surface Water Management Agency of Clackamas County (SWMACC). Monitoring conducted by CCSD #1 and SWMACC is conducted on behalf of Clackamas County and the cities of Happy Valley and Rivergrove, and they are included in this monitoring plan as well.

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 2012 Clackamas County 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 and data collection strategies used 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.
Section 6. Parameters, Methods, and Quality Assurance and Control (QA/QC)	Provides a summary of sampling parameters, sampling procedures, and analytical methods including applicable QA/QC.
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 2012 NPDES MS4 permit lists six specific monitoring objectives to be addressed with the stormwater 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 environmental monitoring activities listed in Section 5 includes monitoring question(s) that the activity will answer corresponding to the specific monitoring objectives listed above. The monitoring activities also include a narrative describing how the objectives will be addressed through implementation of each (environmental) monitoring plan component.

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 MS4 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 NPDES MS4 permit. Prior to development of the comprehensive monitoring program, each jurisdiction had been collecting samples independently in conjunction with the locations and frequencies outlined in Tables B-1 of the 2004 NPDES MS4 permit. Given the variability in stormwater data and limited individual monitoring efforts, smaller jurisdictions with more limited environmental monitoring requirements (per Table B-1 of the 2004 NPDES MS4 permit) would not be able to address the monitoring objectives without substantial additional effort, and costs would be beyond the “maximum extent practicable” for those communities.

The 2006 Plan was developed by reviewing each participating co-permittee’s existing monitoring efforts (through annual reports), and all monitoring activities were summarized graphically and in tables. Information compiled included monitoring location, sample collection method, sample collection frequency, waterbody, TMDL/ 303(d) list status, and contributing land use. 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 and activities 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. Observations related to the original (pre-2006 Plan) instream monitoring and stormwater monitoring activities were as follows.

Instream Monitoring:

1. Limited tracking or targeting of storm events was conducted when collecting samples, which created difficulties when trying to evaluate the impact of stormwater runoff on receiving water quality.
2. Inconsistent pollutant parameter lists and analytical methods were being used among participants.
3. Monitoring locations were either too clustered or did not target “high priority” tributaries. High priority tributaries were identified as those on the 303d list (water quality impaired), and/or those with significant development potential upstream.

Stormwater Monitoring:

1. Limited representation of some land use categories.
2. Inconsistent pollutant parameter lists and analytical methods were being used among participants.
3. Some monitoring locations had significant baseflow such that samples collected were not truly representative of stormwater runoff.
4. Sample collection utilized single grab samples that did not represent changing conditions through a storm event.

For the 2006 Plan development, monitoring activities were refined to 1) address the observations listed above, 2) minimize duplication of monitoring efforts, and 3) 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.). Finalized monitoring locations, frequencies, parameters, and monitoring methods were described in the 2006 Plan, along with background related to the process for development of the Plan.

With the issuance of the 2012 NPDES MS4 permit, the original 2006 Plan was reviewed for consistency with the revised monitoring objectives (per the 2012 NPDES MS4 permit). Monitoring activities have been updated in conjunction with the revised Table B-1 (per the 2012 permit). Additional information such as quality assurance procedures has also been added in conjunction with Schedule B.2. This 2012 Plan reflects the results of these reviews and updated efforts.

4. Data Gathering Strategies

As described in Section 3.0, development of the original 2006 Plan applied adaptive management principals in order to refine co-permittees existing, individual monitoring programs and develop a coordinated approach to address the monitoring objectives from the 2004 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 2012 NPDES MS4 permit and revised monitoring objectives and plan requirements, the 2006 Plan has been 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 2012 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, macroinvertebrate data, and geomorphic data (as applicable) in conjunction with Table B-1 of the 2012 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 future decisions related to adaptive management and refinement of both the stormwater management plan and environmental monitoring plan.

With respect to item 1 above, monitoring locations, frequencies, and parameters established in Table B-1 have been reviewed by the co-permittees as providing beneficial information for the City/jurisdiction in order to address the current monitoring objectives. Selection of the monitoring locations and adherence to frequencies and parameters outlined in the 2012 NPDES MS4 permit also reflect data that co-permittees have historically collected so that adequate data will be available to assess trends in the future.

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 an equivalent type of 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 continually conduct this type of research and examine complex stormwater-related issues. 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 support of adaptive management goals. In conjunction with the monitoring objectives and adaptive management approach submitted to DEQ by co-permittees in November 2012, 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 stormwater 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 environmental 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
- pesticide monitoring efforts
- biological monitoring efforts
- geomorphic 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.*

Instream monitoring activities will attempt to address the following questions:

- What is the water quality status of the receiving water body?
- Can water quality trends be determined for the receiving water?
- How is stormwater runoff impacting receiving water quality?

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 2012 Plan include a total of 21 sampling locations representing 18 water bodies. Monitoring locations were originally identified as part of the 2006 Plan development and refined for inclusion in the 2012 Plan.

Monitoring site selection in 2006 prioritized locations with water quality impairment, meaning they 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	pH	Mercury	PCBs	PAHs	DDE/DDT	Dieldrin	Iron	Manganese
TMDLs												
Willamette River (and tributaries) (2006)	■	■				■						
Johnson Creek (2006)	■	■				■			■	■		
Tualatin River (1998/ 2001)	■	■	■	■	■	■						
Additional 303(d) listed streams/Parameters												
Johnson Creek							■	■				
Willamette River (Lower)							■	■	■	■	■	■

Instream monitoring locations were also selected in 2006 based on the length of record of historical data for a particular location and in order to ensure geographic coverage of the participating co-permittees MS4 permit area. Paired instream monitoring locations were identified if possible. Paired monitoring locations include 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. Paired monitoring also helps identify the affects of development on receiving water quality.

Monitoring locations reflected in the 2006 Plan were refined in 2012 based on 1) adjusted monitoring requirements documented in Table B-1 of the 2012 NPDES MS4 permit for select jurisdictions, and 2) improved site accessibility (i.e., the original location was shifted to a more easily accessible location). Figure 1 identifies the instream monitoring locations and identifies the specific waterbody, the responsible jurisdiction, and the type of sampling method employed.

Number	Jurisdiction	Sampling Method	Site Description	Stream Name
1	CCSD #1	Grab and Composite	SE 120th Ave and Carpenter Dr (manhole)	Carli Creek
2	CCSD #1	Grab and Composite	Hwy 212 and SE 135th Ave	Sieben Creek
3	CCSD #1	Grab and Composite	Hwy 212 and SE 142nd Ave	Rock Creek
4	CCSD #1	Grab and Composite	SE 84th Ave and SE Sunnybrook Blvd	Phillips Creek
5	CCSD #1	Grab and Composite	North Clackamas Park	Mt. Scott Creek
6	CCSD #1	Grab and Composite	SE Rusk Rd and SE Aldercrest Ln	Kellogg Creek
7	CCSD #1	Grab and Composite	SE Last Rd	Cow Creek
8	CCSD #1	Grab and Composite	Rowe Middle School (SE Lake Rd)	Kellogg Creek
9	Milwaukie	Grab and Composite	Box Culvert at SE Lake Rd	Minthorn Creek
10	Oregon City	Grab and Composite	Holly Lane Bridge	Abernathy Creek
11	Oregon City	Grab and Composite	SE 17th Street at railroad tressel	Abernathy Creek
12	Oregon City	Grab and Composite	Outfall at Willamette	Coffee Creek
13	Oregon City	Grab and Composite	Behind 13530 Redland Rd	Park Place Creek
14	Oregon City	Grab and Composite	North end of Singer Cr Park	Singer Creek
15	Oregon City	Grab and Composite	7th Street (manhole)	Singer Creek
16	West Linn	Grab and Composite	Imperial Dr	Tanner Creek
17	West Linn	Grab and Composite	Caloroga Rd	Trillium Creek
18	West Linn	Grab and Composite	Johnson Rd at Ryan Ct	Summerlinn Creek
19	Gladstone	Composite	Outfall at Risley Rd	Rinearson Creek
20	SWMACC	Grab and Composite	SW Mossy Brae Rd	Pecan Creek

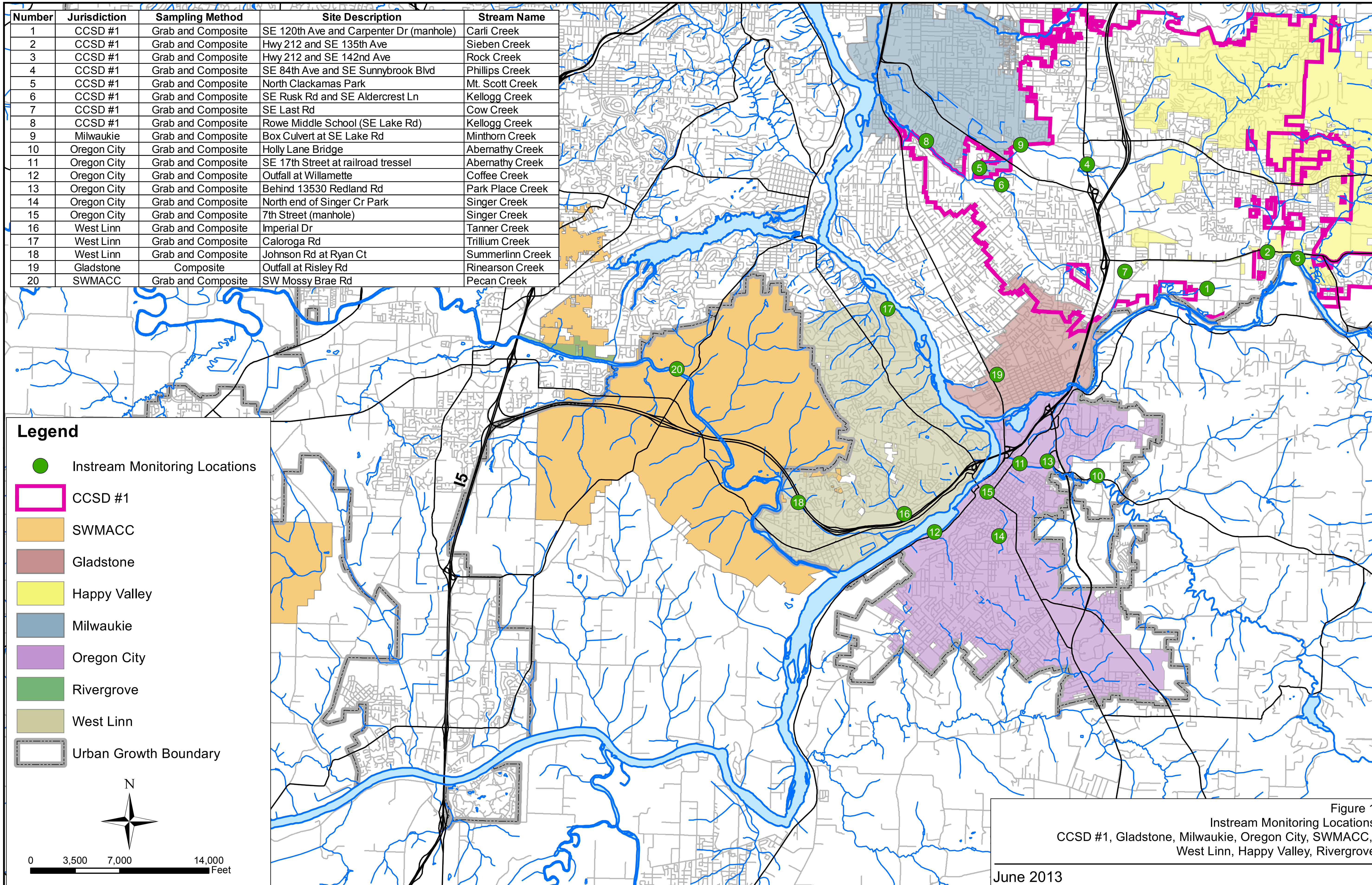


Figure 1
Instream Monitoring Locations
CCSD #1, Gladstone, Milwaukie, Oregon City, SWMACC,
West Linn, Happy Valley, Rivergrove

June 2013

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 and conditions. 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 instream sampling events.

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 127 individual samples (grab or composited) are planned for collection instream per year representing 20 sampling sites across 17 waterbodies. Approximately 53 of those samples are time-composite samples collected during storm events. Note that continuous sampling for field parameters is conducted at one monitoring location.

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 does not 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 2 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. This provision applies to only those parameters that would not otherwise be collected via a single grab sample.

