City of Seattle
Seattle Public Utilities

October 2, 2014

Rachel McCrea
Municipal Stormwater Specialist
Water Quality Program
Department of Ecology
Northwest Regional Office
3190 160th Ave SE
Bellevue, WA 98008-5452

Re: NPDES Phase I Municipal Stormwater Permit, S8.C – Stormwater Management Program Effectiveness QAPP

Dear Ms. McCrea,
The purpose of this letter is to submit the Final Stormwater Management Program Effectiveness Quality Assurance Project Plan (QAPP) under S8.C of the 2013 NPDES Phase I Municipal Permit. Attached are two hard copies of the Street Sweeping Water Quality Effectiveness QAPP. Also attached (Attachment 1) is a table of the technical review comments with a column identifying the revisions or actions that were included in the final QAPP.

Please feel free to contact Kate Rhoads, of my staff, if you have any questions regarding this letter. Kate is the lead for the Municipal Stormwater Permit for the City of Seattle and can be reached at (206) 684-8298 or at kate.rhoads@seattle.gov.

I certify under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violation.

Sincerely,

Nancy Ahern

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Attachments

cc: Helge Ferchert, SPU
Julie Crittenden, SPU
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Kate Rhoads, SPU
Doug Hutchinson, SPU
Theresa Wagner, Seattle City Attorney's Office

ATTACHMENT 1
Ecology technical review comments and SPU QAPP revision/action
Seattle Public Utilities 07102014 draft *Street Sweeping Water Quality Effectiveness QAPP*

#	Page	Text or Section	Comment/Question	Required Edit[1]	Suggestion[2]	SPU Revision/Action
1	All	Overall QAPP	This QAPP was well written overall. These comments primarily address clarity of intentions. Required edits are mandatory, but suggested edits can be made at the City's discretion.	NA	NA	NA
2	Pg 1	First paragraph	Revise the text "…independent effectiveness study per section S8.C of the 2013…" to specify S8.C.3.	No	Yes	Revised
3	Pg 12	Last sentence on page in section 5.3.1	"Since no conclusions can be made until sweeping is ceased and the "after impact" samples are collected, no sample results will be presented in annual reports." This is not consistent with the permit requirement at S8.C.3.b.iv and the associated annual report question #84 (Appendix 12 of the Permit). Each annual report must include "interim results and a status of the study." Ecology agrees with the City that conclusions cannot be made until the project is complete. However "interim results" for annual reports must, at a minimum, summarize the sample results that became available during the relevant annual reporting year. This summary could be in tabular form (i.e., a data dump). Efficiency evaluations and statistics are not necessary for the annual report. Note that Ecology does agree with the language in Section 14.3.1 that states the Annual Report is primarily a project status report. Ecology also concurs that submission to EIM is not required.	Yes	No	Revised to state that the annual reports will present a tabular summary of data collected during the corresponding year.
4	Pg 18	Table 11	The City could probably ask the lab for a better	No	Yes	We requested a lower reporting limit

#	Page	Text or Section	Comment/Question	Required Edit[1]	Suggestion[2]	SPU Revision/Action
			target reporting limit for TKN. Consider standard methods: SM4500-N_{org}B/C and SM4500NH_3-B/C/D/EF/G/H. The RL is closer to 0.3 mg/L			(RL) and our lab will commit to lowering to 0.5 mg/L. They have previously reported as low as 0.3 mg/L as the RL but their QC data suggests that 0.5 mg/L is as low as they can confidently go. Revision = TKN RL in QAPP lowered to 0.5 mg/L and method changed to 351.2.
5	Pg 19	7.2	Ecology likes the BACI design approach and believe the study will provide valuable results for this housekeeping BMP.	NA	NA	NA
6	Pg 27	8.1.3.1	Clarify if the samples will be taken before the flow reading. This may negligibly affect the flow readings for medium to larger sized storms. But may need to be taken into account for very small storm volumes/flows. Clarify how you will account for the removed sample volume in the flow record. If it is negligible for event very small storm flows, then state as much.	Yes	No	Added text to explain that sample volume collected is considered negligible and the flow record will not be adjusted for volume sampled.
7	Pg 27	8.1.3.1	Has the City also considered more directly investigating the first flush of the storm runoff? This might be done on a sub-set of samples. Just a question of curiosity. The effectiveness of sweeping may influence the first flush concentrations most, and the signal in the full storm composite may/may not be a strong.	No	Yes	The City will not be investigating first flush impacts because this is a BMP effectiveness study and characterizing the presence/absence of a first flush effect has proven very difficult for other studies that were designed to only evaluate this phenomena. No QAPP revisions made.
8	Pg 30	8.1.4; last paragraph	It may be more cost effective to replace the tubing than testing it for the contaminants.	No	Yes	The tubing will replaced at least annually but tubing blanks are still

#	Page	Text or Section	Comment/Question	Required Edit[1]	Suggestion[2]	SPU Revision/Action
						necessary to determine if the tubing, even when new, is a source of cross contamination. No QAPP revisions made.
9	Pg 32	8.3.5	Clarify how the city will flag the dissolved metals samples if they exceed the 15 minute holding time. Does the City add a "J" qualifier?	Yes	No	QAPP revised to state all samples exceeding holding times will be J-flagged.
10	Pg 40	14.1	The proposed data qualifiers in Table 7 are fine, but the City should explicitly state how data that are below the detection limit and data that are between the detection limit and the quantitation limit will be used in analysis. Will the City report the data at the RL? Does the city also plan to use ½ the detection limit for analyses of non-detect data?	Yes	No	None of the City's contract labs provide numerical values below the reporting limit (RL). The City will report values at the reporting limit if reported by the lab. For results below the reporting limit (i.e., non-detects), ½ the RL will be used for the analyses. Revised language added to Section 14.1.1. Note – "handling of field duplicates" text in same section slightly edited for clarity.
11	Pg 42	14.3.2	In the discussion of results, include how antecedent moisture conditions (as well as street sweeping) might have influenced pollutant concentrations.	Yes	No	Text added to Section 14.3.2.5 on page 43 to explain how a backward stepwise regression will be performed to determine whether antecedent rainfall or sweeping occurrence, in combination or isolation, has a significant influence on influent concentrations.

1= Comments marked as a required edits are deficiencies that must be addressed in the City's final QAPP.

2= Comments marked as a suggestion are intended for the City to consider for clarification.

Street Sweeping Water Quality Effectivenes
Quality Assurance Project Plan

Permit No.: WAR04-4503

NPDES Phase I Municipal Stormwater Permit, Independent Effectiveness Project

Revision: R1D0 Final

Effective Date: 09/22/2014

Seattle Public Utilities
Seattle, Washington

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TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

Street Sweeping Water Quality Effectiveness Study

Internal Review and Approval

Principal Investigator, Study Manager (Doug Hutchinson) — Approved On 9/24/2014

NPDES Stormwater Permit Coordinator (Kate Rhoads) — Approved On 9/29/14

QA Coordinator (Amy Minichillo) — Approved On 9/25/14

External Review and Approval

Field Supervisor (Dylan Ahearn – Herrera Environmental Consultants) — Approved On 9/24/14

Laboratory Project Manager (Mark Harris – Analytical Resources Inc.) — Approved On 9/25/14

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ACRONYMS

µg/L	micrograms per liter
%R	percent recovery
BACI	Before/After-Control/Impact
BMPs	Best Management Practices
CAR	Corrective Action Report
COC	chain-of-custody
DQI	data quality indicator
DQO	data quality objective
Ecology	Washington State Department of Ecology
EDDs	electronic data deliverable
HDPE	high-density polyethylene
LCS	laboratory control sample
MDL	method detection limit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
MQO	measurement quality objective
MS	matrix spike
MSD	matrix spike duplicate
NPDES	National Pollutant Discharge Elimination System
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RL	reporting limit
RPD	relative percent difference
SOP	standard operating procedure
SPU	Seattle Public Utilities
TOC	total organic carbon
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency

TABLE OF CONTENTS

3 Background 2
3.1 Study Area 3
3.2 Parameters of Interest 3
3.3 Previous Studies 6
4 Project Description 8
4.1 Study Goals 8
4.2 Information Requirements 8
4.3 Study Boundaries 8
4.3.1 Target Population 8
4.3.2 Spatial Boundaries 9
4.3.3 Temporal Boundaries 9
4.3.4 Practical Constraints 9
4.3.5 Decision Making 10
5 Organization and Schedule 10
5.1 Roles and Responsibilities 10
5.2 Special Training Needs/Certification 11
5.3 Timeline/study schedule 12
5.3.1 Study Deliverables 12
5.3.2 Study Success Factors 13
6 Quality Objectives 14
6.1 Data Quality Objectives 14
6.2 Measurement Quality Objectives 15
6.2.1 Precision, Bias and Accuracy 15
6.2.2 Representativeness 17
6.2.3 Completeness and Comparability 17
6.2.4 Sensitivity 18
7 Sampling Process Design (Experimental Design) 18
7.1 Street Sweeping Program Overview 18
7.2 Monitoring Strategy Overview 19
7.3 Monitoring Site Selection 20
7.3.1 Parameters and Analytical Methods 23
7.3.2 Qualifying Sample Criteria 23
8 Sampling (Field) Procedures 24
8.1 Sampling/Monitoring Equipment and Procedures 24
8.1.1 Precipitation Monitoring 24
8.1.2 Flow Monitoring 24
8.1.3 Water Quality Sampling 25
8.1.4 Field Quality Control Sample Collection Procedures 30
8.2 Equipment Decontamination Procedures 30
8.3 Sample Handling and Custody 31
8.3.1 Sample Identification 32
8.3.2 Sample Transportation 32
8.3.3 Sample Preservation 32
8.3.4 Sample Processing 32
8.3.5 Holding Times 32
8.3.6 Chain of Custody 33
9 Measurement Procedures 33
10 Quality Control 34
10.1 Analytical Quality Control 34
10.2 Field Quality Control 34
11 Data Management & Documentation Procedures 34
11.1 Documents and Records 35
11.1.1 Field Operation Records 35
11.1.2 Laboratory Records 35
11.1.3 Data Handling Records 35
11.1.4 Revisions to the QAPP 35

12 Audits and Reports 35
12.1 Assessments and Response Actions 35
12.2 Deficiencies, Nonconformances and Corrective Action 36
13 Data Verification and Validation 38
13.1 Data Review, Verification and Validation 38
13.2 Verification and Validation Methods 39
14 Data Quality (Usability) Assessment 39
14.1 Data Usability Assessment 40
14.1.1 Data Processing Guidelines 40
14.1.2 Roles, Responsibility, and Documentation 41
14.2 Data Analysis Methods 41
14.3 Data Presentation and Reporting 41
14.3.1 Annual Report 42
14.3.2 Final Report 42
15 References 44
16 List of Revisions 45
17 Glossary 46

List of Figures

Figure 1. Map of current SS4WQ program routes. 4
Figure 2. Monitoring site location map. 5
Figure 3. Photograph of site SS2 inlet. 21
Figure 4. Photograph of site SS3 inlet. 21
Figure 5. Photograph of site SS4 inlet. 22
Figure 6. Photograph of site SS5 inlet. 22
Figure 7. Monitoring station schematic detail (plan view). 28
Figure 8. Monitoring station schematic detail (section view). 29

List of Tables

Table 1. Common stormwater pollutants and their sources (Ecology 2006, modified). 6
Table 2. Parameters to be analyzed. 6
Table 3. Monitoring station location information. 9
Table 4. Study team key individuals. 10
Table 5. Roles and responsibilities description. 11
Table 6. Data quality objectives. 14
Table 7. Precision validation criteria. 15
Table 8. Association of precision QC sample type to sample results. 16
Table 9. Accuracy validation criteria. 16
Table 10. Association of accuracy QC type to sample results. 17
Table 11. Sensitivity MQOs in stormwater. 18
Table 12. Sensitivity MQOs for hydrologic monitoring. 18
Table 13. Qualifying storm event criteria. 23
Table 14. Qualifying composite sample collection criteria. 23
Table 15. Stormwater sample collection goal. 25
Table 16. Field QC sample description and goals. 30
Table 17. Sample containers, holding times and preservation methods. 31
Table 18. Laboratory quality control samples 34
Table 19. Assessment and response action schedule. 36
Table 20. Data qualifier definitions. 38

Quality Assurance Project Plan

Street Sweeping Water Quality Effectiveness Study

This Quality Assurance Project Plan (QAPP), prepared by Seattle Public Utilities (SPU), describes the Street Sweeping Water Quality Effectiveness Study which is being conducted as an independent effectiveness study per section S8.C.3 of the 2013 National Pollutant Discharge Elimination System (NPDES) Municipal Phase I Stormwater Permit (Permit)

The primary goal of this QAPP is to define procedures that ensure the quality and integrity of the collected samples, help interpret the acceptability and usability of the sample data using project-specific Data Quality Indicators (DQIs), and ultimately delivers defensible products and decisions for SPU and the Street Sweeping for Water Quality (SS4WQ) Program.

This document was developed with guidance from the Washington State Department of Ecology (Ecology), Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004).

This QAPP is organized and presented using the following elements:

I. Goals and objectives of the study,

II. Type, quality, and quantity of data needed to meet the objectives,

III. Sampling and measurement procedures needed to acquire those data,

IV. Quality Assurance (QA)/Quality Control (QC) procedures to ensure the QAPP is implemented as prescribed, and

V. Assessment procedures to determine if the data conform to specified criteria and satisfy the study objectives. Additionally, this element presents the analysis and format for presentation of the results.

ELEMENT I. GOALS AND OBJECTIVES OF THE STUDY

This element covers basic project management, including project background and objectives, roles and responsibilities of participants, and other factors to ensure that the project has a defined goal and clear outcomes understood by all the participants. This element includes the following sections:

Section 3 – Background

Section 4 – Project Description

Section 5 – Organization and Schedule

3 BACKGROUND

The 2013 NPDES Permit uses a collective funding approach to fund the three components of the Regional Stormwater Monitoring Program (RSMP) created under the Permit: 1) status and trends monitoring, 2) stormwater management program effectiveness studies, and 3) source identification and diagnostic monitoring. Components 1 and 2 have an "opt out" option that allows Permittees to perform their own monitoring or studies in lieu of paying all or some of their allotted payment amount to the regional fund.

In a letter dated November 26, 2013, SPU notified Ecology that we had selected Effectiveness Studies Option Number 3. This means SPU will both pay into a collective fund to implement RSMP effectiveness studies and independently conduct an effectiveness study that will not be undertaken as part of the RSMP. The effectiveness study that SPU selected, which is the subject of this QAPP, is to study the effectiveness of street sweeping at reducing pollution in urban stormwater runoff. A brief account of the background that led Seattle to want to study this topic is discussed below.

The City of Seattle (Seattle) has been using street sweeping as a good housekeeping practice since the early 1900s. Street sweeping technology has changed significantly over the last two decades. The newer model sweepers use regenerative air and vacuum technology to remove very fine particulates (less than 10 microns). By mass, these smaller particles carry more pollutants than larger street dirt particles.