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)[a]	Storm event monitoring (Y/N)
Carli Creek	CCSD #1	1	grabs and composites	9/year	field and lab	Y (3 of 9)
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)
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)
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)

a. The term "Field" indicates samples that are analyzed using meters in the field–typically for temperature, conductivity, DO, 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 sampling events during storms is in parenthesis)
CCSD #1	8	72 (24)
SWMACC	1	9 (3)
Milwaukie	1	4 (2)
Oregon City	6	24 (12)
West Linn	3	15(9)
Gladstone	1	3 (3)
Total	20	127(53)

5.1.3 Additional Instream Monitoring Efforts

Since 2000, the City of Milwaukie has participated in a comprehensive Johnson Creek watershed study with the U.S Geological Survey (USGS) and other partners (Clackamas County, Gresham, Portland, etc.). The study was initiated by USGS in 1998. The project objectives included the following:

1. **Assessment of Hydrologic hazards.** Analysis of real-time flow and water surface elevations will allow for assessment of flooding conditions as a result of ongoing, significant changes in land use and groundwater discharges.

2. **Assessment of Water quality.** Analysis of stream temperature and turbidity data will provide insight into the effects of land-use practices and pollutant sources.
3. **Assessment of the Interaction between surface water and ground water.** The study provides data and analyses that relate directly to the inter-related nature of the surface and groundwater systems.

As part of this ongoing project, multiple technical reports and publications have been developed. Publications are available for public use and include topics such as 1) pesticide contributions and transport, 2) overall system hydrology, and 3) suspended sediment loading and the relationship to turbidity levels.

The City of Milwaukie has a Joint Funding Agreement (JFA) with USGS that was established in 2010 and expires in 2014. The JFA provides funds to USGS (in part) to operate and monitor a continuous flow gage on Johnson Creek (river mile 0.7). This continuous monitoring location was reflected in the 2006 Plan and the 2012 NPDES MS4 Permit. However, due to the variable nature of the funding of this study and the fact that continued participation is unknown after 2014, this monitoring location has not been included in this 2012 Plan.

The City of Milwaukie submitted a letter to apply for a permit modification from DEQ on June 21, 2013, in order to remove the continuous monitoring site on Johnson Creek from Table B-1 of their NPDES MS4 permit. Although the City is requesting removal of this monitoring site from their NPDES MS4 permit obligations, the City intends to continue reporting on data collected from this site during the duration of the Johnson Creek watershed study.

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.

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.*

Stormwater (outfall) monitoring activities will attempt to address the following questions:

- Are there stormwater-related sources of 303(d) pollutants to receiving waters?
- How do stormwater pollutant concentrations vary based on land use?
- Are pollutant loads from stormwater being reduced over time?

The following 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 2012 Plan represent a total of nine sampling locations and four land use categories. As with the instream monitoring locations, stormwater outfall monitoring locations were originally identified as part of the 2006 Plan development and refined for inclusion in the 2012 Plan.

In 2006, stormwater monitoring locations were selected based on the distribution and consistency of the upstream land use type or category (i.e., residential, commercial, industrial, and mixed use). 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 BMPs 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.

Monitoring locations reflected in the 2006 Plan were refined in 2012 based on 1) adjusted monitoring requirements documented in Table B-1 of the 2012 NPDES MS4 permit for select jurisdictions, and 2) improved ability to collect stormwater samples, typically due to site accessibility (i.e., the original location was shifted to a more easily accessible location). Stormwater monitoring locations are shown on Figure 2.

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 discussion in Section 5.1.2 regarding limitations on the commitments for storm event sampling for instream monitoring efforts is also applicable to stormwater monitoring efforts.
7. For each monitored storm event, the contributing storm event rainfall depth will be estimated based on local rainfall gage records. In lieu of storm event rainfall depth estimates, the flow rate in the pipe may be estimated. Flow rate may be estimated using the average depth of flow measurement taken in the pipe (or outfall) during sample collection activities, the pipe (or outfall) slope and diameter, and Manning's equation.

Number	Jurisdiction	Site Description	Receiving Water	Associated Land Use	Sampling Frequency
1	CCSD #1	Outfall #19 at SE Webster Rd	Kellogg Creek	Residential	3 / Year
2	CCSD #1	Outfall #12 at Pheasant Ct	Mt Scott Creek	Mixed Use	3 / Year
3	CCSD #1	Outfall #26 SE Tollbert Rd & SE 94th Ave	Dean Creek	Mixed Use	3 / Year
4	CCSD #1	SE Oregon Trail Dr near SE Sieben Park Way	Sieben Creek	Commercial	3 / Year
5	Milwaukie	Outfall #23003 at Roswell Street	Johnson Creek	Residential	3 / Year
6	Oregon City	Oregon City Shopping Center	Clackamas River	Commercial	3 / Year
7	Oregon City	Clackamette Cove	Clackamas River	Industrial	3 / Year
8	SWMACC	Rivergrove Boat Ramp at SW Dogwood Dr	Tualatin River	Residential	3 / Year
9	West Linn	Summit St & Horton Rd	Willamette River	Residential	3 / Year

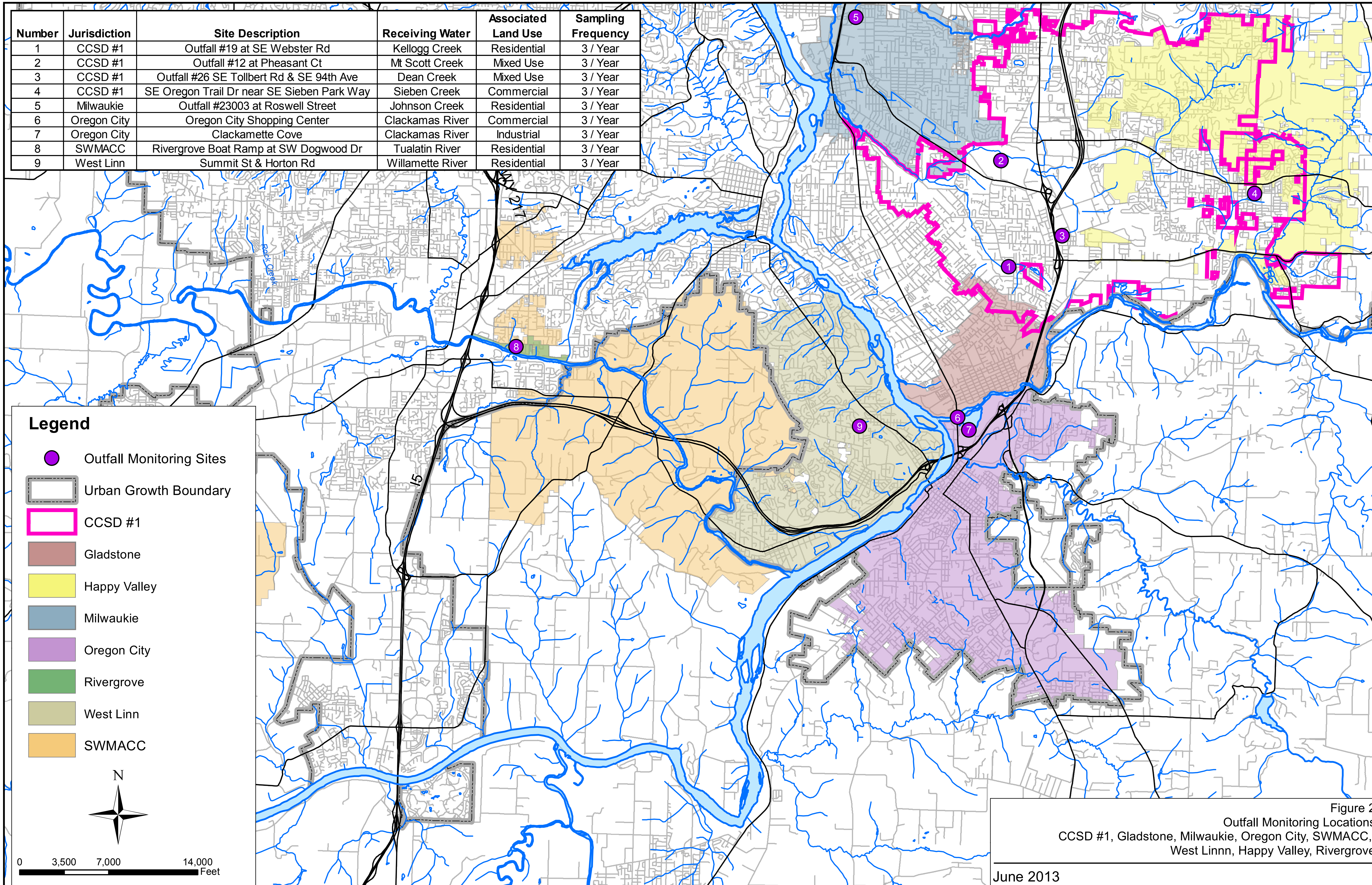


Figure 2
Outfall Monitoring Locations
CCSD #1, Gladstone, Milwaukie, Oregon City, SWMACC,
West Linnn, Happy Valley, Rivergrove

June 2013

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	Receiving water	Responsible party	Sampling frequency	Parameters monitored (field/lab)
Residential	Outfall #19– SE Webster Road	Kellogg Creek	CCSD #1	3/year	field and lab
Mixed use (industrial, highway, commercial, residential)	Outfall #12– SE Pheasant Court	Mt. Scott Creek	CCSD #1	3/year	field and lab
Mixed use (industrial, school, commercial, residential)	Outfall #26– SE Tolbert Road and 94th Avenue	Dean Creek (tributary to Mt. Scott Creek)	CCSD #1	3/year	field and lab
Commercial	SE Oregon Trail Drive near SE Sieben Park Way	Unnamed tributary to Sieben Creek	CCSD #1	3/year	field and lab
Residential	Outfall #23003 at Roswell Street	Johnson Creek	Milwaukie	3/year	field and lab
Commercial	Oregon City Shopping Center	Clackamas River	Oregon City	3/year	field and lab
Industrial	Clackamette Cove	Clackamas River	Oregon City	3/year	field and lab
Residential	Rivergrove Boat Ramp at SW Dogwood Drive	Tualatin River	SWMACC	3/year	field and lab
Residential	Summit Street and Horton Road	Willamette River	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
Total	9	27

5.2.3 Additional Outfall Monitoring Efforts

Stormwater mercury monitoring is required for CCSD #1 (which includes Clackamas County and the city of Happy Valley) and SWMACC (which includes the city of Rivergrove) and the cities of West Linn, Oregon City, and Milwaukie per guidelines outlined in Table B-1 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 jurisdiction is responsible for sample collection from one location.

3. Each jurisdiction is required to collect two storm events per year (at their selected monitoring location). One storm event must be 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. Per Table B-1, jurisdictions are grouped according to whether sample collection must occur during the 2012/2013 monitoring year (October 1, 2012 to September 30, 2013) or the 2013/2014 monitoring year (October 1, 2013 to September 30, 2014). Four jurisdictions (Lake Oswego, Milwaukie, Oregon City, and West Linn) are scheduled to sample during 2012/2013 monitoring year, and four jurisdictions (CCSD #1, Oak Lodge, SWMACC, and Wilsonville) are scheduled to sample during the 2013/2014 monitoring year.

As a result of the required coordination that is reflected in the Clackamas NPDES MS4 permit language (Table B-1), CCSD #1, SWMACC and the cities of West Linn, Oregon City, and Milwaukie, along with Oak Lodge Sanitary District and 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 jurisdiction identified a stormwater mercury monitoring location that considers upstream land use characteristics. For participants in the 2012 Plan, 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.

Table 6. Comprehensive Clackamas County Monitoring Plan–Stormwater Mercury Monitoring

Monitoring year	Upstream land use	Outfall description	Receiving water	Responsible party	Sampling frequency	Parameter
2012/2013	Residential	Outfall #23003 at Roswell Street	Johnson Creek	Milwaukie	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2012/2013	Industrial	Clackamette Cove	Clackamas River	Oregon City	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2012/2013	Commercial	Lake Grove Avenue at Reese Road	Oswego Lake	Lake Oswego	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2012/2013	Residential	Summit Street and Horton Road	Willamette River	West Linn	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2013/2014	Residential	Rivergrove Boat Ramp at SW Dogwood Drive	Tualatin River	SWMACC	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2013/2014	Commercial	SE Oregon Trail Drive near SE Sieben Park Way	Unnamed tributary to Sieben Creek	CCSD #1	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2013/2014	Mixed Use	Inlet to the Library Detection Pond	Boeckman Creek	Wilsonville	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS
2013/2014	Commercial	Manhole at Naef Road, 500 feet upstream from outfall	Boardman Creek	Oak Lodge Sanitary District	2/year	Total/dissolved mercury and methyl mercury, field parameters, and TSS

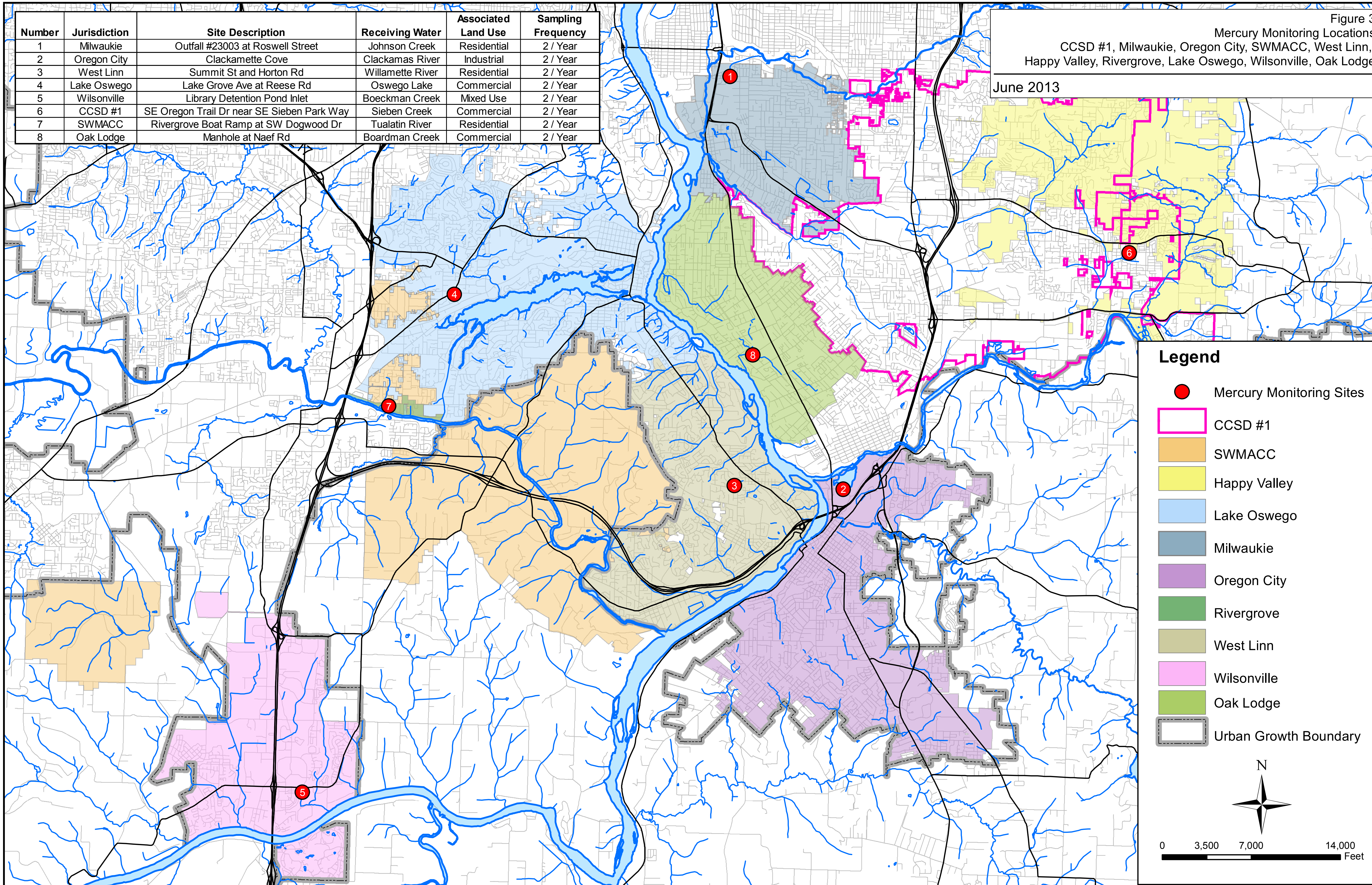
Jurisdictions required to sample during each applicable monitoring year will coordinate to ensure continuity and consistency in sample collection activities. A jurisdictional point of contact will be established prior to the start of sample collection activities. QA/QC protocols defined in EPA Method 1669 and confirmed with DEQ staff will be adhered to during sample collection activities (i.e., the specified number of field blank and duplicate samples required).

Staff attended 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.

Number	Jurisdiction	Site Description	Receiving Water	Associated Land Use	Sampling Frequency
1	Milwaukie	Outfall #23003 at Roswell Street	Johnson Creek	Residential	2 / Year
2	Oregon City	Clackamette Cove	Clackamas River	Industrial	2 / Year
3	West Linn	Summit St and Horton Rd	Willamette River	Residential	2 / Year
4	Lake Oswego	Lake Grove Ave at Reese Rd	Oswego Lake	Commercial	2 / Year
5	Wilsonville	Library Detention Pond Inlet	Boeckman Creek	Mixed Use	2 / Year
6	CCSD #1	SE Oregon Trail Dr near SE Sieben Park Way	Sieben Creek	Commercial	2 / Year
7	SWMACC	Rivergrove Boat Ramp at SW Dogwood Dr	Tualatin River	Residential	2 / Year
8	Oak Lodge	Manhole at Naef Rd	Boardman Creek	Commercial	2 / Year

Figure 3
Mercury Monitoring Locations
CCSD #1, Milwaukie, Oregon City, SWMACC, West Linn, Happy Valley, Rivergrove, Lake Oswego, Wilsonville, Oak Lodge

June 2013



5.3 Pesticide Monitoring Efforts

The 2012 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.

Pesticide monitoring throughout the Clackamas MS4 permit area will be conducted during the 2012—2017 NPDES MS4 permit term to address NPDES MS4 objective 5 from Schedule B.1.a.

5. *Assess the chemical, biological, and physical effects of MS4 stormwater discharges on receiving waters.*

Pesticide monitoring activities will attempt to address the following questions:

- Are pesticides present in stormwater runoff or receiving waters within the Clackamas MS4 NPDES permit area?
- Are pyrethroids and other current-use pesticides present in streambed sediment or sediment accumulated from the storm system?

The following describes the coordinated pesticide monitoring approach (Section 5.3.1), pesticide monitoring site selection (Section 5.3.2), and summarizes sample collection processes and methods (Section 5.3.3).

5.3.1 Pesticide Monitoring Approach

In 2008, Clackamas County co-permittees (including those participating in the Comprehensive Clackamas County Monitoring Plan) initiated discussions with the USGS to conduct a coordinated, joint pesticide monitoring study. The study would provide a baseline characterization of pesticides in stormwater, receiving waters, and bed sediment within Clackamas County. Efforts would build on past USGS pesticide monitoring efforts that were focused on the Clackamas River and Johnson Creek watersheds.

With receipt of the 2012 NPDES MS4 permit, Clackamas County co-permittees revisited discussions with USGS and refined the 2008 proposal to address specific conditions of the reissued permit. The revised study includes collection of water and sediment from stormwater outfalls and natural stream channels for analysis of 90–120 pesticide compounds including insecticides, herbicides, fungicides, and select degredates. Most compounds will be analyzed in both water and sediment.

Selection of pesticides for analysis was determined by the Clackamas co-permittees with input from USGS. Table B-1 of the NPDES MS4 permit requires consideration of 16 pesticides in the coordinated study, along with any pesticides currently used by the co-permittee. As part of this collective monitoring effort, Clackamas co-permittees documented current pesticide use for consideration in the study. This list can be provided on request.

Selection of pesticides for inclusion in the study was ultimately determined based on use of the USGS Pesticide Fate Research Laboratory in Sacramento, California, which specializes in “current use” pesticides and uses methods to achieve ultra-low detention limits. The suite of compounds analyzed by this laboratory includes 6 of the 7 insecticides listed in the permit, plus 35 additional insecticides. The laboratory suite of compounds also includes 2 of the 6 herbicides and all three of the fungicides included in the permit, along with 35 additional herbicides, three herbicide degredates, and 35 additional fungicides.

Rationale for the selection of pesticides for inclusion in this study is documented in the USGS proposal, which is provided as Appendix C. In summary, the selected pesticide schedule focuses on compounds that have not been well characterized as of yet and targets those current-use pesticides that may be regulated or controlled in the future. A comprehensive list of pesticides to be included in the study is also listed in the proposal (Appendix C).

5.3.2 Description of Pesticide Monitoring Locations

A total of three workshops were held with participating Clackamas co-permittees in order to select appropriate monitoring sites for the instream, bed sediment, stormwater runoff, and stormwater sediment sampling effort.

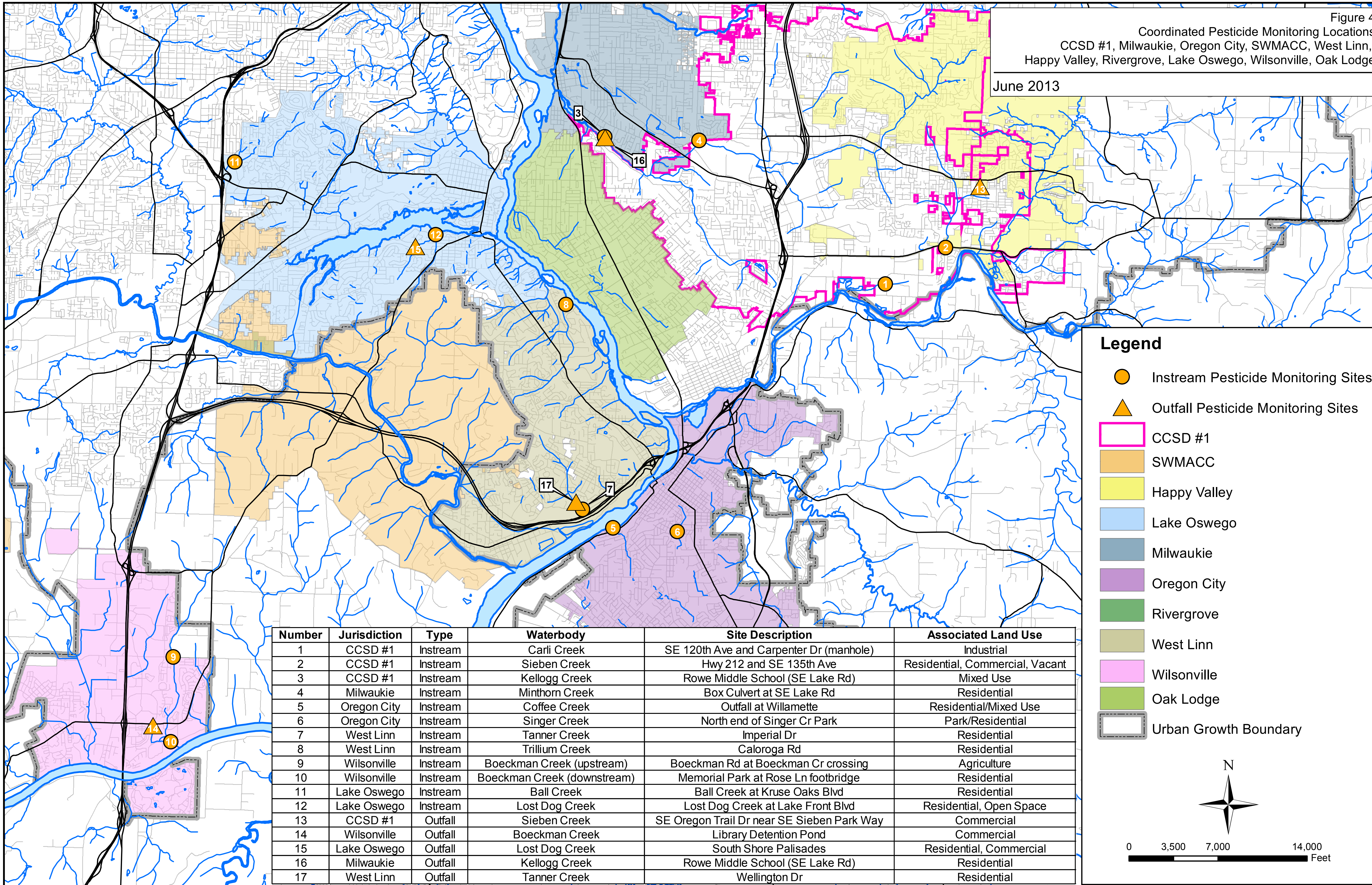
Based on the finalized proposal from USGS, a total of 12 instream monitoring locations needed to be identified. Each instream location would also have streambed sediment samples collected. A total of five stormwater outfall monitoring locations also needed to be identified. Three of the five stormwater outfall locations would include stainless steel sediment traps (i.e., SIFT device) installed for collection and analysis of stormwater sediment.