In 2006, SPU conducted a pilot study, which showed that street sweeping was effective at reducing roadway pollutants. In 2009, SPU further evaluated the economics of street sweeping and found it to be a cost-effective method for reducing the stormwater pollutant load from City roadways.

In February 2011, SPU launched the Street Sweeping for Water Quality (SS4WQ) Program which is a partnership between SPU and the Seattle Department of Transportation (SDOT). Under the direction and funding of SPU, a limited number of SDOT's regenerative air sweepers are used on roadways that drain to surface waters as a source control/stormwater management activity.

SPU sets the program direction and provides water quality expertise and funding for the portion of routes that discharge directly to Seattle's receiving waters. Currently, 24 routes covering 660 lane miles, of which 490 drain to surface waters; are swept using regenerative air sweepers. SDOT provides operational expertise, street sweeping services and funding for the portion of the non-SS4WQ routes on roadways that drain to a sewage treatment plant.

With technological improvements in street sweepers, the ability of sweepers to reduce street dirt yield and remove finer particulate matter specifically has been documented by the ongoing SPU SS4WQ program monitoring of the SS4WQ program (which currently monitors street dirt collected but does not

directly monitor water quality) and several recent national studies. However, the direct effect of street sweeping on stormwater quality has not been well studied and/or the limited studies have not had sufficient rigor. In a 2007 study, significant differences between stormwater runoff from swept and unswept streets were not detected in a Madison, Wisconsin study (USGS, 2007); however, this was likely due to a flawed design and potential uncontrolled sources of variability. A recent study by the City of San Diego did detect significant differences in stormwater quality between swept and unswept roadways but was based on a limited number of grab samples (City of San Diego, 2010). The study documented in this QAPP is designed to add to the knowledge base about the effectiveness of street sweeping on stormwater quality.

3.1 Study Area

The SS4WQ program routes across Seattle are presented in Figure 1. As discussed later in this report, the current SS4WQ routes were assessed to find locations that would be suitable for monitoring. After an initial screening using Geographical Information System (GIS) and field reconnaissance, grab samples were collected to further characterize the sites. Based on these assessments, four inlets on M.L. King Way S between S Lilac and S Hudson Streets in South Seattle were selected as the monitoring locations for this study. These locations are designated SS2 through SS5 and are presented in Figure 2.

3.2 Parameters of Interest

Pollution sources that may affect stormwater quality include land use activities, operation and maintenance activities, illicit discharges and spills, atmospheric deposition, and vehicular traffic conditions. Many of these sources are not under the direct control of the municipalities that own or operate storm sewers. Table 1 lists common stormwater pollutants with related potential sources.

The parameters of interest for this study have a history of association with stormwater discharges, are found in urban environments, and/or are commonly used to evaluate stormwater Best Management Practices (BMPs). Table 2 contains the water quality and related parameters that will be collected for this study.

Figure 1. Map of current SS4WQ program routes.

Figure 2. Monitoring site location map.

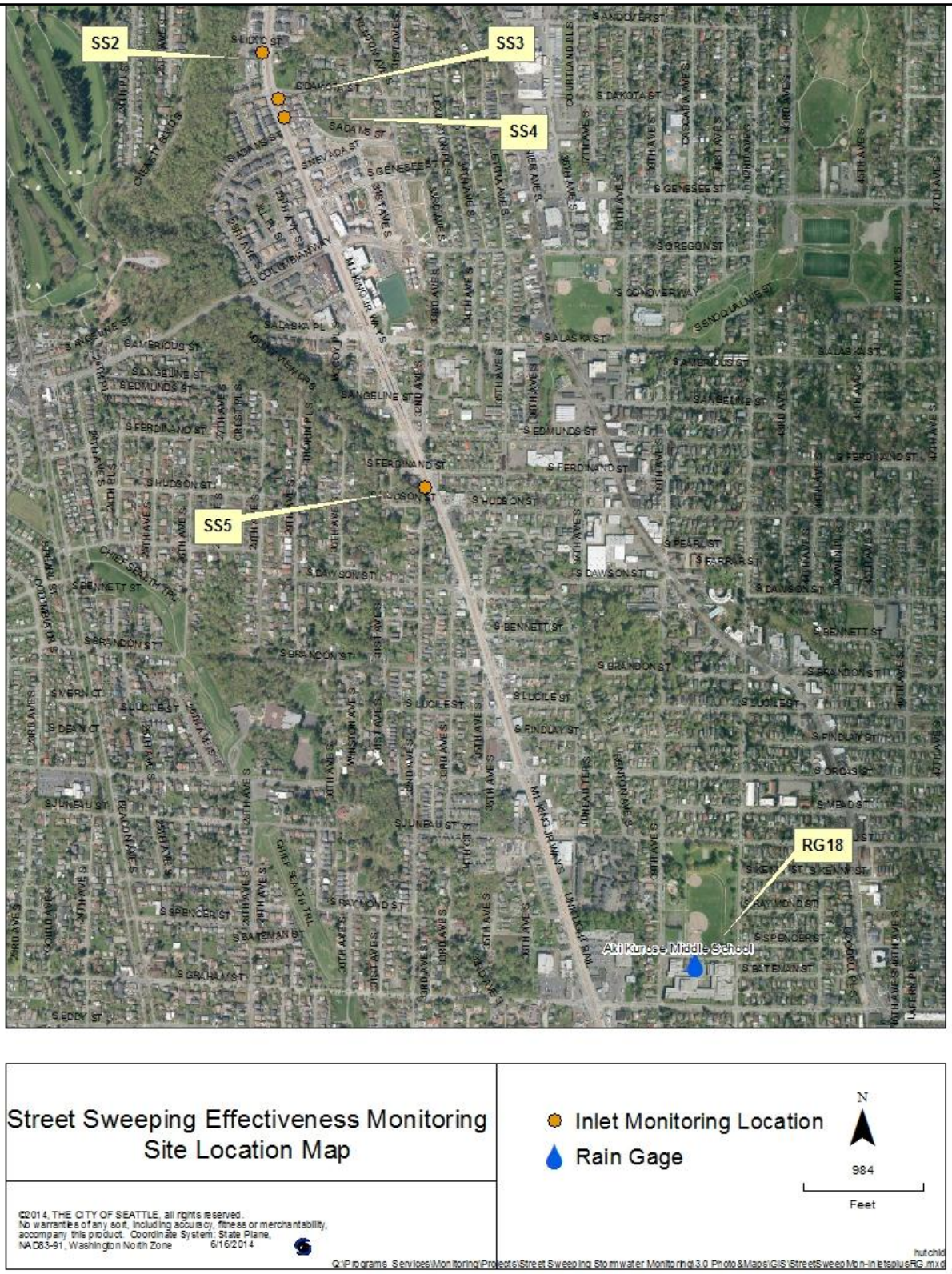


Table 1. Common stormwater pollutants and their sources (Ecology 2006, modified).

Pollutant	Potential Sources
Arsenic	Atmospheric deposition (ASARCO Smelter, fossil fuel combustion)
Cadmium	Tire wear, metal plating, batteries
Chromium	Metal Plating, rocker arms, crank shafts, brake linings, yellow lane strip paint
Copper	Vehicles (brake pads, thrust bearings, bushings), copper pesticides, atmospheric deposition from fuel combustion and industrial processes
Lead	Motor oil, transmission bearings, gasoline
Zinc	Vehicles (motor oil, tire wear), galvanized materials (roofing – flashing, down spouts, uncoated galvanized roofs, pipes, fencing)
Bacterial/Viral Agents	Wild and domestic animals, septic systems, animal & manure transport
Nutrients	Sediments, fertilizers, wild and domestic animals, septic systems, vegetative matter
Oil & Grease	Motor vehicles, illegal disposal of used oil
Organic Toxins	Pesticides, combustion products, petroleum products, paints & preservatives, plasticizers, solvents
Oxygen Demanding Organics	Vegetative matter, petroleum products
Sediments	Construction sites, stream channel erosion, poorly vegetated lands, slope failure, vehicular deposition, atmospheric deposition
Temperature	Pavement runoff, loss of shading along streams

Table 2. Parameters to be analyzed.

Group Type	Parameter
Conventional parameters in stormwater	Total Suspended Solids (TSS)
	Total Organic Carbon (TOC)
	Chemical Oxygen Demand (COD)
	Suspend Solids Concentration (SSC)/Particle Size Distribution (PSD)
	pH
	Hardness
Metals (total and dissolved) in stormwater	Copper
	Zinc
Nutrients in stormwater	Total Phosphorus
	Nitrate-Nitrite (N03-N02)
	Total Kjeldahl Nitrogen (TKN)
Organics in stormwater	Polycyclic Aromatic Hydrocarbons (PAHs)*
Bacteria in stormwater	Fecal coliform*
Stormwater flow data	Level/flow at each inlet
Precipitation data	Local rainfall in project area

** - Fecal coliform and PAHs are secondary parameters that will be attempted initially. If grab sample collection and meeting related holding times becomes problematic, these parameters may be discontinued.*

3.3 Previous Studies

On behalf of SPU, Herrera Environmental Consultants (Herrera, 2005a) conducted a literature review of street sweeping and catch basin effectiveness. Two general approaches for evaluating effectiveness were typically used by the studies reviewed. The first was a monitoring approach where stormwater samples were collected and pollutant concentrations or pollutant loads were compared between treated and untreated areas. The second was a modeling approach where solids and other non-stormwater

data were collected in order to calibrate a model that estimates water quality in relation to sediment accumulation and transport.

Next, Herrera (2005b) evaluated the advantages, disadvantages, and relative costs associated with the monitoring approaches identified in the literature and provided recommendations for the future SPU street sweeping pilot study.

SPU sponsored a one-year street sweeping pilot study which started in 2006 to evaluate whether street sweeping could significantly reduce the mass of pollutants that could be discharged to receiving water bodies while reducing the frequency of catch basin cleaning by removing sediment/debris from the street before it is transported in stormwater runoff. The study used a mass balance approach, which focused on measuring the amount of sediment and associated pollutants present on the street, removed by sweeping, and accumulated in catch basins between test (swept) and control (unswept) sites, rather than measuring stormwater quality to quantify the effects of street sweeping. Street sweeping was found to have the potential to be a cost effective strategy for removing pollutants when compared to cleaning catch basins or to a regional stormwater treatment facility (SPU and Herrera 2006).

SPU elected to build upon the 2006 Pilot Study and further evaluate street sweeping as the Program Effectiveness monitoring component (Special Condition S8.E) required under the 2007 NPDES Phase I Municipal Stormwater permit. As the “Targeted Action” element of the S8.E monitoring, SPU re-analyzed archived street dirt and sweeper waste samples collected during the 2006 pilot study to compare the effectiveness of street sweeping to structural stormwater BMPs. Using a target that structural stormwater BMPs reduce the average street dirt load by 60 percent for fine particles (less than 250 microns in diameter), the study determined that street sweeping removed a significantly greater load for both sediment and metals (chromium, copper, lead and zinc) as compared to structural BMPs (SPU 2012).

For the “Target Outcome” element of the S8.E monitoring, SPU created a spreadsheet model that predicts an annual load reduction (using TSS as a surrogate pollutant) for varying conditions such as sweeping frequency, sweeper speed and parking enforcement compliance.

The ongoing SS4WQ monitoring program builds on the foundation of the 2006 pilot study and follow-up 2007 permit S8.E study by collecting street dirt/sweeper waste samples and using a modeling approach to estimate water quality benefits. However, the scale of the current monitoring program is greatly expanded over the pilot (e.g., 662 miles under the current monitoring program vs. 3.5 miles of roadway for the pilot study, additional land use types monitored [multiple commercial/minor industrial routes currently vs. one industrial and two residential basins in the pilot], and multiple and higher sweeper speeds [5 and 8 miles per hour currently vs. 5 miles per hour during the pilot]).

Between November 2013 and March 2014, six rounds of roadway runoff grab samples were collected from six storm drain inlets along a section of M.L. King Jr. Way S in Seattle to assist in final sampling station site selection for the study described in this QAPP. Three rounds of samples were collected during a period when the roadway was being swept on a weekly basis and three rounds of samples were collected from the same locations during a period that no sweeping was occurring (n=3 for each treatment – swept/unswept). Based on this limited data set, a significant difference was detected for the three parameters analyzed (total suspended solids, total copper and total phosphorus) at all monitoring locations. This preliminary evaluation suggests that street sweeping may have a statistically significant beneficial impact on water quality (SPU 2014).

In addition to these internal SPU studies, street sweeping has been evaluated by others over the years beginning with 1983 Nation Urban Runoff Pollution (NURP) study (NURP 1983) and

continuing to the present. However, it is SPU's opinion that there has not been a well-designed and implemented study on the water quality effectiveness of current sweeper technology.

4 PROJECT DESCRIPTION

This section presents the goals and objectives of the project; describes the boundaries, target populations, and practical constraints of the study; and specifies the information and data required to meet the study objectives.

4.1 Study Goals

The goal of this study is to quantify the effect of street sweeping on stormwater quality by directly measuring runoff concentrations from roadways from swept and unswept treatments. Specifically, this study will assess the ability of the current regenerative air Schwarze® A9 Monsoon™ street sweepers utilized by SDOT to reduce pollution in stormwater runoff. This study will serve as SPU's independent effectiveness study per section S8.C of the 2013 NPDES Phase I Municipal Stormwater Permit. This information will be used by SPU to more accurately credit its SS4WQ program for reducing pollution and quantify the cost effectiveness of street sweeping compared to other stormwater controls.

4.2 Information Requirements

A paired Before/After–Control/Impact (BACI) design will be used to test if stormwater quality differences can be detected when street sweeping is discontinued. Since sweeping is the normal condition for arterial roadways in Seattle, sweeping will be considered the "control" and not sweeping will be considered the "impact;" meaning that this study will be testing if by not sweeping, there is a measurable impact to stormwater quality.

The sampling design for this study consists of stormwater monitoring of roadway runoff at four monitoring stations. Grab and automatic flow-weighted composite sampling methods will be used to collect stormwater samples from 12 qualifying storm events per site per year over two years. Stormwater samples collected during each storm event will be analyzed for a suite of parameters that are identified in Table 2 to generate Event Mean Concentrations (EMCs) for these parameters.

Hydrologic monitoring will involve measurements of water level (for estimating flow using a weir as the primary measuring device) as well as precipitation depth. Flow data will be used to characterize the peak discharge rate, the runoff volume, and the flow duration at each station. Flow data will also be used to pace the automatic samplers for the purposes of collected flow-weighted composite samples. Precipitation data will be used to characterize the storm event antecedent dry period, total rainfall distribution during the sampled events, inter-event dry period, and average and peak rainfall intensity. The precipitation data will also be used to define the start and stop of qualifying storm events.

4.3 Study Boundaries

This section describes the target population, spatial and temporal boundaries of the problem, the scale of decision-making when appropriate, and any practical constraints on data collection.

4.3.1 Target Population

The population of interest is stormwater quality entering four storm drain catch basin inlets along M. L King Jr. Way S in Seattle under swept and unswept conditions.

4.3.2 Spatial Boundaries

Stormwater samples and flow data will be collected from four inlets to the stormwater drainage system located along M.L. King Jr. Way S between S Lilac and S Hudson Streets in South Seattle. These inlets, the roadway surface and the adjacent Sound Transit Light Rail line where installed in approximately 2008 as improvements related to the light rail construction. The four monitoring stations are shown on Figure 2 and details are listed in Table 3.

Table 3. Monitoring station location information.

Station ID	Address	FEA_KEY	EQNUM_ID	X_COORD	Y_COORD
SS2	4051 M. L. King Way Jr S	7329200	978552	1279074.49	210314.26
SS3	2961 S Dakota (on M. L. King Way Jr. S)	4061938	929412	1279202.99	209938.85
SS4	4118 M. L. King Way Jr S	7331900	978926	1279257.93	209787.44
SS5	No address, approx. 4925 M. L. Jr Way S, 130' south of S Ferdinand St	7349489	983834	1280405.63	206774.28

4.3.3 Temporal Boundaries

The temporal boundaries of this study are dependent on both the approval by SDOT of a street use permit and the approval of this QAPP by Ecology.

It is anticipated that monitoring equipment will be installed during September 2014 and stormwater sampling will begin after October 1, 2014. Sampling will be performed over Water Year (WY – which extends from October 1 to September 30 with the second year being the year the water year is named after) 2015 under swept conditions at all locations and WY2016 under swept conditions at the control locations (SS2 and SS5) and unswept conditions at the impact locations (SS3 and SS4). Thus, the goal for the sampling period temporal boundaries are October 2014 through September 2016. If delays in necessary approvals are encountered, the time period will be pushed back one year from October 2015 through September 2017. The goal during each water year is to sample 12 storm events at each of the four locations.

4.3.4 Practical Constraints

The primary practical constraints to a successful study are discussed below and include:

- Sampling design assumptions and construction and installation of equipment
- SDOT street use permit
- Ecology QAPP approval
- Typical logistical challenges associated with the difficult task of stormwater monitoring

Sampling design - Sampling and monitoring runoff into roadway inlets can be very challenging and the sampling design makes many assumptions about the ability to collect samples and monitor flow. Until equipment is designed, built, installed, and tested; the success of the sampling design is unknown.

SDOT street use permit - Each monitoring station requires an equipment cabinet to be installed in the right-of-way. SDOT is the agency with authority to issue permits for usage of the right-of-way. The street use permit applications have been completed and submitted but there is no guarantee that the permits will be approved.

Ecology QAPP approval - This QAPP is due to Ecology on August 5, 2014 but can be submitted earlier. Per the Permit language, "if Ecology does not request changes within 90 days of submittal, the QAPP is considered approved."

Logistical challenges - The unpredictable nature of storm events poses one of the greatest logistical challenge for this study. Only storms of particular depths and intensities will result in qualifying storm events and successful sample collection. However, the location, timing, duration, magnitude, and intensity of storm events cannot be forecast with certainty.

Since long-term forecasts have greater uncertainty, mobilization of field staff and equipment setup for a potential storm sampling event cannot happen more than two days ahead of a forecasted storm. It is not uncommon that during long duration and intense monitoring studies, equipment malfunction and human error will result in unsuccessful sample collection of qualifying storm events.

Although sites are selected to minimize safety concerns, traffic control will be necessary to access the monitoring stations safely. This is a special concern with a heavy traffic arterial like M. L. King Jr. Way S. Access may be necessary during high traffic periods, at night, and/ or during severe weather. These access conditions pose additional logistical challenges for sample collection.

4.3.5 Decision Making

The field sampling team led by Herrera will make the decision to mobilize the sample team for stormwater sampling based on weather forecasts and input from the Principal Investigator (PI) (Table 4). Qualifying event criteria will be used to determine if the event was successful and samples are submitted to the laboratory. The PI will make the final decision on the usability of the data for the final analysis.

5 ORGANIZATION AND SCHEDULE

This section describes the roles and responsibilities of the study team, the study timeline and schedule.

5.1 Roles and Responsibilities

Contact information for key individuals involved in the study is provided in Table 4 and the responsibility associated with each role is described in Table 5.

In general, the PI is assigned to manage the monitoring study. In this role, he provides technical expertise; coordinates sampling activities with the laboratory and the Study Manager (SM), who coordinates the field team; and reports the status and results of the study to the Program Manager. For this project, the PI and Study Manager (SM) are the same person.

Table 4. Study team key individuals.

Role	Name	Organization	Telephone No.
NPDES Permit Coordinator	Kate Rhoads	SPU	206.684.8298
NPDES Monitoring Lead (Principal Investigator and Study Manager)	Doug Hutchinson	SPU	206.233.7899
QA Coordinator	Amy Minichillo	SPU	206.684.0974
Field Supervisor	Dylan Ahearn	Herrera Environmental Inc.	206.441.9080
Data Steward/Data Validator	Jennifer Arthur	SPU	206.286.4651
Laboratory Project Manager	Mark Harris	Analytical Resources Inc.	206.695.6200

Table 5. Roles and responsibilities description.

Roles & responsibilities
NPDES Permit Coordinator. Coordinates the requirements specified by the NPDES stormwater permit. Coordinates with Ecology representative. Provides study/program direction. Ensures that there is sufficient managerial, technical and support staff with the authority and resources (equipment, etc.) to perform their stated duties.
Principal Investigator (PI) Responsible for the development, approval, implementation, and maintenance of the QAPP. Acts as a liaison between the analytical laboratory, the study manager, the field team leader, the QA Coordinator and the organization. Responsible for: maintaining records of QAPP distribution, including appendices and amendments; identifying, receiving, and maintaining study quality assurance records; coordinating with the QA Coordinator to resolve QA- related issues. Notifies Permit Coordinator of particular circumstances that may adversely affect the quality of data derived from the collection and analysis of samples. Ensure that staff has the necessary education, experience, and/or training to perform their stated duties. Enforces corrective action.
Quality Assurance Coordinator (QAC) Reports to the Principal Investigator indirectly and is independent of the field, laboratory, data, and reporting staff. Major responsibilities include monitoring QC activities to determine conformance, distributing quality related information, training personnel on QC requirements and procedures, reviewing QA/QC plans for completeness, noting inconsistencies, and signing-off on the QA plan and reports.
Study Manager (SM) Responsible for ensuring tasks and other requirements in the contract for field implementation are executed on time and are of acceptable quality. Monitors and assesses the quality of work. Coordinates attendance at conference calls, training, meetings, and related study activities. Responsible for verifying QAPP compliance and ensuring the study produces data of known and acceptable quality. Ensures adequate training and supervision of all monitoring and data collection activities. Complies with corrective action requirements. Supervises the assigned study personnel (scientists, technicians, and support staff) and is directly or indirectly responsible for their efficient utilization. Other specific responsibilities include: coordinate study assignments in establishing priorities and scheduling, ensure the completion of high-quality studies within established budgets and time schedules, provide guidance and technical advice to those assigned to studies by evaluating performance, implement corrective actions and provide professional development to staff, and prepare and/or review preparation of study deliverables, interact with clients, and technical reviewers to ensure technical quality requirements are met in accordance with contract specifications.
Field Supervisor Responsible for: supervising all aspects of the sampling and measurement in the field; directing monitoring equipment installation and operations and maintenance and decommissioning of monitoring locations, acquisition of samples and field data measurements in a timely manner that meet the quality objectives; field scheduling, staffing, and ensuring that staff are appropriately trained.
Data Steward/Data Validator Responsible for the acquisition, verification, and transfer of data to the SPU EQuIS™ database. Oversees data management for the study. Ensures data are submitted according to work plan specifications. Responsible for validation and verification of data collected. Point of contact with project analytical laboratory to resolve issues related to the data.
Laboratory Project Manager Responsible for supervision of laboratory personnel involved in generating analytical data for this study. Responsible for ensuring that laboratory personnel involved in generating analytical data have adequate training and a thorough knowledge of the QAPP and all SOPs specific to the analyses or tasks performed and/or supervised. Responsible for oversight of all laboratory operations, ensuring compliance with all QA/QC requirements, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates instrument audits. Responsible for supervising and verifying all aspects of the QA/QC in the laboratory. Performs validation and verification of data before the report is sent to the PI. Ensures that all QA reviews are conducted in a timely manner from real-time review at the bench during analysis to final transfer of data to the QA officer.

5.2 Special Training Needs/Certification

Field personnel will either receive training in proper sampling and field analysis for sampling and monitoring task required and/or they will demonstrate to the Field Supervisor (in the field) their ability to properly collect grab samples, operate the automatic samplers and retrieve the samples.

In addition to technical training, field personnel will receive training that addresses stormwater monitoring activities that have the potential to adversely affect their health and safety. Stormwater monitoring field crews often work in wet, cold, and poor visibility conditions. Sampling sites will be located in high traffic areas that need to be accessed on a 24-hour basis. Monitoring personnel and workers installing or maintaining equipment will be exposed to traffic hazards, confined spaces, biological hazards (e.g., stagnant water), vectors (e.g., rats, spiders), fall hazards, hazardous materials, fast moving stormwater, and slippery conditions. Field personnel will be required either to obtain, or already process, necessary certifications such as Confined Space Entry and Flagger certification.

The selected laboratory will be accredited or registered under the provisions of Accreditation of Environmental Laboratories, Chapter 173-50 Washington Administrative Code (WAC).

5.3 Timeline/study schedule

This section specifies the relevant deadlines for the study. The critical milestones are provided below.

Key dates include:

November 2013	SPU notifies Ecology in writing that we will both pay in to the Regional Stormwater Monitoring Program and perform an independent effectiveness project (Effectiveness Studies Option #3 of S8.C.3)
November 2013-March 2014	Program development begins. Six potential monitoring sites are selected and grab samples are collected to assess site suitability.
January 2014	SPU submits detailed study proposal to Ecology (S8.C.3.b.ii).
April 2014	Ecology approves SPU's study proposal. QAPP due August 5, 2014 (120 days from day of approval).
May-August 2014	Project development continues. SDOT permits obtained. QAPP prepared.
August 5, 2014	QAPP due to Ecology
September 2014	Monitoring equipment installed.
October 2014 – September 2015	First Water Year of sample collection under swept conditions at both control and impact sites. Goal is to sample 12 events at each site.
October 2015 – September 2016	Second Water Year of sample collection under swept conditions at control sites and unswept conditions at impact sites. Goal is to sample 12 events at each site.
October 2016-March 2017	Data evaluated and report prepared
March 2017	Final report submitted to Ecology

Note on timeline – SPU would prefer to begin monitoring approximately September/October 2014. However, given that either the Ecology approval of this QAPP and SDOT permits necessary to begin the project may not be obtained under after October 2014, there is the possibility that the whole schedule may be pushed back one year and sampling would not begin until October 2015.

5.3.1 Study Deliverables

This section describes the project deliverables. Section 14.3 provides additional details describing the procedure and method for developing the deliverables.

The final results of the study, which include the efficiency measured, will be presented in one final report submitted when the study is completed. Study status and updates will be presented in the annual NPDES Phase I Municipal Stormwater Report due each March 31, which documents activities of the previous year. Annual reports will include a narrative summarizing the status of implementing the study, number of events successfully sampled, any major problems or setbacks encountered, and a tabular summary of analytical results collected during the period covered by the annual report. Since no conclusions can be made until sweeping is ceased and the "after impact" samples are collected, these

annual reports are considered interim reports and thus no efficiency evaluations will be presented in the annual reports.

When all samples are collected, one stand-alone report will be submitted to Ecology and posted on SPU's webpage. This final report will include analytical data in both tabular and graphical form, hydrographs for each event sampled (displaying rainfall, flow and sample aliquot information) and results of statistical analysis comparing runoff from swept and unswept treaments.

5.3.2 Study Success Factors

The indicator of success for this study is the successful sample collection, analysis, statistical testing and reporting as described in this QAPP.

Element II. Type, Quality, and Quantity of Data Needed

This element describes the type, quality, and quantity of data needed to meet the study objectives and includes:

Section 6 - Quality Objectives, which describe the type and quality of data needed to meet the study goals and objectives.

Section 7 - Sampling Process Design, which determines the quantity of data needed.

6 QUALITY OBJECTIVES

This section presents the Data Quality Objectives (DQOs) and Measurement Quality Objectives (MQOs), which describe the type and quality of data needed to meet the study goals and objectives.

DQOs are qualitative and quantitative statements developed using the DQO process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors. These form the basis for establishing the quality and quantity of data needed to support decisions.

Once established, DQOs become the basis for the MQOs are used specifically to address analytical performance. MQOs are "acceptance criteria" for the quality attributes measured by the study data quality indicators (DQIs). During study planning, MQOs are established as quantitative measures of performance against selected DQIs, such as precision, bias, representativeness, completeness, comparability, and sensitivity. By extrapolation, data that meets defined MQOs are considered acceptable for use in study decision making.

6.1 Data Quality Objectives

DQOs serve to guide the eventual determination of the data quality that is needed to make good decisions, but do not directly set criteria for the quality of the data or express data quality characteristics. The outputs of a DQO process are needed to determine the number, type and locations of samples that must be collected and analyzed.

The DQO's for the study are listed in Table 6.

Table 6. Data quality objectives.

DQO Step	Statement
1. Define the problem	There is an existing data gap whether street sweeping has a measureable effect on stormwater quality and the magnitude of this effect. The effect of street sweeping on stormwater quality using current sweeping technology (high efficiency regenerative air sweepers) has not been well studied and/or the limited recent studies have not had sufficient rigor.
2. Identify the goal of the study	To quantify the change in stormwater runoff concentration by using high efficiency regenerative air street sweepers on a weekly basis. This quantification will be used to adaptively manage SPU's Street Sweeping for Water Quality program.
3. Identify information inputs to the decision	Stormwater concentration of runoff from swept to unswept roadways, flow volume, rainfall and sweeper operator information.
4. Define the boundaries of the study	Monitoring sites will be four inlets to the stormwater drainage system located along M.L. King Jr. Way S between S Lilac and S Hudson Streets in South Seattle. The study will be conducted over two consecutive years beginning in October 2014 and ending September 2016.
5. Develop the analytic approach	A paired Before/After–Control/Impact (BACI) design will be used to test if stormwater quality differences can be detected when street sweeping is discontinued. Stormwater monitoring will be conducted at four sites located on the same arterial street with similar characteristics, where two sites will serve as Control sites (swept on a weekly basis) and two sites will serve as Impact sites (not swept during the impact/after period). The four sites will be monitored over a two year period where Year 1 (2014-

DQO Step	Statement
	2015) represents the *Before* condition and Year 2 (2015-2016) represents the *After* condition. A 2-factor analysis of variance (ANOVA) test will be conducted to determine whether there are significant differences in pollutant concentrations between stormwater from swept and unswept roadways.
6. Specify acceptance or performance criteria	For samples to be submitted for analysis, the qualifying storm event and sampling criteria (Table 13 and Table 14). For analytical and hydrological data to be used in the study analysis, data must meet the Measurement Quality Objectives listed in Section 6.2.
7. Develop the detailed plan for obtaining data	This QAPP serves as the detailed plan for obtaining data.