Maps were developed of each participating co-permittee's current instream, stormwater, and macroinvertebrate (if applicable) monitoring locations, in order to facilitate site selection. To the extent possible, site selection targeted existing instream or stormwater monitoring locations with known accessibility. Site selection (particularly for the instream locations) targeted locations where historic or future biological (macroinvertebrate) sampling would occur, in order to relate pesticide occurrence to the quality of benthic invertebrate assemblages.

General criteria used to evaluate instream and stormwater monitoring locations was as follows:

- Instream Site Selection Criteria
  - Represents an existing instream water quality monitoring location.
  - Represents a historic or future macroinvertebrate monitoring location.
  - Easy accessibility.
  - Comprised of consistent drainage (flow either originates entirely within the jurisdiction or outside of the jurisdiction).
  - Contains a single representative upstream contributing land use.
- Stormwater (Outfall) Site Selection Criteria
  - Location is correlated with a proposed instream pesticide monitoring location.
  - Easy accessibility. For locations where stormwater sediment monitoring is proposed, the location must be secure with limited potential for outside interference with the SIFT device.
  - Contains a representative upstream contributing land use.

During the three workshops, each co-permittee evaluated their own monitoring sites based on the above criteria. Sites were prioritized as Tier 1 (highest priority) and Tier 2 (lower priority). The goal of the pesticide monitoring effort is to collect representative data and not have a sampling site necessarily in each participating jurisdiction. The selected pesticide monitoring locations are provided in Table 7 and shown graphically in Figure 4.



Number	Jurisdiction	Type	Waterbody	Site Description	Associated Land Use
1	CCSD #1	Instream	Carli Creek	SE 120th Ave and Carpenter Dr (manhole)	Industrial
2	CCSD #1	Instream	Sieben Creek	Hwy 212 and SE 135th Ave	Residential, Commercial, Vacant
3	CCSD #1	Instream	Kellogg Creek	Rowe Middle School (SE Lake Rd)	Mixed Use
4	Milwaukie	Instream	Minthorn Creek	Box Culvert at SE Lake Rd	Residential
5	Oregon City	Instream	Coffee Creek	Outfall at Willamette	Residential/Mixed Use
6	Oregon City	Instream	Singer Creek	North end of Singer Cr Park	Park/Residential
7	West Linn	Instream	Tanner Creek	Imperial Dr	Residential
8	West Linn	Instream	Trillium Creek	Caloroga Rd	Residential
9	Wilsonville	Instream	Boeckman Creek (upstream)	Boeckman Rd at Boeckman Cr crossing	Agriculture
10	Wilsonville	Instream	Boeckman Creek (downstream)	Memorial Park at Rose Ln footbridge	Residential
11	Lake Oswego	Instream	Ball Creek	Ball Creek at Kruse Oaks Blvd	Residential
12	Lake Oswego	Instream	Lost Dog Creek	Lost Dog Creek at Lake Front Blvd	Residential, Open Space
13	CCSD #1	Outfall	Sieben Creek	SE Oregon Trail Dr near SE Sieben Park Way	Commercial
14	Wilsonville	Outfall	Boeckman Creek	Library Detention Pond	Commercial
15	Lake Oswego	Outfall	Lost Dog Creek	South Shore Palisades	Residential, Commercial
16	Milwaukie	Outfall	Kellogg Creek	Rowe Middle School (SE Lake Rd)	Residential
17	West Linn	Outfall	Tanner Creek	Wellington Dr	Residential

Table 7. Comprehensive Clackamas County Monitoring Plan–Pesticide Monitoring							
Type (instream/ outfall)	Upstream contributing land use	Site description	Receiving water	Jurisdiction	Existing water quality monitoring location?	Macroinvertebrate monitoring location?	Notes
Instream	Mixed use	Rowe Middle School	Kellogg Creek	CCSD #1	Y	Y (historic, future)	Associated with Milwaukie pesticide outfall monitoring location
Instream	Industrial	SE 120th Ave	Carli Creek	CCSD#1	Y	Y (historic, future)	
Instream	Residential/ commercial/ vacant	At Hwy 212 and SE 135th	Sieben Creek	CCSD #1	Y	Y (historic, future)	Associated with CCSD #1 pesticide outfall monitoring location
Instream	Residential	Rose Ln footbridge at Memorial Park	Boeckman Creek	Wilsonville	Y	Y (historic, future)	Associated with Wilsonville pesticide outfall monitoring location
Instream	Agriculture (outside City boundary)	Boeckman Rd crossing	Boeckman Creek	Wilsonville	Y	N	Upstream Boeckman Creek site (for paired analysis).
Instream	Residential, commercial	Kruse Oaks Blvd.	Ball Creek	Lake Oswego	Y	Y (historic, future)	
Instream	Residential, Open space (golf course)	Lake Front Blvd.	Lost Dog Creek	Lake Oswego	Y	Y (historic, future)	Associated with Lake Oswego pesticide outfall monitoring location
Instream	Residential	SE Lake Rd.	Minthorn Creek	Milwaukie	Y	Y (future)	
Instream	Residential, open space	Singer Creek Park	Singer Creek	Oregon City	Y	Y (future)	
Instream	Residential, mixed use	Outfall to Willamette	Coffee Creek	Oregon City	Y	Y (future)	
Instream	Residential	Imperial Dr.	Tanner Creek	West Linn	Y	Y (future)	
Instream	Residential	Caloroga Rd	Trillium Creek	West Linn	Y	Y (future)	Associated with West Linn pesticide outfall monitoring location
Outfall	Commercial	SE Oregon Trail Dr. near SE Sieben Park Way	Sieben Creek	CCSD #1	Y	NA	
Outfall	Mixed use	Library Detention Pond inlet	Boeckman Creek	Wilsonville	Y	NA	Also a sediment sampling location
Outfall	Residential, commercial	S Shore Palisades	Lost Dog Creek	Lake Oswego	Y	NA	
Outfall	Residential, mixed use	Rowe Middle School	Kellogg Creek	Milwaukie	N	NA	Also a sediment sampling location
Outfall	Residential	Wellington Dr.	Tanner Creek	West Linn	N	NA	Also a sediment sampling location

5.3.3 Sample Collection Process and Methods

Pesticide monitoring efforts are targeted for the summer and fall of 2013.

Instream and stream bed sediment samples will be collected at the 12 instream monitoring locations defined in Table 7. Sample collection will occur from July to September 2013 using standard USGS techniques. Stormwater outfall sampling will occur at the five outfall monitoring locations defined in Table 7. Stormwater monitoring will target a significant flushing event in October or November 2013. Grab sampling techniques will be used to collect the water samples.

Stormwater sediment sampling will be conducted at specified stormwater outfalls using stainless steel sediment traps (SIFT samplers), developed by the City of Portland. SIFT samplers will be deployed in three stormwater outfalls for a one month period, including the significant flushing event targeted for stormwater sampling. Staff from City of Portland will deploy the SIFT samplers on behalf of the project.

Data analyses will include site characterization efforts using GIS and comparisons with existing information on benthic invertebrate assemblage quality. Results of the pesticide monitoring effort and analysis will be provided in an interpretive report that describes data collection, results, evaluation of potential sources, and implications.

Detail related to the pesticide monitoring approach is contained in the USGS proposal (Appendix C).

5.4 Biological Monitoring Efforts

Biological monitoring throughout the Clackamas MS4 permit area will be conducted during the 2012—2017 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 will attempt to address the following questions:

- What are the biologic conditions of receiving waters?
- Based on historic macroinvertebrate sampling efforts (as applicable), are there noticeable trends of improvement or impairment in receiving waters?

The following describes the macroinvertebrate monitoring site selection (Section 5.4.1) and sample collection processes and methods (Section 5.4.2).

5.4.1 Description of Biological Monitoring Locations

Biological monitoring requirements listed in the 2012 NPDES MS4 permit vary for participants of the CCCSMP. CCSD #1 (which includes Clackamas County and the city of Happy Valley) and SWMACC (which includes the city of Rivergrove) are required to conduct instream biological monitoring in conjunction with the number of monitoring locations and frequencies identified in Table B-1. The cities of Gladstone, West Linn, Milwaukie, and Oregon City are required to conduct or contribute to an instream biological monitoring project/task.

CCSD #1/ SWMACC

For CCSD #1 and SWMACC, Table B-1 specifies that a total of nine biological monitoring sites (eight for CCSD #1 and one for SWMACC) must be monitored once over the permit term. Biological monitoring locations were selected by CCSD#1 as part of a comprehensive, watershed-based, clustered monitoring approach that was initiated in 2010. Historically, Clackamas County Water Environment Services oversees a variety of monitoring activities to address various permit conditions and program implementation needs. Such monitoring includes macroinvertebrate/ biological monitoring, physical habitat monitoring, geomorphic monitoring and water quality monitoring. Specific for biological monitoring, CCSD #1 and SWMACC conducted sampling in 2002 and continued in 2007, 2008, 2009, and 2011 at a variety of locations.

Clackamas County WES began working on a clustered monitoring approach, consolidating locations and expanding select monitoring efforts, to allow for a more comprehensive assessment of watershed conditions as a whole. Historic monitoring locations were mapped and evaluated internally. Sites for ongoing macroinvertebrate monitoring reported for this plan were selected based on 1) the physical condition of the stream and ability to collect macroinvertebrate samples in accordance with defined protocols; 2) locations where existing instream water quality and geomorphic monitoring efforts are being conducted (in order to help evaluate overall stream health); and 3) historical macroinvertebrate sampling data.

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

For the cities of Gladstone, Milwaukie, Oregon City, and West Linn, biological monitoring has not historically been conducted, and the number of monitoring sites and frequency of monitoring is not specified in the permit.

For this plan, these jurisdictions identified their biologic monitoring locations in conjunction with the site selection methodology employed for pesticide monitoring, as one of the goals of the pesticide monitoring effort is to relate pesticide occurrence to the quality of benthic invertebrate assemblages. Therefore, macroinvertebrate monitoring was proposed for each instream pesticide monitoring location. For the City of Gladstone, who does not have a city-specific pesticide monitoring location, the identified macroinvertebrate monitoring site is located at the City's current instream monitoring site.

Selection of biologic monitoring locations in conjunction with objectives of the pesticide monitoring study allows collected data to be used for a variety of purposes. Sites also have ongoing instream water quality monitoring, which further supports drawing correlations and conclusions as part of the overall monitoring program. This effort is the first biological monitoring effort employed by the cities of Gladstone, Milwaukie, West Linn, and Oregon City.

The selected macroinvertebrate monitoring locations are provided in Table 8 and shown graphically in Figure 5.

Table 8. Comprehensive Clackamas County Monitoring Plan–Biologic Monitoring

Jurisdiction	Target monitoring date	Site description	Receiving water	Past biologic monitoring efforts?	Existing water quality monitoring location?	Pesticide monitoring location?
CCSD #1	2015	Rowe Middle School	Kellogg Creek	Y (2009, 2011)	Y	Y
CCSD #1	2015	11814 Jennifer Street	Carli Creek	Y (2007, 2009, 2011)	Y[a]	Y
CCSD #1	2015	At Hwy 212 and SE 135th	Sieben Creek	Y (2007, 2009, 2011)	Y	Y
CCSD #1	2015	SE Troge Road and SE Foster Road	Rock Creek	Y (2007, 2009, 2011)	N	N
CCSD #1	2015	SE Rusk Road and SE Aldercrest Lane	Kellogg Creek	Y (2007, 2009, 2011	Y	N
CCSD #1	2015	North Clackamas Park	Mt Scott Creek	Y (2007, 2009, 2011)	Y	N
CCSD #1	2015	Hwy 212 and SE 142nd Avenue, upstream of confluence with Trillium Creek	Rock Creek	Y (2007, 2009, 2011)	Y	N
CCSD #1	2015	Downstream of SE Dean Drive	Cow Creek	Y (2007, 2009, 2011)	N	N
SWMACC	2015	SW Mossy Brae Road	Pecan Creek	Y (2007, 2009, 2011)	Y	N
Gladstone	Fall 2013	Risley Road	Rinearson Creek	N	Y	N

Table 8. Comprehensive Clackamas County Monitoring Plan–Biologic Monitoring						
Jurisdiction	Target monitoring date	Site description	Receiving water	Past biologic monitoring efforts?	Existing water quality monitoring location?	Pesticide monitoring location?
Milwaukie	Fall 2013	SE Lake Road	Minthorn Creek	N	Y	Y
Oregon City	Fall 2013	Singer Creek Park	Singer Creek	N	Y	Y
Oregon City	Fall 2013	Outfall to Willamette	Coffee Creek	N	Y	Y
West Linn	Fall 2013	Imperial Drive	Tanner Creek	N	Y	Y
West Linn	Fall 2013	Caloroga Road	Trillium Creek	N	Y	Y

a. The Carli Creek biologic monitoring location corresponds to the CCSD #1 instream monitoring location at SE 120th Avenue and Carpenter Drive. This biologic monitoring site description is consistent with the historic biologic monitoring reports.