6.2 Measurement Quality Objectives

Measurement quality objectives (MQOs) specify how good data must be to meet the objectives of the study. MQOs are the performance or acceptance thresholds or goals for the study's data, based primarily on the data quality indicators. Another name for MQOs is measurement performance criteria (MPC). For existing data, these correspond to acceptance criteria. MQOs are used to select procedures for sampling, analysis and quality control (QC).

Of the six principal DQIs, precision, bias, and sensitivity are quantitative measures; representativeness and comparability are qualitative; completeness is a combination of both qualitative and quantitative measures; and accuracy is a combination of precision and bias.

6.2.1 Precision, Bias and Accuracy

Precision refers to the degree of agreement among independent measurements as the result of repeated application of the same process under similar or prescribed conditions. Precision reflects random error and may be affected by systematic error. It also reflects variation imposed by a given matrix (e.g., sediment, effluent or water).

Precision will be demonstrated by analysis of laboratory sample duplicates (LD), field sample duplicates, laboratory control sample duplicates (LCSD) and matrix spike duplicates (MSD). The following table lists the qualification actions resulting from the precision analysis.

Table 7. Precision validation criteria.

Original & Duplicate		Associated Sample	Action
Criterion 1	**Criterion 2**		
Both Original and Dupicate Results < 5x RL		Result < RL (non-detects)	Qualify sample results as estimated non-detect (UJ).
	|original - duplicate| > RL	Result > RL (detects)	Qualify sample results as estimated (J).
	|original - duplicate|≤ RL	All	No qualification needed.
		Result < RL (non-detects)	Qualify sample results as estimated non-detect (UJ).
	|original - duplicate| > 2x RL	Result > RL (detects)	Qualify sample results as estimated (J).
	|original - duplicate|≤ 2x RL	All	No qualification needed.
Both Original or	RPD† > 20*%	Result < RL (non-detects)	Qualify sample results as estimated non-detect (UJ).

Original & Duplicate		Associated Sample	Action
Criterion 1	**Criterion 2**		
Duplicate Results > 5x RL		Result > RL (detects)	Qualify sample results as estimated (J).
	RPD ≤ 20*%	All	No qualification needed.
	RPD > 35%	Result < RL (non-detects)	Qualify sample results as estimated non-detect (UJ). Note in report.
		Result > RL (detects)	Qualify sample results as estimated (J).
	RPD ≤ 35%	All	No qualification needed.

RL – Reporting Limit

† RPD – Relative Percent Difference between the original and the duplicate, calculated as follows:

$$RPD = 100 \times \left| \frac{(original - duplicate)}{Mean\ (original, duplicate)} \right|$$

*An RPD control limit of 25% will be used when assessing field duplicate water samples.

The following table illustrates the application of qualifiers to sample results based on the precision QC sample types.

Table 8. Association of precision QC sample type to sample results.

QC Sample Type	Associated Results
Lab Duplicate	All results in prep batch
Laboratory Control Sample Duplicate	All results in prep batch
Matrix Spike Duplicate	Parent sample results[1]
Field Duplicate/ Field Split	Parent sample results only[2]

Notes:

1. In cases where the only associated precision QC was the MSD, the MSD will be used to evaluate all results in the prep batch.

2. In cases where the laboratory was deficient in providing laboratory precision QC, field precision QC will be used to evaluate all results in each prep batch.

Accuracy is the degree of agreement between an observed value and a "true" value and includes a combination of the random error (precision) and systematic error (bias) components that result from the sampling and analytical procedures.

Analytical accuracy will be demonstrated by analysis of matrix spikes (MS), laboratory control samples (LCS), reference materials (RM) and surrogate compounds (SUR). Laboratory control limits will be used. The project laboratory (ARI) will have documentation available for the calculation their laboratory control limits, the limits prescribed in the approved methods and/or those limits provided by the manufacturer of reference materials. The following table lists the qualification actions resulting from the accuracy analysis.

Table 9. Accuracy validation criteria.

Percent Recovery*	Associated Sample	Action
%R < LowLimit	Result < RL (non-detect)	Qualify sample result as estimated non-detect (UJ).
	Result ≥ RL (detects)	Qualify sample result as estimated (J).
	Parent† > 4x spike added	No qualification needed.
%R > UppLimit	Result <RL (non-detects)	No qualification needed.
	Result ≥ RL (detects)	Qualify sample result as estimated (J).
	Parent > 4x spike added	No qualification needed.

RL – reporting limit

† Parent - The sample from which an aliquot is used to make the spiked QC sample.

* The percent recovery of the spiked compound and is calculated as:

$$\%R = 100 \text{ x } \frac{(Spiked\ QC\ Sample\ Result - Parent\ Sample\ Result)}{Spike\ amount}$$

The following table illustrates the application of qualifiers to sample results based on the accuracy of QC sample types.

Table 10. Association of accuracy QC type to sample results.

QC Type	Associated Results
LCS/LCSD/RM	All results in prep batch without additional supporting evidence
MS/MSD	All results in prep batch without additional supporting evidence
Surrogate	Results for associated analyte in current sample only

6.2.2 Representativeness

The representativeness of the data is dependent on: 1) the sampling locations, 2) the rainfall and flow occurring during sample collection, 3) the number of events and years sampling is performed, and 4) the sampling procedures. Site selection and use of only approved analytical methods will ensure that the measurement data represent the population being studied at each site.

The representativeness of the water quality data to be collected through this study will be ensured by targeting representative storms for sampling based on the criteria (listed in Table 13 and Table 14) that are based on recommended procedures in the *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE)* (Ecology 2011).

The representativeness of the hydrologic data will be ensured by the proper selection and installation of all associated monitoring equipment. Rainfall patterns, stormwater conveyance features, and surrounding land uses were also considered in the identification of monitoring locations and sampling frequencies to ensure that representative data will be obtained for this study. Monitoring will be conducted over a sufficient number of events (12 per site per year) and length of time (2 years) to ensure that data are collected during representative climatic conditions for the region.

6.2.3 Completeness and Comparability

The completeness of the analytical data will be maximized by using proven sampling techniques, packaging samples for transport to avoid breakage, and timely delivery to and processing at the laboratory. For completeness requirements, valid results are all results not rejected (qualified with an R-flag) after a usability assessment has been performed. A completeness target of 90 percent has been set for the analytical data collected during this study.

The completeness of the hydrologic data will be maximized by using a redundant system of batteries and solar panels to avoid data gaps due to power loss. Completeness of hydrologic data will be assessed on the basis of the occurrence of gaps in the data record for rainfall and flow monitoring equipment. A completeness target of 90 percent has been set for the hydrologic data collected during this study.

Comparability is a qualitative indicator of the confidence with which one data set can be compared to another data set. The objective for this project is to produce data with the greatest possible degree of comparability. Sites were initially assessed and final sites selected with base-condition runoff concentrations as comparable as possible. Comparability is also achieved by using standard methods

for sampling and analysis, reporting data in standard units, normalizing results to standard conditions, and using standard and comprehensive reporting formats. Complete field documentation using standardized data collection forms shall support the assessment of comparability.

6.2.4 Sensitivity

The following tables list the sensitivity for both analytical parameters in stormwater and hydrologic measurements. Reporting limits will be provided by the laboratory with the analytical results for each sample and may differ from the target reporting limits listed below due to matrix interference.

Table 11. Sensitivity MQOs in stormwater.

Group Type	Parameter	Target Reporting Limit	Units	Lab Method[1]
Conventional parameters	Total Suspended Solids (TSS)	1.0	mg/L	SM2540D
	Total Organic Carbon (TOC)	1.5	mg/L	EPA 415.1
	Chemical Oxygen Demand (COD)	10.0	mg/L	EPA 410.4
	Modified Suspended Solids Concentration (SSC)	1.0	mg/L	ASTM D3977-97
	pH	0.2	standard units	EPA 150.2
	Hardness as CaCO3	1	mg/L CaCO3	SM2340B
Metals - total/dissolved	Copper	0.5/(0.5)	µg/L	EPA 200.8
	Zinc	4.0/(4.0)	µg/L	EPA 200.8
Nutrients	Total Phosphorus	0.008	mg/L	SM4500-PE
	Nitrate-Nitrite (N03-N02)	0.01	mg-N/L	EPA 353.2
	Total Kjeldahl Nitrogen (TKN)	0.5	mg-N/L	EPA 351.2
Bacteria	Fecal Coliform[2]	1	cfu/100mL	SM9222D
Organics	Polycyclic Aromatic Hydrocarbons (PAHs)[2]	0.1	µg/L	8270D-SIM

1 - Or equivalent lab method.

2 - Fecal coliform and PAHs are secondary parameters that will be attempted initially. If grab sample collection and meeting related holding times becomes problematic, these parameters may be discontinued.

Table 12. Sensitivity MQOs for hydrologic monitoring.

Monitoring Equipment	Measurement Type	MQO for Percent Bias	Manufacturer Specified Operational Range	Manufacturer Specified Accuracy
Campbell Scientific CS451-L pressure transducer	Water Level	≤10%	0 to 6.7 feet	±0.1% of full-scale-range
Hydrologic Services TB3 tipping bucket rain gauge	Precipitation Depth	≤5%	0 to 27.6 inches/hour	±2% for rainfall intensities ranging from 1 to 19.6 inches/hour

7 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

This section describes the overall sampling design for this study. A background of the current street sweeping program is presented first, followed by the sampling study design overview and methods used to select the study's monitoring stations. Sampling procedures are described in Section 8.

7.1 Street Sweeping Program Overview

SPU's Street Sweeping for Water Quality (SS4WQ) program began in February 2011. Under the direction and funding of SPU, a limited number of SDOT's sweepers are used on roadways that drain to surface waters as a pollution reduction activity.

Currently, the SS4WQ program includes 24 routes covering 660 lane miles, of which 490 lane miles drain to surface waters that entails the use of Schwarze® A9 Monsoon™ regenerative air sweepers every two weeks for a period of approximately 40 weeks per year. The current SS4WQ sweeper routes are shown on Figure 1. SDOT funds and directs the street sweeping services of areas that drain to sewage treatment plants (these routes not shown).

On each swept route, only the curb lane is swept. Sweepers travel at a speed between 5 and 8 miles per hour (mph).

In 2016, the SS4WQ program will be expanded to increase the extent of arterials swept from 83 to 85 percent, increase sweeping frequency from every two weeks to weekly, and extend the sweeping season from 40 to 48 weeks per year. This study will test the effectiveness of street sweeping under the future, weekly sweeping scenario. Specifically, sweeping will occur on a weekly basis and be extended year-round on M.L. King Way S during the “swept” treatment period at relevant sites.

Street sweepings (solid material removed from roadways by sweepers) are collected by the sweepers into built-in 9.6 cubic yard hoppers on the sweeper equipment. The sweeper operators empty the hoppers into two temporary storage bins. Sweepings collected on arterials located in the northern portion of Seattle are emptied into a bin at the Haller Lake maintenance facility and sweepings collected on arterials in the southern portion of Seattle are emptied into a bin at the Charles Street facility. Bins are emptied periodically, at intervals ranging from two weeks to two months, and solids material is disposed at a waste disposal facility where the mass of the disposed materials is measured and logged.

The SS4WQ program has been tracking wet and dry sweepings load removed since mid-2011 and analyzing pollutant concentrations since December 2011. Analysis of the fine particulate matter (PM) fraction and additional pollutants on both the whole samples and fine PM fraction began in the fall of 2012.

7.2 Monitoring Strategy Overview

A paired Before/After–Control/Impact (BACI) design will be used to test if stormwater quality differences can be detected when street sweeping is discontinued. Since sweeping is the normal condition for arterial roadways in Seattle, sweeping will be considered the “control” and not sweeping will be considered the “impact;” meaning that this study will be testing if by not sweeping, there is a measurable impact to stormwater quality.

Stormwater monitoring will be conducted at four sites located on the same arterial street with similar characteristics, where two sites will serve as Control sites (swept on a weekly basis) and two sites will serve as Impact sites (not swept). The four sites will be monitored over a two year period where Year 1 (2014-2015) represents the Before condition and Year 2 (2015-2016) represents the After condition. *Note on study years – SPU would prefer to begin monitoring approximately October 2014. However, given the Ecology QAPP approvals and SDOT permits necessary to begin the project, if we are unable to begin the monitoring by October 2014, we will start in October 2015.*

The two Control sites will be monitored during typical street sweeping operations in both years. The two Impact sites will be monitored during typical street sweeping operations in Year 1 and under unswept conditions in Year 2. Sampling will be initiated in October to sample seasonal first flush conditions and continue through July of the following year to sample under both wet and dry season conditions. Thus, Year 1 sampling will be targeted from October 2014 through July 2015 and Year 2 sampling will be targeted from October 2015 through July 2016 (see note above regarding preferred or alternate schedule). Sweeping will be discontinued at the Impact sites by July, or when Year 1 sampling goals are met. This schedule provides 2 to 3 months of street dirt accumulation and equilibration at the

Impact sites between Before (Year 1) and After (Year 2) conditions. The goal is to collect 12 composite samples from each location per each year for a total of 24 samples at each site.

A paired BACI design is more powerful than a standard paired design (i.e., one control and one impact site) because it accounts for changes with location and time, whereas the standard paired design does not account for changes with time. Having two control sites and two impact sites increases the likelihood that changes to the water quality of the impact sites are due to the treatment and are not coincidental. To do this, a relationship needs to be established between the two control sites before and after the treatment is enacted to have a temporal control to determine if the relationship also changed between the two control sites.

Monitoring and sampling methods and equipment are detailed in Section 8.

7.3 Monitoring Site Selection

Finding suitable and representative monitoring locations for stormwater studies of this nature is critical to the success of the study but can be very challenging. To ensure comparable sample data, the following requirements where imposed on stormwater monitoring site selection. Each stormwater monitoring site will be located on the same arterial where the basin area of each site extends only the distance between two adjacent storm drain inlets (typically 200-300 lineal feet) and from the curb line to the roadway crown. Sites with no nighttime parking will be selected so sweepers will be the most effective and parking restrictions will not be needed. Sites need to be located in arterial roadway sections of nearly identical land use, slope, size, road surface type and condition, vegetation coverage, and similar traffic counts and type of vehicle usage. Sites also have no paving or construction activities planned for the next four years; have parking strips and adjacent residences/businesses amendable to an above-ground sampling cabinet installation; and have inlets suitable for monitoring (large enough both vertically and horizontally, enough vertical drop to bottom or water surface, abut curb, be structurally sound, etc).

Potential arterials to monitor were investigated using a GIS review and field reconnaissance to locate roadways that contain a minimum of six stations meeting the above requirements. Based on the review and field reconnaissance, six locations on M.L. King Jr. Way S were selected for initial, project development-phase grab sample monitoring. The goal of this grab sampling was to select four locations to monitor during the full phase study.

Between November 2013 and March 2014, a total of six rounds of roadway runoff grab samples were collected from the six initial sites (identified as SS1 through SS6). The original plan was to identify the four stations with the most similar water quality conditions to sample under the full phase study. Because of unresolved capacity/drainage issues observed at sites SS1 and SS6, those two sites were eliminated from future consideration. The final sites selection for the full-scale study, SS2-SS5, are shown on Figure 2 and specific location details are provided in Table 3. Photos of the four site inlets (before monitoring station installation) are shown on the following pages.

Figure 3. Photograph of site SS2 inlet.

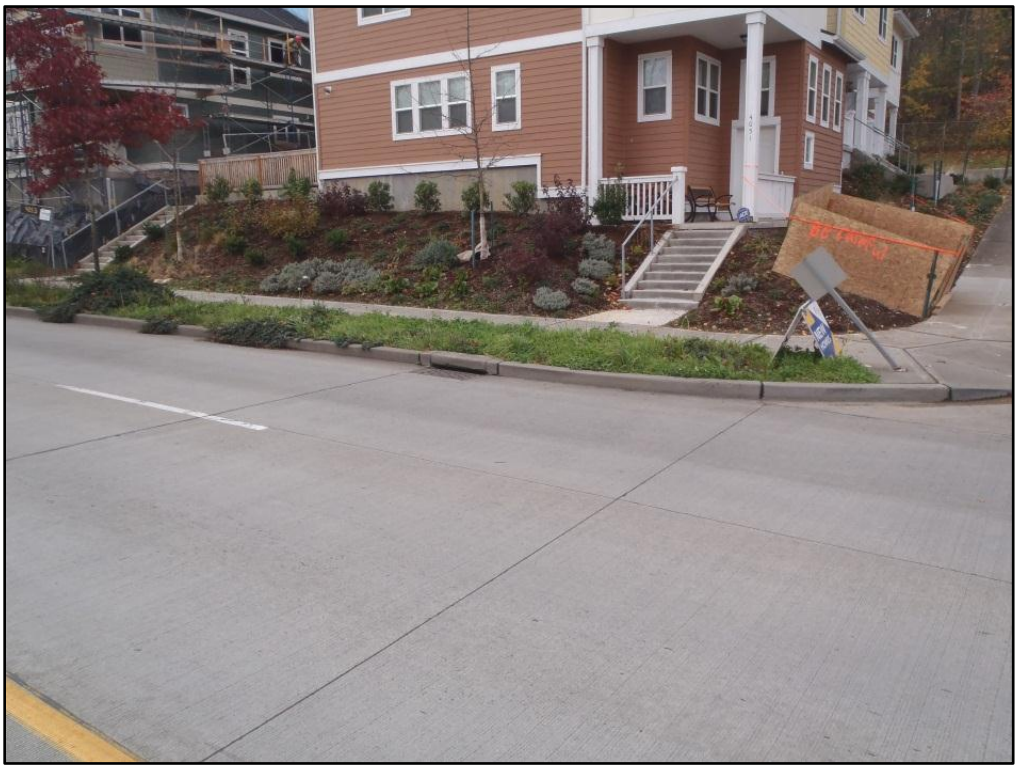


Figure 4. Photograph of site SS3 inlet.

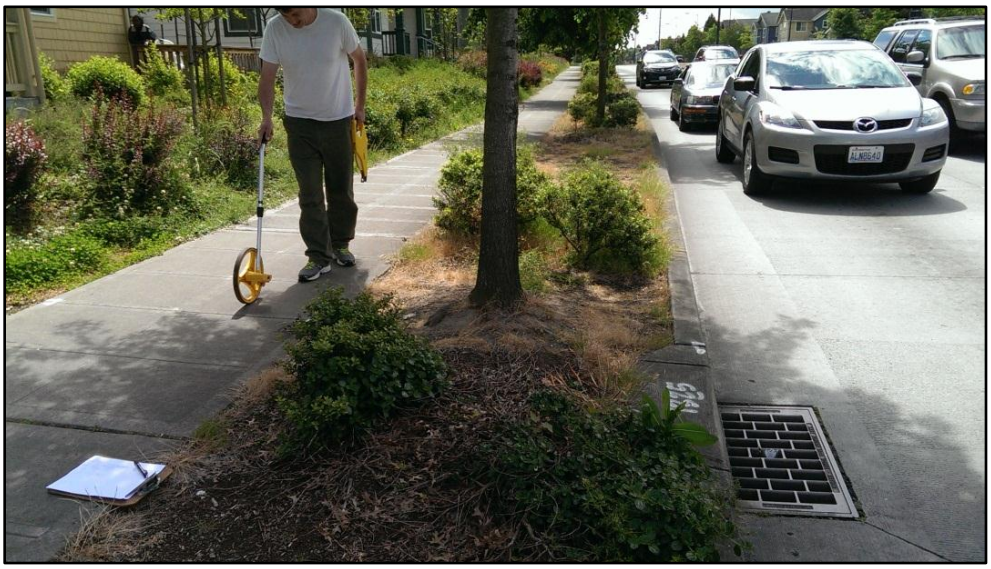
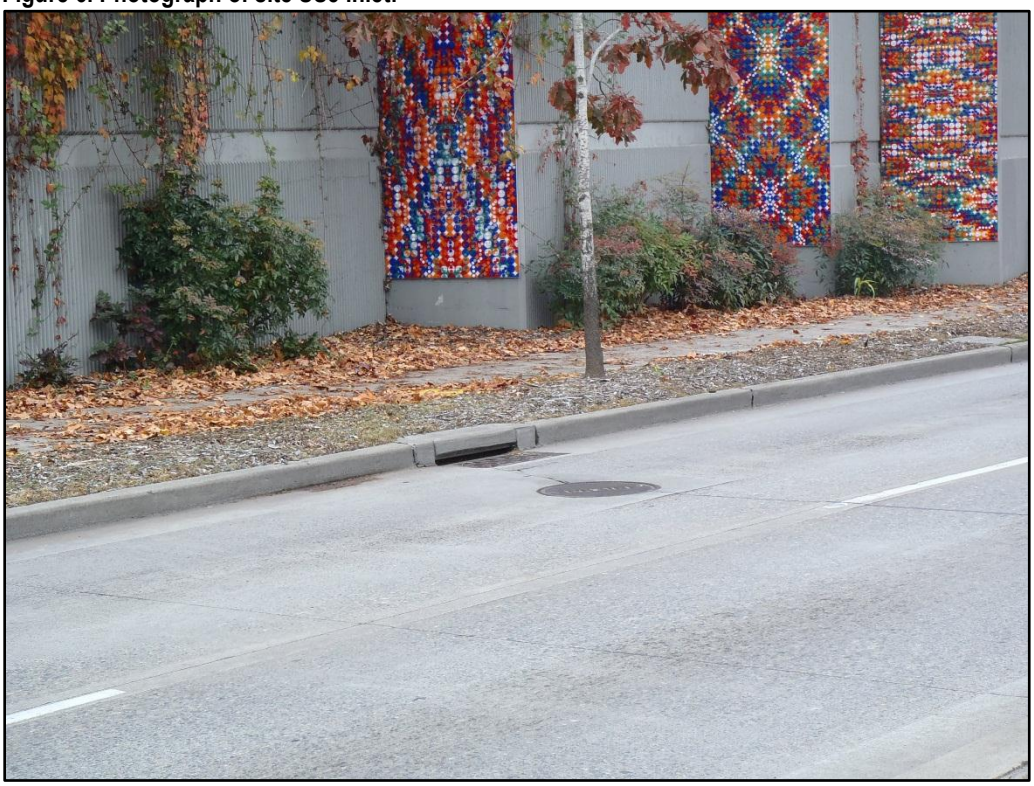


Figure 5. Photograph of site SS4 inlet.

Figure 6. Photograph of site SS5 inlet.



7.3.1 Parameters and Analytical Methods

Parameters were selected based upon their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information (see Section 3.2 for additional information). Chemical analysis will be conducted on the stormwater samples collected from each site. Analytical parameters, methods and reporting limits are listed in Table 11.

7.3.2 Qualifying Sample Criteria

This study is designed to mimic the TAPE protocol (Ecology 2011) as much as possible with a critical difference being that TAPE was established to test structural BMPs which have an inlet and outlet, have design flow rates, internal bypasses, etc.; not activities such as street sweeping.

The TAPE protocol defines "representative" storms that must be monitored when ascertaining performance of treatment BMPs. Storm event criteria are established to: 1) ensure that adequate flow will be discharged; 2) allow some build-up of pollutants during the dry weather intervals; and 3) ensure that the storm will be "representative," (i.e., typical for the area in terms of intensity, depth and duration).

Collection of samples during a storm event meeting these criteria ensures that the resulting data will accurately portray the most common conditions for each site. Ensuring a representative sample requires two considerations: 1) the storm event must be representative, and 2) the sample collected must represent the storm event.

Table 13 lists the qualifying storm event criteria to ensure the storm event sampled is representative.

Table 13. Qualifying storm event criteria.

Criteria	Requirements
Minimum storm depth	A minimum of 0.15 inches of precipitation over a 24-hour period
Minimum storm duration	Target storms must have a duration of at least one hour
Antecedent dry period	A period of at least 6 hours preceding the event with less than 0.04 inches of precipitation.
Post-storm dry period	A continuous 6-hour period with less than 0.04 inches of precipitation.

Table 14 describes the criteria to ensure the composite sample collected is representative of the storm event sampled.

Table 14. Qualifying composite sample collection criteria.

Storm event duration	<24 hours	>24 hours
Minimum storm volume to sample	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm
Minimum aliquot number	At least 10 flow-weighted sub-samples (or aliquots) must be collected during the duration of the event. If fewer than 10, but 7 or more aliquots are collected, then the sample will be considered valid only if all other sampling criteria have been met.	
Maximum time period for sample collection (hours)	36	

Element III. Sampling and measurement procedures

This element describes the sampling and measurement procedures needed to acquire the data and include:

Section 8 – Sampling (Field) Procedures, which describe the methods and equipment used to ensure that data collected are representative of the matrix; and

Section 9 – Measurement Procedures, which describes the analytical methods used by the Study.

8 SAMPLING (FIELD) PROCEDURES

This section describes field procedures that will be used to ensure that samples are collected in a consistent manner and are representative of the matrix being sampled, and the data will be comparable to data collected by other existing and future monitoring programs.

The implementation of this study will generally follow the guidance of the Ecology TAPE manual (*Ecology 2011*). The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations, practices and specific sample collection will be well planned and carefully implemented.

8.1 Sampling/Monitoring Equipment and Procedures

The following sections describe equipment and procedures that will be used to collect precipitation, flow and water quality data for this study.

8.1.1 Precipitation Monitoring

SPU collects precipitation data from a network of 17 Hydrological Services model TB03 tipping bucket rain gages located throughout Seattle. Precipitation data are collected over one-minute intervals and transmitted via wireless telemetry to a centralized server. The rain gage network is operated and maintained by both SPU staff and some sites are maintained under contract by ADS Environmental Services, Inc. (ADS).

Rain gage inspection and maintenance is performed on a quarterly basis. Maintenance includes: checking the levelness of the gage and re-leveling, if necessary, and cleaning of filter screens, drain holes and siphons. Gages are verified and calibrated annually by sending a known volume of water through the gage a minimum of two times, averaging the gage's measurement and comparing the average to the known volume. If the measurement is greater than +/- 2 percent of the actual volume, the gage is adjusted in the field until it reads within 2 percent or replaced with another gage, with the inaccurate gage sent back to the manufacturer for calibration.

The project rain gage is RG18 located at Aki Kurose Middle School at 3928 S. Graham Street which is located about 0.8 miles southeast of SS5 (see Figure 2). If feasible, a second, temporary rain gage may be installed at one of the four monitoring stations to assist with controlling the monitoring equipment but data from RG18 will be the primary rain data for this project.

8.1.2 Flow Monitoring

Stormwater flow rates entering each of the four inlets will be continuously monitored. Flow monitoring equipment will be identical at each site. Accurate flow monitoring within elements of stormwater collection systems like catch basins is challenging since these units are compact and not designed for flow monitoring. To facilitate flow monitoring, custom-made weir boxes will be installed in each

monitored catch basin. A sampling tray positioned above each weir box will direct all the flow entering each catch basin into the influent chamber of the weir box. An internal baffle will calm the flow prior to it exiting the outlet chamber where the flow will exit through a Thel-Mar volumetric weir installed in the downstream wall of the outlet chamber. The weirs will serve as the primary measurement devices which constrict and shape the flow, creating a relationship between hydraulic head and flow. Pressure transducers (Campbell Scientific Inc. CS451-L) will be installed in a stilling chamber to monitor water depth mounted upstream of the weir in the outlet chamber.

The pressure transducers will be connected to Campbell Scientific CR1000 data loggers to record water level measurements. Loggers will be programmed to record measurements every five (5) minutes. Level data will be converted to flow based on an equation provided by the weir manufacturer. Each data logger will be equipped with a digital cellular modem to provide remote access to flow data. Equipment will be powered by rechargeable batteries supported by solar panels (if possible). Aboveground monitoring equipment (data logger, modem, batteries and automatic samplers) will be housed in Knaack Jobmaster Model 4830 storage cabinets. Cabinets will be installed in the vegetated planting strip between the sidewalk and curb immediately adjacent to each catch basin. Monitoring equipment cables will be routed to the enclosures in buried conduit. See Figure 7 and Figure 8 for plan and section views of the monitoring station configuration.

Flow monitor maintenance visits will be performed at a minimum of once per month, prior to every storm event or as needed based on remote real-time monitor checks or data reviews. During these visits, level sensors will be adjusted to exact level based on manual measurements by topping off the weirs by adding water and zeroing the transducers. As part of the calibration procedure, level values before and after calibration will be recorded. If the before and after values differed by more than 0.02 feet (0.02 feet is less than one percent of the full 6.7 feet sensor range), the data will be corrected for the level drift during post processing data editing. The difference between the pre- and post-calibration values will also tracked over time to assess long-term level sensor drift. Long-term drift will be used to indicate when to replace the level sensors.

8.1.3 Water Quality Sampling

The goal of the water quality sampling is to collect grab and flow-weighted composite samples from each of the four locations during 12 storm events each year to obtain 24 stormwater samples at each location over this two-year study. The grab samples will be collected once during each event. The composite samples will be collected over the duration of the storm event in proportion to flow volume to generate one Event Mean Concentration (EMC) per analyte per station per event. Primary environmental samples and quality control (QC) sample goals are listed in Table 15. This section describes in detail the sampling procedures that will be used to meet this goal.

Table 15. Stormwater sample collection goal.

Station ID	Stormwater Samples per Station (grab and composite)	Number of years of monitoring	Total Number of Stormwater Samples per Station	Year 1 Treatment	Year 2 Treatment	No. of Field QC Samples per Site	
						Tubing Blank	Duplicate
SS2	12/year	2	24	Swept	Swept	1/year	1/year
SS3	12/year	2	24	Swept	Unswept	1/year	1/year
SS4	12/year	2	24	Swept	Unswept	1/year	1/year
SS5	12/year	2	24	Swept	Swept	1/year	1/year

Grab samples for bacteria and PAHs will be collected either directly into the sample bottle (for bacteria) or by filling stainless-steel beakers and pouring into analyte-specific bottles. Flow-weighted (i.e., volume-proportioned) stormwater composite samples will be collected using automatic samplers.