5.4.2 Sample Collection Process and Methods

All jurisdictions are proposing to contract out the macroinvertebrate sampling and associated physical habitat, riparian assessment, and water chemistry sampling that accompanies the sampling. Historically, CCSD #1 and SWMACC have used ABR Environmental (now Cole Environmental) for conducting their biologic and physical habitat monitoring. The cities of Gladstone, Milwaukie, West Linn, and Oregon City are contracting with Cole Environmental for their sampling effort in the fall 2013.

Sampling efforts are typically targeted for summer or early fall, low-flow conditions.

Sample collection processes and methods described below are referenced in the Clackamas County CCSD #1 Aquatic Resource Study, 2011. Consistent methodology is proposed for future CCSD #1 and SWMACC efforts and for the fall 2013 study for the cities of Gladstone, Oregon City, Milwaukie, and West Linn.

Instream physical habitat and riparian assessment efforts will utilize the modified Rapid Assessment Technique (RSAT), which includes data collection from channel habitat units (a sample reach equal to 20 times the wetted width or 75 meters, whichever is greater), channel cross sections, and the adjacent riparian zone. Habitat surveys include measurement or visual estimation of the number, length, gradient, and depth of pools and riffles instream; the percent of eroding or downcutting banks; woody debris characteristics; and substrate characteristics. Riparian assessment efforts include identification of riparian plant community type and percent vegetative cover present in the riparian area.

Water temperature, dissolved oxygen, and specific conductivity will be measured at each site. Standard operating procedures and calibration procedures shall be provided to participating jurisdictions by the contractor prior to field sampling efforts.

Macroinvertebrate community sampling will be conducted using the Benthic Macroinvertebrate Sampling Protocol for Wadeable Rivers and Streams (DEQ 2003). Samples are sorted and identified to the level of taxonomic resolution recommended for Level 3 macroinvertebrate assessments. Level 3 protocols include duplicate composite sampling for quality assurance. Both glide and riffle samples are assessed using a multimetric analysis and using a predictive model.

Sample collection processes and methods described above are based on the previous assessment effort conducted CCSD #1 (in 2011). At the time of sampling to fulfill requirements of this plan, sampling methods may be slightly adjusted to conform to new technology. Such changes will be documented by the contractor prior to sampling and in a final assessment report at the conclusion of the monitoring event.

Number	Jurisdiction	Site Description	Stream Name
1	CCSD #1	Downstream of 11818 Jennifer St	Carli Creek
2	CCSD #1	Hwy 212 and SE 135th Ave	Sieben Creek
3	CCSD #1	SE Troge Rd at Se Foster Rd	Rock Creek
4	CCSD #1	SE Rusk Rd and SE Aldercrest Ln	Kellogg Creek
5	CCSD #1	North Clackamas Park	Mt. Scott Creek
6	CCSD #1	Hwy 212 and SE 142nd Ave	Rock Creek
7	CCSD #1	Downstream of SE Dean Dr	Cow Creek
8	CCSD #1	Rowe Middle School (SE Lake Rd)	Kellogg Creek
9	SWMACC	SW Mossy Brae Rd	Pecan Creek
10	Milwaukie	Box Culvert at SE Lake Rd	Minthorn Creek
11	Oregon City	Singer Creek at Singer Creek Park	Singer Creek
12	Oregon City	Coffee Creek to Willamette	Coffee Creek
13	Gladstone	Outfall at Risley Rd	Rinearson Creek
14	West Linn	Imperial Drive	Tanner Creek
15	West Linn	Caloroga Rd	Trillium Creek

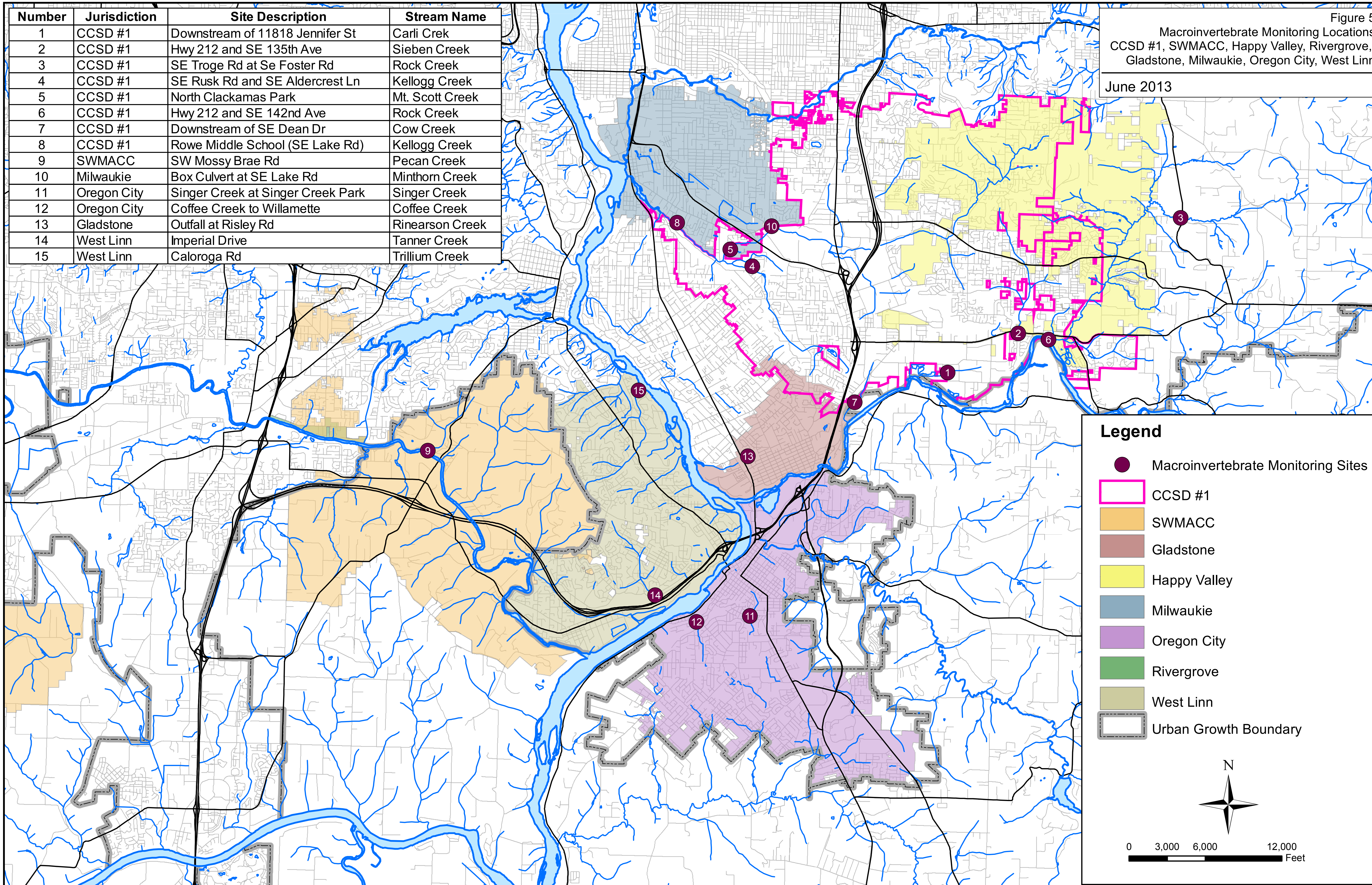


Figure 5
Macroinvertebrate Monitoring Locations
CCSD #1, SWMACC, Happy Valley, Rivergrove, Gladstone, Milwaukie, Oregon City, West Linn

June 2013

5.5 Geomorphic Monitoring Efforts

Geomorphic monitoring will be conducted during the 2012 - 2017 NPDES MS4 permit term by CCSD #1 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.*

Geomorphic monitoring activities will attempt to address the following questions:

- Are channels incising or widening when compared to previous geomorphic monitoring efforts?
- Are there observed effects of urbanization on receiving waters?

The following describes the geomorphic monitoring site selection (Section 5.5.1) and sample collection processes and methods (Section 5.5.2).

5.5.1 Description of Geomorphic Monitoring Locations

Geomorphic monitoring activities are required for CCSD #1 (which includes Clackamas County and the city of Happy Valley) in accordance with Table B-1 in the permit. Per Table B-1, a total of seven sites must be monitored once over the permit term.

Clackamas County CCSD #1 initiated geomorphic monitoring in 2009. Sites were originally selected based on the potential for increased development within the watershed and where field observations identified potential bank erosion and channel modification activities. In 2010, geomorphic monitoring sites were updated based on the comprehensive, watershed-based, clustered monitoring (see Section 5.4.1). Historically, Clackamas County Water Environment Services oversees a variety of monitoring activities to address multiple permit conditions and program implementation needs. Such monitoring includes macroinvertebrate/ biological monitoring, physical habitat monitoring, geomorphic monitoring, water quality monitoring. The clustered monitoring approach, which consolidated locations and expanded select monitoring efforts, allows for a more comprehensive assessment of watershed conditions as a whole.

As part of the clustered monitoring approach, geomorphic monitoring locations were refined to reflect those locations where 1) existing instream water quality and macroinvertebrate monitoring efforts are being conducted (in order to help evaluate overall stream health) and 2) where historical geomorphic monitoring activities were conducted.

The selected geomorphic monitoring locations are provided in Table 9 and shown graphically in Figure 6.

Table 9. Comprehensive Clackamas County Monitoring Plan–Geomorphic Monitoring						
Jurisdiction	Target monitoring date	Site description	Receiving water	Past geomorphic monitoring efforts?	Existing water quality monitoring location?	2015 biologic monitoring location?
CCSD #1	2015	Rowe Middle School	Kellogg Creek	Y (2009, 2011)	Y	Y
CCSD #1	2015	Three Creeks Restoration site, west of SE 82nd Avenue and SE Sunnybrook Boulevard	Mt. Scott Creek	Y (2009, 2011)	N	N
CCSD #1	2015	At Hwy 212 and SE 135th	Sieben Creek	Y (2009, 2011)	Y	Y
CCSD #1	2015	Tributary to lower Rock Creek off SE 172nd Ave	Rock Creek	Y (2009, 2011)	N	N
CCSD #1	2015	Downstream of SE 172nd Avenue, and SE Troge Road	Rock Creek	Y (2009, 2011)	N	N
CCSD #1	2015	Tributary to upper Rock Creek at SE Hemrick Road	Rock Creek	Y (2009, 2011)	N	N
CCSD #1	2015	Hwy 212 and SE 142nd Avenue, upstream of confluence with Trillium Creek	Rock Creek	Y (2009, 2011)	Y	Y

5.5.2 Sample Collection Process and Methods

With urbanization and increased development along the stream corridor, the timing and magnitude of discharge to stream channels often results in changes to the geomorphic character of the channel. This change is referred to as hydromodification and can be observed through changes to stream channel width and depth. The objective of geomorphic monitoring is to establish a baseline with which to compare against future monitoring efforts (Clackamas County CCSD #1 Aquatic Resource Study, 2011).

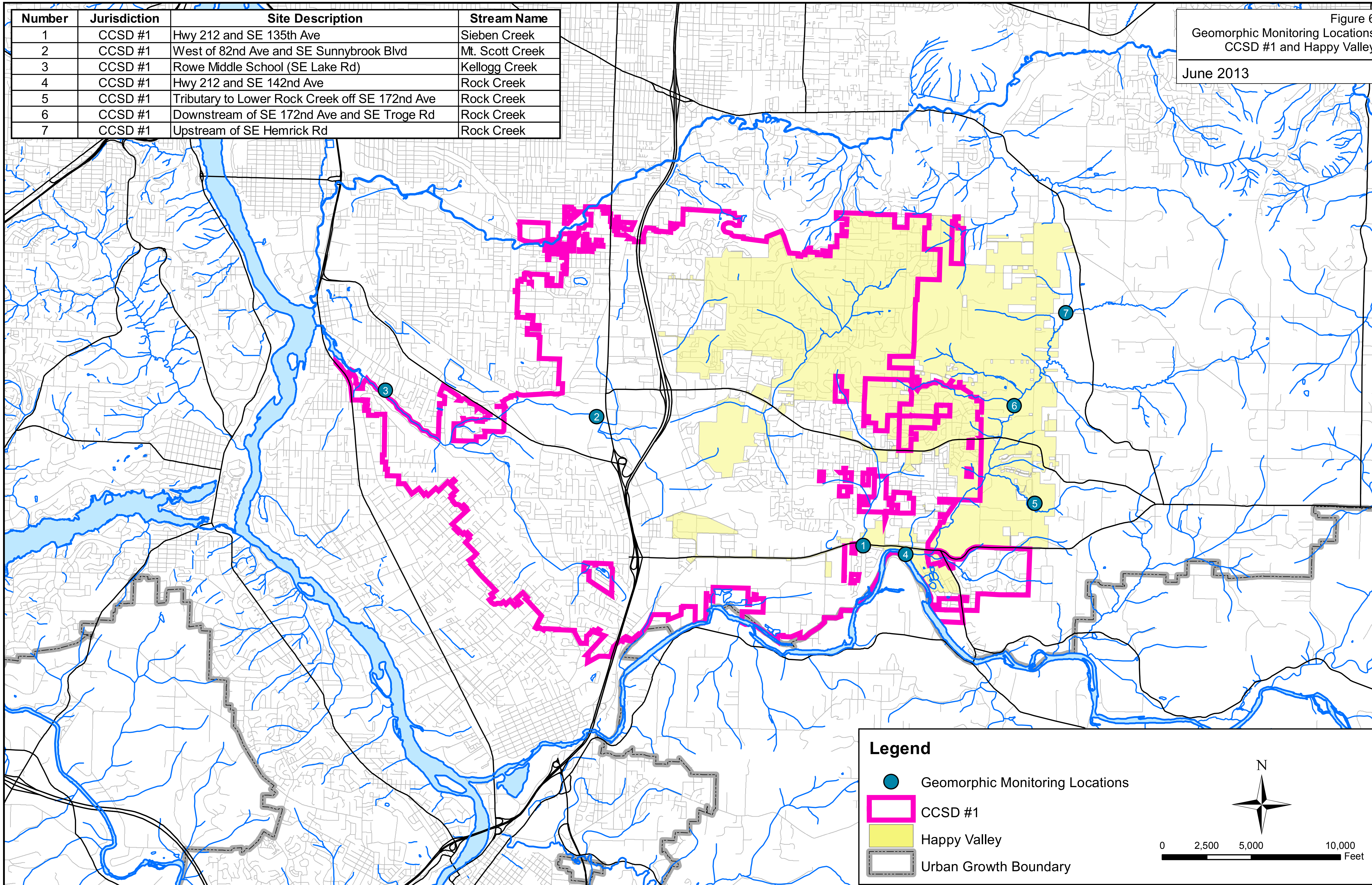
CCSD #1 proposes to contract out the geomorphic monitoring effort at the same time as they conduct their macroinvertebrate monitoring effort (similar to the process conducted in 2009 and 2011). Sample collection processes and methods described below are referenced in the Clackamas County CCSD #1 Aquatic Resource Study, 2011. Consistent methodology is proposed for future CCSD #1 geomorphic monitoring effort planned for 2015.

At the start of the CCSD #1 geomorphic monitoring effort in 2009, reach monuments, and permanent benchmarks were installed at each monitoring location. In cases where monuments were disturbed, upon resurvey in 2011, monuments were reinstalled. This is also expected in 2015.

The geomorphic monitoring effort involves longitudinal and cross section profile surveys, measurements of surficial substrate conditions, collection of bulk samples of bed conditions, measurements of pool characteristics, and assessment of bank conditions. Longitudinal surveys are conducted to capture information related to sediment deposition. Cross section surveys are used to identify whether incisions or headcuts are occurring. Pebble counts characterize surficial substrate conditions, and bulk sediment samples represent bed substrate conditions. Pool surveys include identification of pool density and depth, and indicate whether sediment storage can be achieved. Bank condition assessments are used to define the degree of bank erosion and trajectory of channel conditions.

Sample collection processes and methods described above are based on the previous assessment effort conducted CCSD #1 (in 2011). At the time of sampling to fulfill requirements of this plan, sampling methods may be slightly adjusted to conform to new technology. Such changes will be documented by the contractor prior to sampling and in a final assessment report at the conclusion of the monitoring event.

Number	Jurisdiction	Site Description	Stream Name
1	CCSD #1	Hwy 212 and SE 135th Ave	Sieben Creek
2	CCSD #1	West of 82nd Ave and SE Sunnybrook Blvd	Mt. Scott Creek
3	CCSD #1	Rowe Middle School (SE Lake Rd)	Kellogg Creek
4	CCSD #1	Hwy 212 and SE 142nd Ave	Rock Creek
5	CCSD #1	Tributary to Lower Rock Creek off SE 172nd Ave	Rock Creek
6	CCSD #1	Downstream of SE 172nd Ave and SE Troge Rd	Rock Creek
7	CCSD #1	Upstream of SE Hemrick Rd	Rock Creek



5.6 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.*

BMP monitoring activities will attempt to address the following questions:

- What are the relative pollutant removal capabilities of select structural BMPs being used in the jurisdiction?
- Has implementation of programmatic BMPs provided information to validate whether stormwater quality improvement is being made, based on defined schedules, and frequencies in the SWMP?

BMP 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 (e.g., 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 objective 2 from Schedule B.1.a.

The evaluation of BMP effectiveness also helps indirectly to 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 reflect current conditions more accurately.

The following text describes BMP monitoring efforts pertaining to environmental monitoring (Section 5.6.1) and BMP monitoring efforts pertaining to program monitoring (Section 5.6.2).

5.6.1 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.

5.6.1.1 Structural BMP Monitoring

CCSD #1, SWMACC, Clackamas County, and the City of Milwaukie are currently involved in an ongoing monitoring program related to their underground injection controls (UIC). Implementation of this monitoring activity is the result of UIC program requirements, not MS4 program requirements, and the monitoring program is expected to continue on an annual basis until Water Pollution Control Facility (WPCF) permits are issued to jurisdictions by the Oregon DEQ.

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 the subsurface.

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-event 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 2012 – 2017 NPDES MS4 permit term.

5.6.1.2 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 keep up with current innovations and technological advances effectively.

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.

5.6.2 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 (e.g., have the number of illicit discharge incidents decreased?)
- Public education (e.g., based on survey information, is there increased public awareness related to the jurisdiction's stormwater program and overall stormwater management?)
- Maintenance of structural controls (e.g., based on inspection records, is maintenance being performed more regularly? Are facilities operating more consistently?)

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 (QA/QC) 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 2012 NPDES MS4 permit). A summary of the pollutant parameters required for analysis is included in Table 10.

The applicable analytical methods are also identified in Table 10. Provisions of the 2012 Plan require the use of EPA approved methods listed in the most recent publication of 40 CFR 136. Such identified analytical methods in Table 10 include both EPA and Standard Methods and are consistent with provisions of 40 CFR 136.

Table 10. Pollutant Parameters and Analytical Methods for the Comprehensive Clackamas County Monitoring Plan

Type (field or lab)	Analyte	Sample type (grab or time-spaced composite)	Unit	Analytical method	Estimated MDL	Notes	Analyzed in-house[a] 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	°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	SM 4500-NO_3 F	0.045		In-house
Lab	Phosphorus, total	Composite	mg/L	SM 4500-P A, B, & E	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[b]	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

a. In-house refers to the Water Environment Services (WES) laboratory.

b. CCSD #1 is not required to conduct monitoring for volatile solids in accordance with Table B-1.

Pesticide monitoring will be conducted in conjunction with the list of compounds and associated detection limits documented in USGS proposal (Appendix C). Pesticide samples will be analyzed at the USGS Pesticide Fate Research Group Laboratory in Sacramento, California using USGS-approved methods.

Water quality monitoring conducted as part of the macroinvertebrate sampling will conform to a documented standard operating procedure, provided to each jurisdiction prior to sampling.

6.2 Quality Assurance and Quality Control Procedures

For purposes of this Plan, QA/QC procedures are identified for field analysis and laboratory analysis that are initiated directly by the jurisdiction. 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 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 have been solicited for purposes of conducting the mercury analyses, and one local laboratory TestAmerica has also provided a proposal that includes adherence with the required detection limits. As such laboratories were either identified by DEQ and/or currently used by co-permittees in order to address the mercury monitoring requirements, the laboratories are presumed to have quality assurance protocols that meet the permit requirements

Pesticide samples will be analyzed at the USGS Pesticide Fate Research Group Laboratory in Sacramento, California using USGS-approved methods. A laboratory evaluation plan (LEP) will be prepared prior to ensure data objectives will be met by the laboratory. In addition to regular environmental samples, 10-15 percent of all samples will be submitted for quality assurance (QA). QA samples include one field equipment blank, one field replicate, and one field spike sample (for water samples), and QA samples include one field replicate, one field spike sample and one laboratory spike sample (for sediment samples).

Contracted monitoring activities related to biologic monitoring and geomorphic monitoring employ field procedures and protocols unique to the monitoring effort. Description of study methods and QA/QC guidelines will be documented in the final assessment report provided to each jurisdiction at the conclusion of the monitoring event.

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 this Plan individually (or through an inter-governmental 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 instream and stormwater 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. A summary of monitoring results will be provided to DEQ with submittal of the individual jurisdiction's NPDES MS4 annual reports. Compiled monitoring data may be provided to DEQ in digital format upon request, in accordance with requirements of the 2012 NPDES MS4 permit.

Technical reports documenting results of the pesticide, biologic and geomorphic monitoring effort shall be maintained by individual jurisdictions and results summarized or attached to the NPDES MS4 annual report.

For the annual report due on November 1, 2015, a water quality trends analysis will be required based on the instream 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

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.

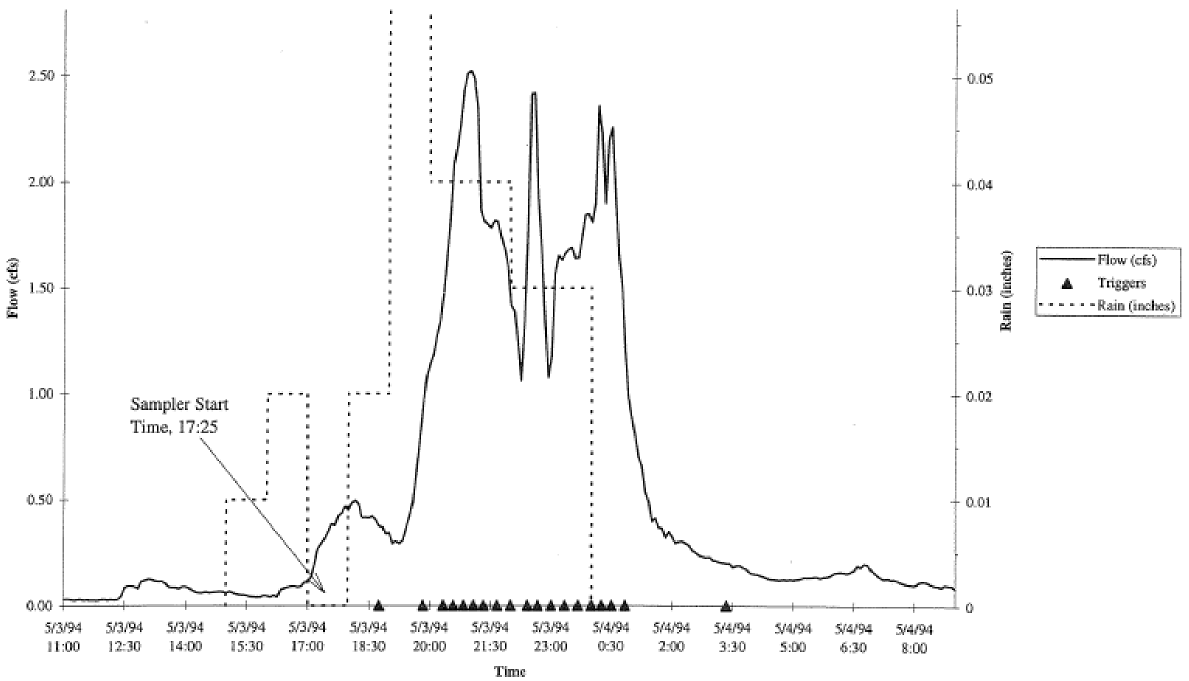


Figure 1. Storm Hydrograph and Sample Collection for Event #1 (City of Portland, May 1995)

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.