For past projects of this type, Isco 6700 or 6712 samplers have been the standard automatic sampler that SPU has used. These samplers use a peristaltic pump to draw stormwater from the strainer installed at the sampling location (e.g., sampling tray) and distribute it to a composite sample bottle. One of the main challenges with stormwater sampling using automatic sampling equipment is capturing and analyzing larger particles which may settle in the sampling line during the sampling process. This occurs with peristaltic pump samplers where sampling velocities are relatively low. To attempt to reduce this source of bias, a new type of sampler with a higher sampling velocity is being considered for this project (discussed in the following paragraph) and careful sample processing procedures will be used (discussed later in Section 8.3.4) to help eliminate bias from sample processing procedures.

As this project is being developed and this QAPP prepared, SPU will purchase and test a vacuum-type automatic sampler (Manning Environmental Inc., VST3 sampler). Vacuum samplers have been introduced to the market as an alternative to peristaltic-pump type samplers. Vacuum samplers use an external vacuum pump to draw water samples instead of the traditional peristaltic pumps that induce flow by compressing flexible tubing. Advantages of the vacuum pumps include higher transport velocities (5.1 feet per second [fps] at 5 feet of head for the VST3 vs. 3 fps for Iscos), greater vertical lift range, larger diameter tubing options (up to 5/8-inch ID) and less disruption of the water because tubing is not being squeezed. Because of these attributes, vacuum samplers are reputed to better represent the solids concentration in stormwater, especially when larger particles are present. However, stormwater sampling with known and understood equipment is already challenging so using new and untested equipment may prove problematic. The VST3 will be tested prior to the start of the full scale project. If the sampler functions as advertised and proves durable, the VST3 will be used over the Isco 6700 samplers for this project.

Regardless of the sampler used, a sampler intake strainer will be installed in a custom-made sampling tray positioned below the inlet grate in each catch basin (see Figure 7 and Figure 8) and pump water to a 20 liter (L) polyethylene (poly) composite bottle in the sampler base.

The data loggers will be programmed to trigger the samplers every time a specified volume (referred to as the “trigger volume”) is measured at the Thel-Mar weir at each location, creating a volume-weighted composite to generate EMCs. Each trigger will result in the collection of one stormwater aliquot (or subsample) collected by each sampler. Each aliquot will measure approximately 200 milliliters (mL) so the composite bottle could receive approximately 100 aliquots before filling. Bottles will be removed and replaced as necessary over the course of each sampled event.

Sampling station schematics are presented on the following pages and specific sampling procedures for each storm event are described in the following subsections.

8.1.3.1 Storm Event Forecasting and Pre-Event Procedures

A key part of any stormwater sampling program is monitoring and forecasting storm events to ensure that field personnel are prepared and field equipment are deployed in advance of the event.

Antecedent conditions and weather forecasts will be monitored using multiple web-based forecasts and a determination will be made as to whether to target an approaching storm for sampling by the Field Supervisor. The speed and intensity of incoming storm events will then be tracked using web-based Doppler radar and satellite imagery.

Once a decision has been made to target a storm event for sampling, field personnel will mobilize to each site and conduct pre-storm site visits per the following section.

8.1.3.1 Storm Sampling Procedures

Prior to the onset of rainfall for each targeted event, field personnel will mobilize to each site and perform the following steps: clean the sampling tray of visible sediment and rinse with deionized water, clear any obstructions from the sampler intakes, add clean composite bottles to the sampler base, add ice to the sampler base (ice is estimated to keep the interior of the samplers cool for 48 hours; consequently, ice will not be added to the samplers more than 24 hours before a targeted storm event), decontaminate the sampler tubing by pumping solutions (listed in Section 8.2) through the tubing, calibrate level sensors and sampler aliquot volume as necessary, replace batteries as needed and check the overall operational status of the monitoring equipment.

The volume used to pace the automatic samplers will be determined in advance of the storm event based on rainfall versus runoff relationships that are developed using linear regressions of precipitation and runoff volume data that were collected during previous storm events. Using these relationships, the runoff volume for each station will be estimated based on the forecasted rainfall total for the targeted storm event. The estimated runoff volume will then be divided by 50 (the median number of 100 mL aliquots that the approximately 20L poly composite bottle will hold) to estimate the sample pacing volume necessary to target an approximately 10L composite sample. The rainfall versus runoff relationships will be continually updated throughout the duration of the study to reflect changing hydrologic conditions.

The Campbell Scientific data loggers will be programmed to record cumulative storm volume at each station and send a 400-millisecond, 5-volt pulse to the associated automatic samplers at preset volume intervals. Each automatic sampler will be programmed to collect 200 mL sample aliquots into a 20L poly composite bottle when triggered by the data logger. The automatic samplers will be programmed to perform one rinse cycle prior to actual sample collection in order to reduce the likelihood of cross-contamination between successive aliquots.

Grab samples will be collected at each station once during the event, targeting the initial portion of the runoff.

The flow volume removed to collect the automatic sampler aliquots (200 mL each aliquot for up to 50 per event) or grab samples (1120mL per event) is considered negligible compared to the overall storm event volume (*minimal* storm event volume expected is over 200 cubic feet or 5,663,000 mL) and within the specified accuracy of the flow monitoring equipment. Thus, the flow record will not be corrected for the sample volume collected.

Flows and sample collection times will be monitored remotely using the telemetry systems associated with each data logger. Field crews will be mobilized to each site during the event if it appears that composite bottles are at risk of filling and will replace bottles as needed.

8.1.3.1 Post-Event Procedures

After the storm event, storm event criteria identified for storm event (Table 13) and sample representativeness (Table 14) will be assessed prior to sample retrieval by analyzing hydrologic data and sample information recorded for each station. If the storm event criteria have not been met, the samples will be discarded and the associated bottles sent to the laboratory for cleaning in preparation for the next storm event. If the criteria have been met, field personnel will remove the chilled 20L composite bottles and place them in coolers. Ice will then be added to the coolers to keep the sample temperatures below 6 degrees Celsius. The bottles will then be transported to the laboratory within the allowable limits for sample holding times (see Table 17). In general, the laboratory will be notified at the onset of each sampling event to ensure that adequate laboratory staff will be available to process the incoming samples.

Figure 7. Monitoring station schematic detail (plan view).

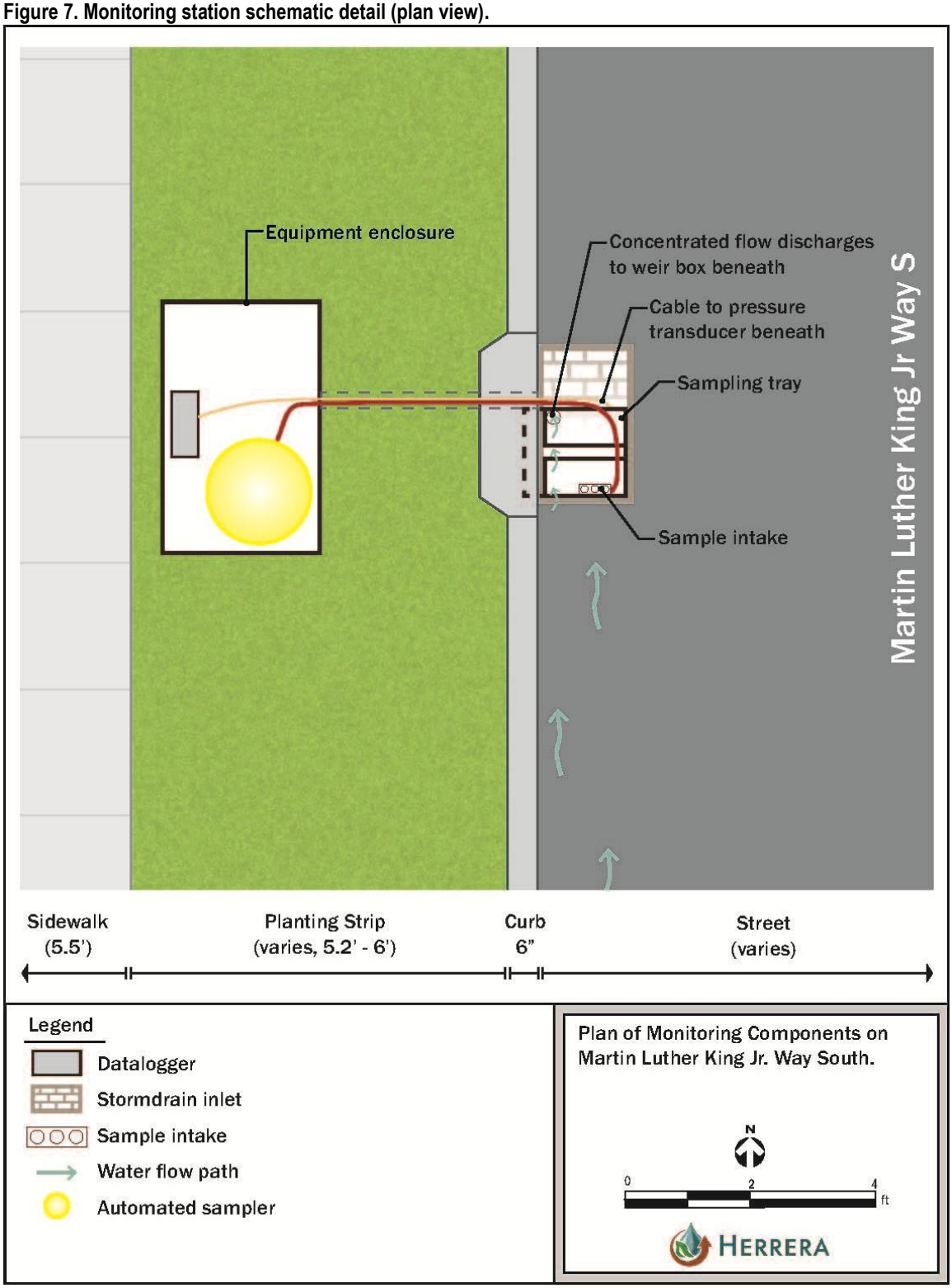
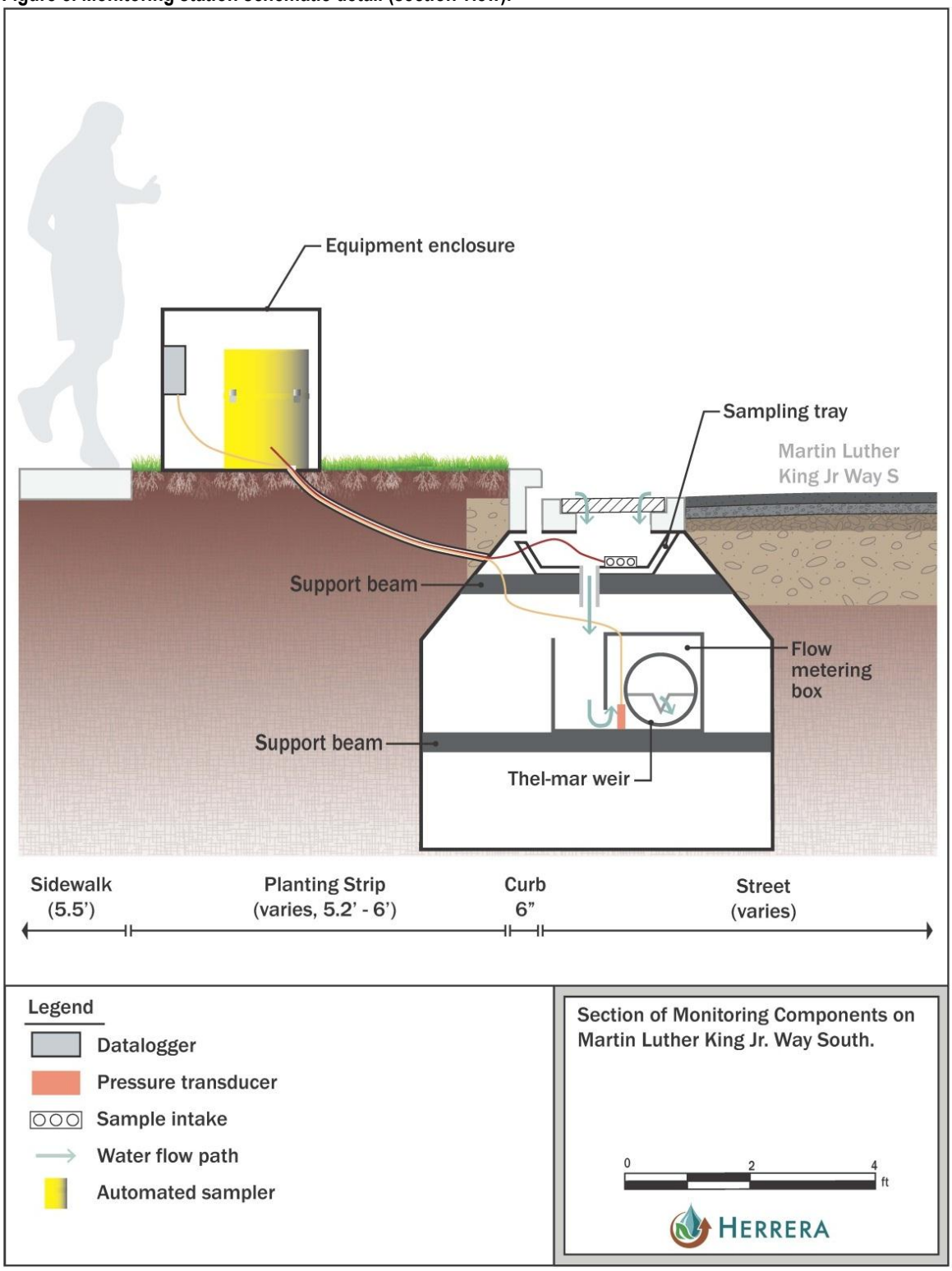


Figure 8. Monitoring station schematic detail (section view).



8.1.4 Field Quality Control Sample Collection Procedures

During this study, numerous field quality control (QC) samples will be collected to evaluate the sampling operation and to quantify and document bias that can occur in the field and variability that can occur in the laboratory. QC samples provide the ability to assess the quality of the data produced by field sampling and a means for quantifying sampling and analytical bias.

Table 16 lists the types of QC samples collected, description of how the QC samples will be collected, the purpose and information provided by each QC sample and the target number of QC samples that will be collected.

The stormwater field split samples (FSS, generically referred to as "duplicates") will be generated in the laboratory by field staff by filling two identical analyte-specific containers simultaneously from the churn splitter. One field FSS will be collected for each station annually.

Field blank samples (FBS, also termed "rinsates"), which will be blanks of the automatic sampler tubing, stainless steel beaker, churn splitter, and composite bottles; will be made by field staff passing reagent grade deionized water through decontaminated sample intake tubing and beakers/churns/bottles and capturing the blank water in analyte-specific bottles. Each of the four sampler tubing lines will be tested once annually. One blank will be collected on the grab beakers, stormwater composite sample bottles and the churn splitter annually.

Table 16. Field QC sample description and goals.