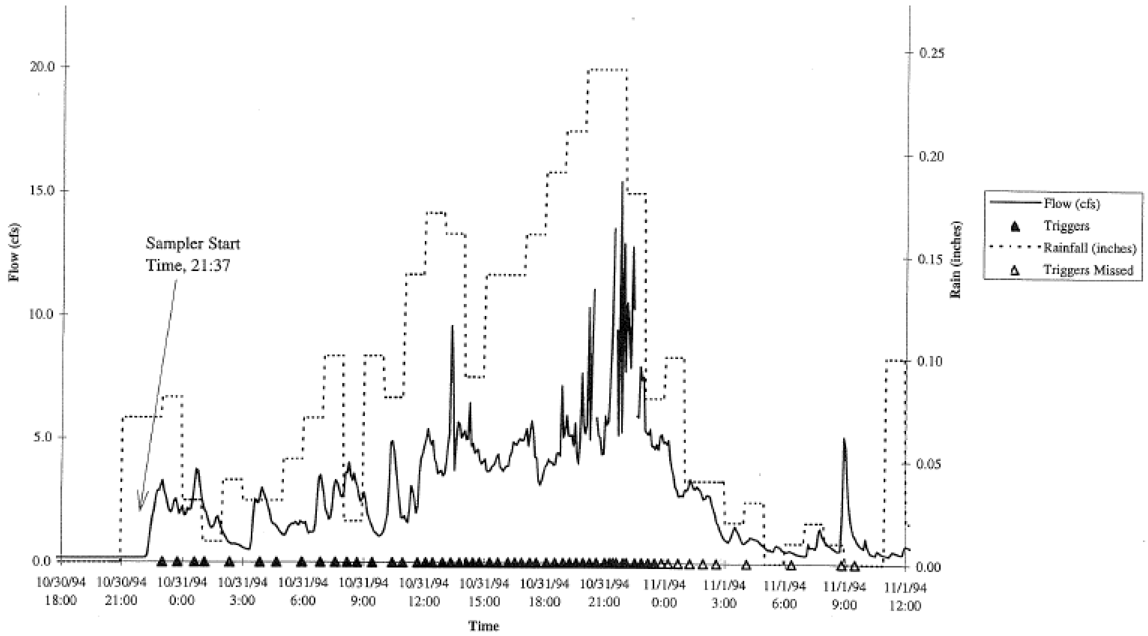


Figure 2. Storm Hydrograph and Sample Collection for Event #3 (City of Portland, May 1995)

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.

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Table 3. Summary of Flow-Weighted Composite EMCs and Time-Composite Mean Concentration (by location and storm event)													
		Monitored parameters											
		TSS (mg/L)			Total phosphorus (mg/L)			Ortho-phosphorus (mg/L)			Nitrate (mg/L)		
Storm event	Monitoring station (by land use)	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	1.3x10^4	0.9x10^4 – 1.9x10^4	0.7x10^4 – 1.9x10^4
	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	1.2x10^4	0.6x10^4 – 1.2x10^4	0.6x10^4 – 1.9x10^4
2	*Mixed-Use* [(3)]	5.63	5.87 – 6.73	5.00 – 6.73	0.07	0.08	0.06 – 0.08				7.5x10^4	3.1x10^4 – 4.6x10^4	3.1x10^4 – 9.9x10^4
	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	1.1x10^4	0.8x10^4 – 2.0x10^4	0.8x10^4 – 2.0x10^4
	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	1.8x10^4	0.7x10^4 – 1.0x10^4	0.6x10^4 – 1.0x10^4
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

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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**

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)**
	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:
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.

1. 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.
2. 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.

<u>Mercury Sampling Procedures</u>

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

<u>Composite Sampling Procedures</u>

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.
3. 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 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 and for samples collected by a single sampling crew. 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.

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:

1. Source/Location
2. Site Code or ID
3. Person(s) sampling
4. Type of sample (instream dry season, instream wet season, instream storm, or outfall stormwater runoff)
5. Date of sample collection
6. Time of sample collection
7. Number of sample (if applicable). Pertains to collection of multiple individual grab samples to compile as a time-composite sample.
8. 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.

1. Keep the Monitoring Field Data Sheet with the samples at all times.
2. Pack samples well within ice chest to prevent breakage or leakage.
3. 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.
4. Samples must be delivered to the water quality laboratory within 6 hours (standard for bacteria sample analysis).
5. 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 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.

Appendix C

USGS Pesticide Monitoring Proposal

Pesticides in Urban Streams in Clackamas County's Portion of the Portland Metropolitan Area

Prepared for the Clackamas County MS4 Permit Co-Permittees
By Kurt Carpenter
USGS Oregon Water Science Center, Portland, Oregon

Background / Introduction / Problem

Recent studies in Oregon have found several pesticides in the urban streams around the Portland Metropolitan area (Waite and others, 2008; Oregon Department of Environmental Quality, unpublished data, 2005-10), including organophosphate (OP) insecticides such as diazinon, chlorpyrifos, and others, which can be highly toxic to aquatic biota. Concern grew after a recent USGS study found pesticides in several samples of source and finished drinking water samples taken from the lower Clackamas River (Carpenter and others, 2008). Additional data collection by the Oregon Department of Environmental Quality (ODEQ) in the agricultural tributaries of the Clackamas River basin also found many pesticides at concentrations that periodically exceed aquatic-life guidelines. The highest pesticide concentrations commonly occur during storms, indicating that rainfall runoff and/or sediment delivery to streams are the dominant pesticide transport processes in this area.

In response to these findings, ODEQ recently included pesticide monitoring in the new Municipal Separate Storm Sewer System (MS4) permits, including the one for the Clackamas County MS4 co-permittees, which includes 11 separate jurisdictions. This proposed study would provide a baseline characterization of pesticides in stormwater and bed sediment of receiving streams within Clackamas County, examine potential effects on stream biota, and allow managers to detect reductions in pesticides over time that may result from watershed improvements, educational outreach, and collection events targeting expired or unwanted pesticides.

Pesticide use changes over time as pests become resistant, environmental problems are discovered, regulations change, and new pesticides are developed. Insecticide use has shifted from more persistent hydrophobic organochlorines like DDT to slightly less persistent and hydrophobic OP insecticides like chlorpyrifos and diazinon, which are now banned for residential use. As pesticides fall out of common use in urban and agricultural settings, specific replacements vary greatly by land use type and specific application.

There is a growing concern about some of the replacement pesticides that have been used since the late 1990s. Pyrethroids are now a common alternative to OP insecticides in commercial and residential settings to control many types of pests. Pyrethroids are hydrophobic and moderately persistent, and can be highly toxic to fresh water fish and benthic invertebrates. Being hydrophobic, pyrethroids sorb to organic carbon and other sediments within the water column and in the streambed. Many of the more soluble pesticides of interest are primarily found dissolved in water. This study proposes analysis of streambed and outfall pipe sediments, suspended sediments, and water.

Objectives

The objectives of the proposed study are to (1) Characterize pesticide concentrations in stormwater runoff from streams and stormwater outfalls in the areas covered by the Clackamas County MS4 permit; (2) Characterize pyrethroids and other current-use pesticide concentrations in streambed sediment during low-flow conditions and in sediments accumulated within stormwater outfall pipes; (3) Use GIS data to examine relations between urban land cover characteristics and pesticide occurrence; (4) Relate pesticide occurrence to the quality of benthic invertebrate assemblages using existing data; and (5) Present findings in a peer-reviewed scientific journal.

Relevance and Benefits

This study addresses issues identified in the Strategic Directions for the USGS' Water Resources Mission Area, including the status of ecosystems, causes of ecological change, effects of water-resource management on the sustainability of aquatic habitats, and the role of environmental quality on human health (U.S. Geological Survey, 2007).

The study anticipates several benefits, including a better understanding of the occurrence, temporal trends, and effects of pesticides on biota in these urban streams. This will be the first study to examine a broad range of pyrethroid compounds and other current-use pesticides in bed sediments in the Clackamas River basin, despite their having been in use for more than a decade. Pyrethroids have widespread popularity as a replacement for OP insecticides because they are less toxic to humans, but they can be quite toxic for aquatic biota. Another benefit is that this study will be the first to use SIFT© devices (explained below) to characterize pesticide concentrations in stormwater-derived sediments within outfall pipes. Development and implementation of such new methods is another high priority direction for USGS outlined in the 2007 science plan (U.S. Geological Survey, 2007).

Approach

The study proposes to collect water and sediment samples from stormwater outfalls and natural stream channels for analysis of 90-120 pesticide compounds, including insecticides, herbicides, fungicides, and select degradates (Table 1). Although the list of compounds analyzed in water versus sediments vary, most (87) compounds will be analyzed in both water and sediment.

Streambed sediments will be collected from depositional areas at 12 sites during the summer low-flow period between July and September 2013 using standard USGS techniques (Radtke, 2005). USGS will follow up with storm sampling at the same 12 sites plus an additional 5 stormwater outfalls, targeting a significant flushing event in October or November 2013. Whole-water samples will be collected from the thalweg directly into 1-liter GCC glass amber bottles using methods outlined in Hladik and others (2009b). Samples will be filtered by the laboratory and dissolved pesticides will be analyzed in the filtrate, whereas pesticides associated with the suspended sediment will be quantified by analyzing pesticide retained on the filter.

In order to provide more direct comparisons between sediment-associated pesticides in streambed sediments with those in stormwater outfalls, stainless steel sediment traps (SIFT© samplers, figure 1) will be deployed in 3 stormwater outfalls for a period of at least one month, including the same autumn "first flush" event targeted for storm sampling (described below). SIFT© samplers were developed by the City of Portland to characterize the occurrence of PCBs and other organic contaminants and provide a means to collect a time-integrated sediment sample from stormwater outfalls. These samplers have a 1,270-micron mesh screen on the front and 226-micron screen on the back and the sampler is held in place by means of an expandable stainless steel band. Although SIFT© devices have not been used to collect sediments for pesticides, previous deployments show good agreement in the sediment-size fractionation of replicate SIFT samplers (Randy Belston, City of Portland, written commun., 2013). Staff from the City of Portland who are specially trained to work in confined spaces will deploy the SIFT© samplers.

Site selection could include 12 different streams, or fewer streams with nested groups of sites upstream and downstream from stormwater outfalls. USGS will process bed sediment and outfall sediment samples in the field through 2-mm stainless steel sieves prior to digestion and analysis, and organic carbon concentrations will be measured to normalize pesticide concentrations found in sediment samples. The final sample design will be important to the overall conclusions of this study. Sites will be selected in close coordination with the Clackamas County MS4 co-permittees, including the choice of using a nested upstream-downstream design in some sub-basins based on their proximity to appropriate stormwater outfalls. Co-permittees assistance may be needed for access to sites or to obtain information about local hydrology, drainage networks, land use, and existing data on aquatic invertebrates.

Data analyses will include site characterization using a Geographic Information System (GIS) to delineate the amount and type of urban development in the upstream drainage areas, along with other urban traits, where possible. Existing information on benthic invertebrate assemblage quality will be used to examine potential effects of insecticides on the quality of the benthic invertebrate assemblages at each stream site. Results will be published in a peer-reviewed professional journal.

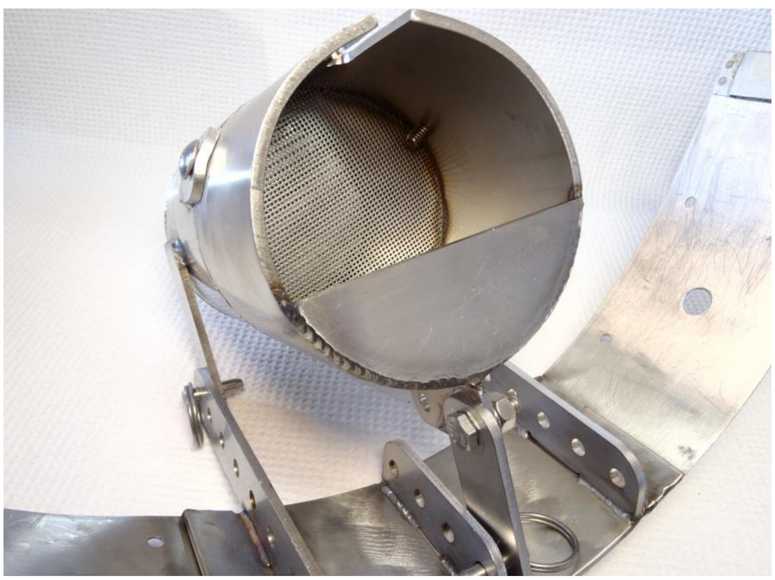

Figure 1. SIFT© sediment trap (photo courtesy of the City of Portland).