QC Sample Type	Code	Description	Purpose/Info Provided	Year 1 Sample Goal	Year 2 Sample Goal	Total Project Goal	Collected on
Field Split Sample	FSS	Primary Environmental Sample (PES) split by field staff	Quantify variability from laboratory procedures	4	4	8	Stormwater composite samples
Field Blank Sample	FBS	Blank water passed through decontaminated sampling equipment in the field	Tests cleaning procedures and quantifies contamination from field sampling and processing activities	6 (4 tubing + 1 beaker +1 churn/bottle)	6 (4 tubing + 1 beaker +1 churn/bottle)	12 (8 tubing + 2 beaker + 2 churn/bottle)	Autosampler tubing, stainless beakers, splitters and poly composite bottles

8.2 Equipment Decontamination Procedures

Prior to sampling, all water quality sampling equipment (including composite sample bottles and churn splitters), will be decontaminated with the following procedure:

1. Wash in a solution of laboratory-grade, non-phosphate soap and tap (city) water.
2. Rinse in tap water.
3. Wash in a 10 percent nitric acid/deionized water solution.*
4. Final rinse in deionized water.

** - nitric wash for metallic equipment (stainless steel beaker)*

The sampler tubing and the sampler vacuum chamber (if a vacuum sampler is used) which will initially be washed using the above procedure but will be rinsed with deionized water between storm events.

Analyte-specific bottles will be decontaminated by the project laboratory using reagents specific to the bottle type and analysis to be performed.

8.3 Sample Handling and Custody

This section presents stormwater sample volume, container type, holding time, and preservative needed for each required parameter.

Sample handling and custody procedures ensure that uniquely identifiable samples are transported to the analytical laboratory with appropriate preservation within prescribed holding times and with proper documentation. The chain-of-custody of the physical sample and its corresponding documentation will be maintained throughout the handling of the sample by following the procedures outlined below.

Table 17. Sample containers, holding times and preservation methods.

Parameter	Field Sample Container	Pre-Filtration Holding Time	Total Holding Time[1]	Field Preservation	Laboratory Sample Container	Laboratory Preservation
pH	Stainless steel beaker	NA	15 minutes	NA	NA	NA
Fecal coliform bacteria		NA	8 hours		120 mL Corning®, sterile	Na2S2O3
Polycyclic Aromatic Hydrocarbons (PAHs)		NA	7 days		2 – 500mL AG	Maintain 4°C
Total suspended solids	20 L HDPE Carboy	7 days	7 days	Maintain ≤ 6°C	1 Liter HDPE	Maintain 4°C
Total Organic Carbon		NA	28 days		250 mL AG	Maintain 4°C, H_2SO_4 to pH < 2
Chemical Oxygen Demand		NA	28 days		250 mL AG	Maintain 4°C, H_2SO_4 to pH < 2
Modified Suspended Solids Concentration (SSC)		NA	7 days		Liter HDPE	Maintain 4°C
Nitrate-Nitrite		NA	48 hours		500 mL HDPE	Maintain 4°C, H_2SO_4 to pH < 2
Hardness as $CaCO_3$		NA	6 months		500 mL HDPE	Maintain 4°C, HNO_3 to pH < 2
Copper, dissolved		15 minutes[2]	6 months		500 mL HDPE	Maintain 4°C, HNO_3 to pH < 2 after filtration
Copper, total		NA	6 months		500 mL HDPE	Maintain 4°C, HNO_3 to pH < 2
Zinc, dissolved		15 minutes[2]	6 months		500 mL HDPE	Maintain 4°C, HNO_3 to pH < 2 after filtration
Zinc, total		NA	6 months		500 mL HDPE	Maintain 4°C, HNO_3 to pH < 2
Total Phosphorus		NA	28 days		500 mL HDPE	Maintain 4°C, H_2SO_4 to pH < 2
Total Kjeldahl Nitrogen		NA	28 days		500 mL HDPE	Maintain 4°C, H_2SO_4 to pH < 2

1 - For a composite sample collected with an automated sampler…the holding time begins at the time of the end of collection of the composite sample." (40 CFR 136, Table II, note 4).
2 - Holding time specified in EPA guidance (U.S. EPA 2007). The holding time may not be realistically met with flow-weighted automated sampling techniques; however, best effort will be made to perform filtration as close to the specified holding time as possible.

NA – not applicable

AG – amber glass

HDPE - High Density Polyethylene

8.3.1 Sample Identification

All samples will be clearly labeled in the field with indelible ink. Each primary environmental sample (PES) will be labeled with the project name, the unique sample identifier (discussed below), and the event date and time stamp. For composite samples, the date and time stamp will reflect the last aliquot collected. To create a unique identifier (ID) for each sample, the sample ID will be a concatenation of the station name, a hyphen, and the date of the last aliquot in YYMMDD format (e.g., SS2-141108 for the composite sample collected at SS2 on November 8, 2014).

Field split samples will be identified using the unique sample ID of the PES with an additional "-FSS" at the end of the unique identifier (e.g., SS2-141108-FSS).

The field blank samples will be identified by either the station ID (for tubing blanks) or the words "Beaker" for the grab sampling beaker or "Churn" for the churn/bottle blank – followed by the date and the code "FBS." SS2-141108-FBS is an example of the unique ID for a tubing blank and Churn-141108-FBS is an example of the unique ID for the churn and bottle blank.

The combination of the sample location identifier, sample method, date and time stamp, and matrix provided on the Electronic Data Deliverable (EDD) by the analytical laboratory will provide the index that links the sample event data and field data, which will identify field split and blank samples where applicable.

8.3.2 Sample Transportation

At the conclusion of each storm event, the sampling team will collect the composite bottles from each sampler, place the samples on ice and transport them as soon as possible to the analytical laboratory.

8.3.3 Sample Preservation

Other than ice, sample preservation will not be required in the field. Composite samples will be chilled with ice as they are collected. Samples will be split and preserved in the project laboratory [Analytical Resources Inc. (ARI) in Tukwila, WA] by ARI staff.

8.3.4 Sample Processing

Since stormwater samples, specifically stormwater solids concentrations and related contaminants, are readily biased without proper processing procedures, all composite samples will be composited and split in the project analytical laboratory by ARI staff using large, custom-made polyethylene churn splitters. The churn splitters will be used to keep solids in suspension while distributing subsamples to analyte-specific containers that are theoretically equal in chemical quality and sediment concentration to any other subsample.

8.3.5 Holding Times

Holding times are listed in Table 17. For composite samples the "sample collection time" used to evaluate holding time limits is the time that the final sample aliquot is collected. To minimize the risk of exceeding holding times, samples will be delivered to the laboratory immediately after sampling is completed.

For samples either prepared or analyzed outside the established holding time, detected values will be qualified as estimated (J) and non-detects (less than the reporting limit) will be qualified as estimated non-detect (UJ).

8.3.6 Chain of Custody

A chain-of-custody (COC) form will accompany each sample batch delivered to the laboratory. The purpose of chain-of-custody forms is to keep a record of the sample submittal information and to document the transfer of sample custody. Standard COC forms will be prepared for the study that will include a sample location identifier, analyses to be requested, and any special considerations, such as analysis priority order and sample filtration needs. At the time of sample collection, the field team will record the sample date and time, sample location, matrix, and analyses requested. Any special instructions for the laboratory will also be noted on the COC. The COC form must be signed by both the person relinquishing the samples and the person receiving the samples every time the samples change hands, thus documenting the chain of custody.

9 MEASUREMENT PROCEDURES

The analytical methods for this study have performance characteristics that meet the MQOs for precision, bias, and accuracy described in Section 6.1.

Table 11 provides the parameters to be analyzed and their method numbers.

Element IV. Quality Assurance/Quality Control

This element describes the Quality Assurance (QA)/Quality Control (QC) procedures used in this Study to ensure the QAPP is implemented as prescribed, and include:

Section 10 – Quality Control, which describe the type and frequency of required laboratory and field quality control samples;

Section 11 – Data Management and Documentation Procedures, which addresses the path of data from recording in the field and laboratory to final use and archiving; and

Section 12 – Audits and Reports, which discusses assessment, response actions and potential corrective actions.

10 QUALITY CONTROL

This section discusses the required quality control samples to be collected in the field and the laboratory. The MQOs or criteria specified for each QC sample result are summarized in Table 7.

10.1 Analytical Quality Control

Laboratory analytical quality control (QC) procedures involve the use of three basic types of QC samples (see Table 18). QC samples are analyzed within a batch of client samples to provide an indication of the performance of the entire analytical system. Therefore, QC samples go through all sample preparation, clean up, measurement, and data reduction steps in the procedure. In some cases, the laboratory may perform additional tests that check only one part of the analytical system. Please refer to the Glossary for a definition of each laboratory QC sample.

Table 18. Laboratory quality control samples

QC Sample	Matrix	Frequency of Analysis
Laboratory (or Matrix) Duplicate (LD)	Water	One per batch of 20 samples of similar matrix.
Method or Preparation Blank (MB)	Water	One per analytical batch of samples of similar matrix.
Laboratory Control Samples (LCS)	Water	One per analytical batch of samples of similar matrix.

10.2 Field Quality Control

Field quality control (QC) procedures involve the use of two basic types of QC samples: field split samples and field blank samples (see Table 16). Please refer to the Glossary for a definition of each.

11 DATA MANAGEMENT & DOCUMENTATION PROCEDURES

This section discusses data management, which addresses the path of data from recording in the field or laboratory to final use and archiving. The data management and documentation strategy provides for consistency when collecting, assessing, and documenting environmental data and electronic storage of all documents and records on servers that are regularly backed up.

Project documents and records will be stored on City of Seattle servers and analytical laboratory data and final, reviewed data including validation qualifiers, if any will be stored in the City of Seattle's EQuIS™ database hosted offsite by Earthsoft. The hosted EQuIS database is backed up daily (differential backup) and weekly (full backup). The documents described below will be retained for a minimum of 5 years.

11.1 Documents and Records

Four types of documentation will be managed: 1) field operation records, 2) laboratory records, 3) data handling records, and 4) QAPP revision documentation.

11.1.1 Field Operation Records

Field operation records may include data sheets and field notes, and photographs taken of the described activities (when taken).

11.1.2 Laboratory Records

Laboratory records will include a data package (lab report in hard copy and PDF formats) and an EDD for each sample batch.

11.1.3 Data Handling Records

All documents associated with a sampling event will be stored electronically. Paper copies will not be archived. Each sampling event will be documented with the following records:

- Chain of Custody (COC)
- Field Reports (field notes)
- Data Package
- Electronic Data Deliverable (EDD)

All documents will be provided in portable document format (PDF) with the exception of the EDD, which will be in Excel® format. Each EDD entry into the EQuIS database will have an electronic record associated with a unique ebatch number traceable to the EDD, which will include the file name, file format used for import, time and date of the ebatch, and identification of who uploaded the data.

11.1.4 Revisions to the QAPP

In the event that significant changes to this QAPP are required prior to the completion of the study, a revised version of the document shall be prepared and submitted to Ecology for review. The approved version of the QAPP shall remain in effect until the revised version has been approved.

Justifications, summaries, and details of expedited changes to the QAPP will be documented and distributed to all persons on the QAPP distribution list by the Principal Investigator.

12 AUDITS AND REPORTS

This section discusses assessment, response actions, and corrective actions to ensure all data are collected as described in this Plan.

12.1 Assessments and Response Actions

Field, analytical and data management activities are evaluated based on the schedule in the table below.

Table 19. Assessment and response action schedule.

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Laboratory Inspections	Dates to be determined	QA Coordinator	Analytical and quality control procedures employed at the laboratory and the contract laboratory	30 days to respond in writing to address corrective actions.
Monitoring Systems Audit	Once at start of monitoring	Study Manager	This assessment will be tailored in accordance with objectives needed to ensure compliance with the QAPP and may include: monitoring equipment inspection; accuracy and functionality checks.	30 days to respond in writing to address corrective actions.
Site Visit	Once annually	Study Manager	This assessment will be tailored to verify that field sampling activities are in compliance with the QAPP and may include: equipment calibration checks, sample collection and handling checks; and field documentation/COC inspection.	30 days to respond in writing to address corrective actions.

12.2 Deficiencies, Nonconformances and Corrective Action

The Study Manager is responsible for implementing and tracking corrective action procedures because of audit findings. Records of audit findings and corrective actions are maintained by both the QA Coordinator and Study Manager.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

Deficiencies are defined as unauthorized deviation from procedures documented in the QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate.

Deficiencies related to sampling methods requirements include, but are not limited to, such things as sample container, volume, and preservation variations, improper/inadequate storage temperature, holding-time exceedances, and sample site adjustments.

Deficiencies related to chain-of-custody include but are not limited to delays in transfer, resulting in holding time violations; incomplete documentation, including signatures; possible tampering of samples; broken or spilled samples, etc.

Deficiencies related to field and laboratory measurement systems include but are not limited to instrument malfunctions, blank contamination, quality control sample failures, etc.

Deficiencies related to Quality Control include but are not limited to quality control sample failures.

Deficiencies are documented in logbooks, field data sheets, etc. by field or laboratory staff and reported to the appropriate field or laboratory supervisor who will notify the Study Manager. The Study Manager will notify the QA Coordinator of the potential nonconformance within 24 hours, who will then initiate a Nonconformance Report (NCR) to document the deficiency.

The Study Manager, in consultation with QA Coordinator, will determine if the deficiency constitutes a nonconformance. If it is determined that the activity or item in question does not affect data quality and therefore is not a valid nonconformance, the NCR will be completed accordingly, and the NCR closed. If it is determined a nonconformance does exist, the Study Manager in consultation with QA

Coordinator will determine the disposition of the nonconforming activity or item and necessary corrective action(s); results will be documented by the contractor QA Coordinator by completion of a Corrective Action Report.

Corrective Action Reports (CARs) document: root cause(s); programmatic impact(s); specific corrective action(s) to address the deficiency; action(s) prevent recurrence; individual(s) responsible for each action; the timetable for completion of each action; and, the means by which completion of each corrective action will be documented. CARs will be included with quarterly progress reports. In addition, significant conditions (i.e., situations that, if uncorrected, could have a serious effect on safety or on the validity or integrity of data) will be reported to the Principal Investigator immediately both verbally and in writing.

Element V. Assessment Procedures

This element describes the assessment procedures implemented after data collection is complete to determine if the data conform to the specified criteria and will satisfy the study objectives and if so, the analysis and format for presentation of the results. It includes:

Section 13 - Data Validation and Verification, and

Section 14 - Data Quality (Usability) Assessment.

Sections 13 and 14 describe the procedures used to determine if the MQOs established in Section 6.2 for the six DQIs (precision, accuracy, representativeness, completeness, comparability, and sensitivity) have been met. The result of sections 13 and 14 are data of known and documented quality, and answer the question, *are the data of sufficient quality and quantity to meet the use for which they are intended*?

The quality of the data is indicated by data qualifier codes, notations used by laboratories and data reviewers to briefly describe, or qualify, data and the systems producing data. Table 20 provides a brief list of data qualifier codes to be used for this study.

During data review, verification, and validation, results are either accepted or reported with data qualifiers or flags. Data that meet all QC acceptance limits are potentially usable and are not qualified. Data that fail one or more QC criteria are qualified as estimated (with the J flag) or rejected (with the R flag).

Table 20. Data qualifier definitions.