Rationale for Selection of Pesticides for Analysis

The new MS4 permit issued by ODEQ required stormwater or instream pesticide monitoring, specifying 16 compounds plus any pesticides currently used by the co-permittees within the jurisdictional areas be considered for monitoring. These included 7 commonly used insecticides (bifenthrin, cypermethrin or permethrin, imidacloprid, fipronil, malathion, and carbaryl), 5 herbicides (triclopyr, 2,4-D, glyphosate and one of its degradates (AMPA), trifluralin, pendimethalin), and 3 fungicides (chlorthalonil, propiconazole, and myclobutanil). After much consideration, it was decided that, for two primary reasons, samples collected for this project would be analyzed at the USGS Pesticide Fate Research Group

Laboratory in Sacramento, California, which specializes in the analysis of “current use” pesticides and uses methods that achieve ultra-low detection limits (Table 1).

The suite of compounds analyzed by this laboratory includes 6 of the 7 insecticides listed in the ODEQ permit plus 35 additional insecticides. Although there is little or no information on the occurrence of many of these pesticide compounds in water or sediments in this area, such data may explain impaired benthic invertebrate assemblage conditions and low stream-health scores in some of these urban streams. Although imidacloprid is not included, previous studies in the Clackamas River basin (Carpenter and others, 2008) found this insecticide in just 2 of 84 samples (less than 3 percent occurrence), with both detections likely attributed to agricultural sources, not urban use. The proposed list of analytes also does not include the commonly detected herbicides: triclopyr, 2,4-D, and glyphosate (or glyphosate’s degradate, AMPA), but does include trifluralin, pendimethalin, and 35 additional herbicides and 3 herbicide degradates (Table 1). All three fungicides listed on the permit are included in the proposed list of analytes, plus 35 additional fungicide compounds.

Because of the expected high amounts of pesticide use by the general public, and relatively scant use of pesticides (mostly herbicides) by the co-permittees (estimated to be <1% of the total), these three herbicides were not a driving factor in the pollutant monitoring selection process. The analytical methods required to analyze these herbicides are different from those used for the compounds listed in Table 1, and including all schedules would have added considerable cost or limited the number of sampling sites. These herbicides are relatively less toxic compared with many of the insecticides currently in use, so these compounds were given a lower priority as the costs and benefits of the various laboratory schedules were weighed. Further, the MS4 pesticide monitoring by the Cities of Portland, Gresham, and Salem has already included many of these herbicides, which provides an opportunity for the Clackamas County MS4 permit monitoring to focus on other compounds that have not been, thus far, well characterized. The selected schedule targets a larger slice of the overall pesticide use by considering an even wider array of current-use pesticides, and therefore fills a potentially important information gap.

Quality Assurance / Quality Control

Although no QAPP is required for this project, a laboratory Evaluation Plan (LEP) will be conducted for the laboratory chosen for this study to ensure that the data objectives of the project can be met by the laboratory. Pesticide samples will be analyzed at the USGS Pesticide Fate Research Group Laboratory in Sacramento, California, using USGS-approved methods published in Hladik and others (2009a) and Hladik and McWayne (2012).

In addition to the regular environmental samples, 10-15 percent of all samples will be submitted for quality assurance. QA samples for pesticides in water will include one field equipment blank, one field replicate, and one field spike sample. QA samples for pesticides in sediment will include one field replicate and one field split sample, plus a laboratory-spike sample.

Products

An interpretive report will be prepared during the 2014–15 federal fiscal years that describes the data collection, results including comparison of any pesticides detected in water versus sediment, evaluation of possible pesticide sources, and potential implications.

Table 1. Pesticides to be analyzed in stormwater and stream bed sediments.
[MDLs for water reported in ng/L (nanograms per liter), or parts per trillion, and sediment in µg/kg (micrograms per kilogram), or parts per billion. -- indicates compound not analyzed]

		Method Detection Limits (MDLs)	
		Water	Sediment
Compound	Type	(ng/L)	(µg/kg)
3,4-DCA	Herbicide	8.3	1.3
3,5-DCA	Herbicide	7.6	1.5
Alachlor	Herbicide	1.7	0.6
Allethrin[1]	Insecticide	6.0	1.7
Atrazine	Herbicide	2.3	1.5
Azinphos-methyl[2]	Insecticide	--	1.7
Azoxystrobin	Fungicide	3.1	0.9
Benefin	Herbicide	--	1.7
Bifenthrin[1]	Insecticide	4.7	0.6
Boscalid	Fungicide	2.8	1.2
Butralin	Herbicide	--	1.6
Butylate	Herbicide	1.8	1.3
Captan	Fungicide	--	3.1
Carbaryl	Insecticide	6.5	1.2
Carbofuran	Insecticide	3.1	1.2
CDEPA	Herbicide degradate	--	1.3
Chlorothalonil	Fungicide	4.1	1.1
Chlorpyrifos[2]	Insecticide	2.1	0.9
Clomazome	Herbicide	2.5	--
Clomazone	Herbicide	--	2.0
Coumaphos[2]	Insecticide	--	1.2
Cycloate	Herbicide	1.1	0.8
Cyfluthrin[1]	Insecticide	5.2	1.3
Cyhalofop-butyl	Herbicide	--	0.8
Cyhalothrin[1]	Insecticide	2.0	0.7
Cypermethrin[1]	Insecticide	5.6	1.2
Cyproconazole	Fungicide	4.7	1.0
Cyprodinil	Fungicide	7.4	1.7
DCPA	Herbicide	2.0	1.7
Deltamethrin[1]	Insecticide	3.5	1.3
Diazinon[2]	Insecticide	0.9	1.6
Difenoconazole	Fungicide	10.5	1.0
Dimethomorph	Fungicide	6.0	1.5
Dithiopyr	Herbicide	--	1.3
EPTC	Herbicide	1.5	0.8
Esfenvalerate[1]	Insecticide	3.9	1.0
Ethalfluralin	Herbicide	3.0	1.2
Etofenprox[1]	Insecticide	2.2	1.0

[1] Pyrethroid compounds
[2] Organophosphate compounds

Compound	Type	Method Detection Limits (MDLs) Water (ng/L)	Sediment (µg/kg)
Famoxadone	Fungicide	2.5	1.7
Fenarimol	Fungicide	6.5	1.4
Fenbuconazole	Fungicide	5.2	1.8
Fenhexamide	Fungicide	7.6	2.5
Fenpropathrin[1]	Insecticide	4.1	1.0
Fenpyroximate	Insecticide	--	1.9
Fenthion[2]	Insecticide degradate	--	2.0
Fipronil	Insecticide	2.9	1.6
Fipronil desulfinyl	Insecticide	1.6	1.8
Fipronil desulfinyl amide	Insecticide degradate	--	2.0
Fipronil sulfide	Insecticide	1.8	1.5
Fipronil sulfone	Insecticide	3.5	1.0
Fluazinam	Fungicide	4.4	2.1
Fludioxinil	Fungicide	7.3	2.5
Flufenacet	Herbicide degradate	--	1.0
Flumetralin	Plant growth regulator	--	1.2
Fluoxastrobin	Fungicide	5.1	1.2
Flusilazole	Fungicide	4.5	2.2
Flutolanil	Fungicide	--	2.1
Flutriafol	Fungicide	4.2	1.1
Hexazinone	Herbicide	8.4	0.9
Imazalil	Fungicide	10.5	1.8
Indoxacarb	Insecticide	--	2.4
Iprodione	Fungicide	4.4	0.9
Kresoxim-methyl	Fungicide	4.0	0.5
Malathion[2]	Insecticide	3.7	1.0
Metalaxyl	Fungicide	--	1.9
Metconazole	Fungicide	5.2	1.2
Methidathion[2]	Insecticide	7.2	1.8
Methoprene	Insecticide	6.4	1.6
Methyl parathion[2]	Insecticide	3.4	1.1
Metolachlor	Herbicide	1.5	0.7
Molinate	Herbicide	3.2	1.0
Myclobutanil	Fungicide	6.0	1.7
Napropamide	Herbicide	8.2	0.9
Novaluron	Insecticide	--	1.1
Oxydiazon	Herbicide	--	1.4
Oxyflurofen	Herbicide	3.1	1.9
p,p'-DDD	Degradate	4.1	1.0
p,p'-DDE	Degradate	3.6	1.0
p,p'-DDT	Insecticide	4.0	0.8
PCA	Herbicide	--	1.1
PCNB	Fungicide	--	1.1
Pebulate	Herbicide	2.3	0.9
Pendimethalin	Herbicide	2.3	0.8
Pentachloroanisole (PCA)	Degradate	4.7	--

[1] Pyrethroid compounds
[2] Organophosphate compounds

Compound	Type	Method Detection Limits (MDLs) Water (ng/L)	Sediment (µg/kg)
Pentachloronitrobenzene (PCNB)	Fungicide	3.1	--
Permethrin[1]	Insecticide	3.4	0.9
Phenothrin[1]	Insecticide	5.1	0.9
Phosmet[2]	Insecticide	4.4	0.9
Piperonyl butoxide	Accelerator	2.3	1.2
Prodiamine	Herbicide	--	1.4
Prometon	Herbicide	2.5	2.7
Prometryn	Herbicide	1.8	1.3
Pronamide	Herbicide	--	1.7
Propanil	Herbicide	10.1	2.2
Propargite	Insecticide degradate	--	2.2
Propiconazole	Fungicide	5.0	1.1
Propyzamide	Herbicide	5.0	1.5
Pyraclostrobin	Fungicide	2.9	1.1
Pyridaben	Insecticide	--	1.2
Pyrimethanil	Fungicide	4.1	1.1
Resmethrin[1]	Insecticide	5.7	1.3
Simazine	Herbicide	5.0	1.3
Tau-Fluvalinate[1]	Insecticide	5.3	1.2
Tebuconazole	Fungicide	3.7	1.2
Tebupirfimfos OA[2]	Insecticide degradate	--	2.0
Tebupirimfos[2]	Insecticide	--	1.5
Tefluthrin[1]	Insecticide	4.2	0.7
Tetraconazole	Fungicide	5.6	1.1
Tetradifon	Insecticide	--	2.0
Tetramethrin[1]	Insecticide	2.9	0.9
Thiazopyr	Herbicide	--	1.9
Thiobencarb	Herbicide	1.9	0.6
Triadimefon	Fungicide	8.9	1.5
Triadimenol	Fungicide	8.0	1.5
Triallate	Herbicide degradate	--	1.4
Tribufos	Herbicide	--	2.2
Trifloxystrobin	Fungicide	4.7	1.0
Triflumizole	Fungicide	6.1	1.1
Trifluralin	Herbicide	2.1	0.9
Triticonazole	Fungicide	6.9	1.8
Vinclozolin	Fungicide	--	1.2
Zoxamide	Fungicide	3.5	1.1

[1] Pyrethroid compounds
[2] Organophosphate compounds

Budget Assumptions

The budget was developed with the following assumptions: (1) USGS will conduct bed sediment sampling during the July–September 2013 low-flow period, and SIFT© sediment traps will be deployed by staff from the City of Portland; (2) 3-4 teams composed of staff from both the USGS and participating MS4 co-permittees will collect storm samples in October–November 2013, targeting the “first flush” or other substantial rain event; (3) SIFT© devices will be retrieved by staff from the City of Portland and samples processed by the USGS; (4) Each municipality or agency will provide the USGS with GIS coverages of urban indicators (e.g., impervious area, population density, etc.), along with assistance in site selection; (5) The USGS laboratory will provide results no later than January 31, 2014; and (6) The interpretive report will be published in FY 2015.

Timeline[1]

	Federal Fiscal Year																						
	2013								2014												2015		
Tasks	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Site selection	X	X	X	X	X																		
GIS data assembly			X	X	X																		
Sediment sampling						X	X	X															
Storm sampling									X	X													
Data analysis									X	X	X	X	X	X	X								
Report writing														X	X	X	X	X					
Peer review																	X	X	X	X			
Address comments																		X	X	X	X		
Approval and publication[2]																				X	X	X	X

[1] Completion of each task, and the timing of the final publication, will depend on when the data are received from the lab. This timeline assumes that the storm samples will be collected no later than November 30, 2013, and results are received no later than January 31, 2014.
[2] Publication timing will be dictated by the scientific journal.

Personnel Requirements

USGS Hydrologic Field Technicians (Oregon Water Science Center) – Field data collection, GIS support: 76 hours

USGS Hydrologists (Oregon Water Science Center) – Project development, management, field data collection, analysis, interpretive report: 828 hours

USGS GIS Analyst (Oregon Water Science Center) – Land use calculations, maps, and other GIS support: 80 hours

Additional Field Personnel (MS4 co-permittees) – Assistance with site selection and field data collection: 80 hours

Additional Field Personnel (City of Portland) – Assistance with deployment of 3 SIFT© sediment traps: 16 hours

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