Data Qualifier	Definition
U	Analyte was analyzed, but not detected above reported result.
J	Reported result is an estimated quantity.
UJ	Analyte was analyzed, but not detected above reported estimate.
R	Result value was rejected. Analyte may or may not be present. Result should not be used in evaluation of the data.

During the data usability assessment, data that are believed to be completely unusable with a high degree of confidence (e.g., because of the gross failure of QC criteria) are qualified as rejected and would not normally be used to support decisions for an environmental study.

13 DATA VERIFICATION AND VALIDATION

This section discusses data review, verification, and validation. Data will be reviewed, verified and validated using a Tier I data review level. Tier I screening includes evaluation of package completeness; sample chain-of-custody; sample preservation and analytical holding times; blank contamination; precision (replicate analyses); accuracy (compound recovery); target analyte list, and detection limits.

13.1 Data Review, Verification and Validation

This section discusses how data are reviewed and decisions made regarding accepting, rejecting or qualifying data.

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance of a set of data to ascertain its completeness, correctness and consistency using the methods and criteria defined in the QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of the study. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to study requirements, and then validated against the measurement quality objectives, which are listed in Section 6. Only those data that are supported by appropriate quality control data and meet the measurement performance specification defined for this study will be considered acceptable and used in the study.

13.2 Verification and Validation Methods

Section 6.2 summarizes the data verification elements that will be assessed, the criterion to be met, and the action to be taken should the criterion not be met. Procedures used to validate and verify analytical data are described below.

All laboratory data packages will be received with a hardcopy report and an electronic data deliverable (EDD). For each data package, laboratory case narratives will be reviewed for quality control issues and corrective action(s) taken. Data will be evaluated for required methods, holding times, reporting limits, accuracy, precision, and blank contamination.

Each EDD will be imported into a review template spreadsheet where deviations from the measurement quality objectives (MQOs) will be identified and associated samples qualified accordingly.

One result value per sample per analyte will be reported. Where the laboratory performed dilutions or re-analyses that resulted in multiple valid values, the result with the lowest detection limit will be reported.

Data qualifiers will be applied to sample chemistry data based on the results of validation. Four data qualifier codes will be used; U, J, UJ and R as defined in Table 20.

14 DATA QUALITY (USABILITY) ASSESSMENT

This section describes the process for determining the data usability, the method for data reduction, and the process for assessing the data quality. The methods and procedures that will be used to determine if the DQO's established in Section 6.1 have been met, as well as to prepare presentation of the study results, are discussed. The purpose of this process is to determine if the decision (or estimate) can be made with the desired confidence, given the quality of the data set.

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Data reduction is the process of converting raw data to results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form.

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality and quantity to support their intended use.

14.1 Data Usability Assessment

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose. Three classes of data quality are used:

- **Accepted** Data conform to all requirements, all quality control criteria are met, methods were followed and documentation is complete.

- **Qualified** Data conform to most, but not all, requirements, critical QC criteria are met, methods were followed or had only minor deviations, and critical documentation is complete.

- **Rejected** Data do not conform to some or all requirements, critical QC criteria are not met, methods were not followed or had significant deviations, or critical documentation is missing or incomplete. The results are unusable.

Data usability assessment is a more complex and comprehensive activity than data review or validation and is usually performed by the end user (rather than by the data reviewer) because the data user typically possesses a greater understanding of the study's DQOs (e.g., because of a more extensive knowledge of the study's history). Therefore, the end user must ultimately determine the acceptability of the data. However, this does not imply that the end user may apply qualified data in an indiscriminate fashion.

Tentatively rejected data must not be used to support study decisions unless the data user presents (i.e., documents) some technical rationale for doing so. In other words, tentatively rejected data must ultimately be rejected (e.g., using the R flag) in the absence of a scientifically defensible rationale to do otherwise. Furthermore, when data qualified as tentatively rejected are used to support decisions for a study, the data reviewer should be consulted for a consensus unless it is clear that the reviewer did not possess a complete understanding of the objectives of the investigation (e.g., new DQOs were established after the data review was performed).

Ideally, estimated (i.e., J-qualified) data, though presumed to be usable by the data reviewer, should be accepted by the end user only after the reasons for the data qualifications and their impact on the achievement of study DQOs have been examined.

The usability assessment includes assessment of potential outliers, confirmation that the data are comparable and representative, and calculation of the completeness:

- Identification of outliers from previous data collection efforts,
- Confirmation of outliers from previous data collection efforts when sufficient data are available to complete the outlier test,
- Confirmation of the comparability of the data,
- Confirmation of the representativeness of the data, and
- Calculation of the completeness for each measurement.

Definitions for each DQI can be found in the Glossary as well as the equation for calculating completeness. Specific methodology for completing the data usability assessment is discussed below.

14.1.1 Data Processing Guidelines

Some additional data processing may be required prior to performing any data usability or data reduction functions. Anticipated data processing needs are described below.

Handling of non-detected values. For any result reported as non-detected (below the reporting limit), the result used for the data analysis will be estimated as half the reporting limit.

Handling of field duplicates. The primary environmental sample result, not the corresponding field duplicate sample result or an average of the two, will be used for the data analysis.

14.1.2 Roles, Responsibility, and Documentation

The Principle Investigator will document the Usability Assessment in each annual report and the final report, which includes:

1. Listing of all data collected for the water year. Include any usability flags qualifying the data.

2. Summary for the water year to date including:

    - A table presenting sample results, and
    - Completeness for each season.

14.2 Data Analysis Methods

The BACI design used for this study was set up with the intent of providing information that can be used in a 2-factor analysis of variance (ANOVA) test. In general terms, an ANOVA test is used to evaluate whether the variability of a parameter can be explained by one or more grouped variables (i.e., variables whose values are simply "from group X"). These grouped variables are referred to as “factors” in an ANOVA test. For this study, the parameters of interest are pollutant concentrations and loads in roadway stormwater runoff. The factors of interest for explaining variability in these parameters are location (Control/Impact) and time (Before/After). When the 2-factor ANOVA test is performed, the influence of both factors are considered simultaneously to evaluate the following null hypotheses (Ho) and alternative hypotheses (Ha):

Ho: Pollutant concentrations/loads in runoff from Control/Impact sites are equal
Ha: Pollutant concentrations/loads in runoff from Control/Impact sites not equal

Ho: Pollutant concentrations/loads in runoff Before/After sweeping is terminated are equal
Ha: Pollutant concentrations/loads in runoff Before/After sweeping is terminated are not equal

Ho: Pollutant concentrations/loads in runoff are not influenced by an interaction between Control/Impact and Before/After influencing
Ha: Pollutant concentrations/loads in runoff are influenced by an interaction between Control/Impact and Before/After influencing

If the interaction between the Before/After and Control/Impact factors is significant, one can conclude there is a significant influence on pollutant concentrations/loads in runoff that is related to location (due to the termination of sweeping) while accounting for any “natural” variation through time. Transformation of the data may be required prior to analysis to ensure conformance with assumptions of normality inherent in the ANOVA test. The 2-factor ANOVA may also be run using a paired design to control for temporal variability in the data sets caused by outside factors not related to the impact (e.g., rain intensity, road sanding, etc.).

14.3 Data Presentation and Reporting

Two types of reports will be prepared and submitted: 1) Annual status reports – submitted as part of the Annual Report required to be submitted per the terms of our NPDES Phase I Permit stormwater every March 31 which documents the stormwater management activities of the previous year, 2) a Final

Study Report which will be submitted to Ecology and posted on SPU's webpage at the conclusion of the project. The content of each report is described in the following sections.

Reporting note – for structural BMP studies, data are sometimes uploaded to the *International Stormwater BMP Database (BMP Database).* Since the BMP Database is not configured for data from non-structural BMP studies of this type, the results of this study will not be uploaded to the BMP Database. The Ecology EIM database is also not a suitable repository for these data because metadata regarding treatment under which the samples were collected cannot be included. Thus, the reports listed below will be the methods of data presentation/reporting.

14.3.1 Annual Report

As part of the Annual Stormwater Report, a narrative of study implementation status, sampling completed, and sample completeness relative to targets for the water year will be presented. Since efficiency evaluations and statistics cannot be performed until all data are collected after Year 2, the Annual Report will serve primarily as a project status report for the study.

14.3.2 Final Report

After the conclusion of Year 2 sampling and data validation and analysis, one standalone Final Study Report will be generated which will include results collected over the whole study. The report will include the following components.

14.3.2.1 Status of Street Sweeping Program in the Study Area

A summary of the street sweeping performed in the study area will be presented. This summary will include sweeping methods, dates of sweeping, and any sweeping problems encountered.

14.3.2.2 Monitoring Station Summary

A summary of each monitoring station including site name, latitude/longitude, maps and pictures will be presented.

14.3.2.3 Individual Storm Reports

A summary of storm event data for each storm sampled at each site will be presented in both tabular and graphical (i.e., hydrograph) formats. The hydrographs will present:

- Time versus precipitation
- Time versus flow rate
- Time versus initiation of aliquot collection

The following storm event data will be presented in tabular format

- Storm ID
- Antecedent dry period
- Rainfall duration
- Total event rainfall amount/rainfall during sampling period
- Total event runoff flow volume/flow volume during sampling period
- Number of sample aliquots
- Percentage of storm runoff sampled
- Comparison of storm and sample data to criteria in Table 13 and Table 14

14.3.2.4 Analytical Data Summary

All primary and QC environmental analytical data will be presented in tabular format. Box plots, which will graphically present mean, median, maximum, minimum, 25th and 75 percentile statistics of all EMCs, will be presented to compare concentrations of swept and unswept runoff for primary analytes.

14.3.2.5 Statistical Data Analysis

The primary data analysis will be the 2-factor ANOVA test to evaluate the interaction between the Before/After and Control/Impact factors described in Section 14.2.

An ancillary evaluation will also be performed to determine how the occurrence of street sweeping and antecedent rainfall may influence pollutant runoff concentrations. Statistical analyses will be performed on the compiled data for TSS and dissolved zinc to determine whether influent concentrations for particulate bound and dissolved pollutants, respectively, are influenced by the following independent variables:

- Peak rainfall intensity during storm event
- Total precipitation depth during storm event
- Hours since at least 0.25 inches of rain fell in a 6 hour period
- Occurrence of street sweeping prior to sampling

These analyses will involve the use of backward stepwise regression to determine whether each variable, in combination or isolation, has a significant influence on influent concentrations at a significance level of 0.05. If more than one variable is shown to have a significant influence, the associated standardized regression coefficients will be compared to determine which variable has the most influence.

14.3.2.6 Results Discussion

A narrative discussing the monitoring status and water quality effectiveness of street sweeping measured during the study will include at a minimum:

- Summary of events sampled, sampling goals achieved or explanation if goals are not achieved and any deviation from sampling procedures
- Discussion of statistical testing performed
- Discussion of water quality performance measured and measured effectiveness of street sweeping
- Recommended future actions.

14.3.2.7 Quality Assurance/Quality Control Summary

The QA/QC summary will include at a minimum:

- A data validation narrative that includes: a) a narrative analysis of appropriate field quality control procedures and DQI results, and any associated issues and corrections made, and b) a narrative analysis of appropriate laboratory quality control procedures with MQOs discussed, and any associated issues and corrections made.
- A summary description of any changes or deviations from the approved QAPP to address problems.
- An overall assessment of the usability and representativeness of the data.

15 REFERENCES

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16 LIST OF REVISIONS

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R0D0	7/10/2014	Draft	Doug Hutchinson	*Not applicable – initial draft.*
R1D0	9/22/2014	Final	Doug Hutchinson	Revised to address 11 Ecology comments on the 7/10/2014 draft QAPP. Revision summary detailed in Attachment 1 of Final QAPP transmittal letter.

17 GLOSSARY

Accuracy - Accuracy is defined as the degree of agreement of a measurement to an accepted reference or true value.

Analytical accuracy will be measured as the percent recovery (percent R) of an analyte in a reference standard or spiked sample. Accuracy (percent R) criteria for matrix spike recoveries and surrogate recoveries will be within limits provided by the laboratory. Percent recoveries will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Certified Reference Material (CRM) –CRM's (also called Standard Reference Material [SRM]) can be used to assess accuracy. They have "certified" concentrations of the analytes of interest, as determined through replicate analyses by a reportable certifying agency using two independent measurement techniques for verification.

Comparability - Comparability is the confidence with which one data set can be compared to another. Comparability can be related to accuracy and precision, as these quantities are measures of data reliability. Data are comparable if sample collection techniques, measurement procedures, analytical methods and reporting are equivalent for samples within a sample set.

To ensure analytical comparability the laboratory will:

- Use National Bureau of Standards or USEPA - traceable standards
- Use standard methodologies
- Apply an appropriate level of quality control
- Participate in inter-laboratory studies to document laboratory performance

As with representativeness, quantitative criteria for data comparability are difficult to establish, hence, a qualitative assessment of data comparability will be made of applicable data sets.

Completeness – An element of the data verification process. Completeness ensures that a sufficient amount of data and information (relative to the prescribed DQOs) are present. A Measurement Quality Objective (MQO), completeness is defined as the percentage of valid analytical results (results not qualified as R, rejected) obtained compared with the total number of analytical results required by the study scope of work. Analytical completeness is defined as the percentage of valid analytical results obtained compared with the total number of analyses requested.

Compliance - An element of the data verification process. Compliance indicates the extent that adherence to SOPs, QAPP, and/or contractual requirements were followed, achieved, and/or completed successfully, and that conditions under which the data were recorded also met the requirements. Compliance ensures that the data pass numerical quality control tests, including criteria on precision and accuracy, based on parameters or specified limits specified in relevant SOPs and or QAPP.

Composite samples – A composite sample is a mixed or combined sample that is formed by combining a series of individual and discrete samples of specific volumes, which are commonly termed aliquots.

Consistency - An element of the data verification process. The extent to which data collection procedures were done in a similar manner across different sites (if applicable) and

data reporting was done in a similar manner in multiple places. Consistency (also known as comparability) ensures that the reported values are the same when used throughout the study.

Correctness - An element of the data verification process. A mechanical, objective check that data collection plans and protocols have been followed and that basic operations and calculations were performed using properly documented and properly applied algorithms. Correctness ensures that the reported values are based on properly documented algorithms.

Field Blanks - Field blanks are also commonly called field rinsate blanks, decontamination blanks and equipment blanks. A field blank evaluates the effectiveness of decontamination procedures when equipment is not dedicated to a site or disposed of after one use. If decontamination procedures are effective, there should be no contamination in the field blanks. A field blank consists of a sample of the reagent grade water supplied by the laboratory and used in the final rinse step of the equipment decontamination procedure. Process the field blank water through the equipment the same way you process any other final rinse water.

Field Replicates - A field replicate (duplicate) sample is collected to determine the variability of analytical results caused by the sampling equipment and procedures used.

Field replicates are samples collected simultaneously or sequentially from the same sampling location using identical sampling methods. The samples equally represent as nearly as possible the medium being sampled, and may provide information of the variance of chemicals at a sampling location and the consistency of sampling techniques.

Replicate samples will be collected at the time of sample collection. Replicate samples will be sent to the laboratory. The final number of replicate samples collected and submitted for analysis to each laboratory will equal or exceed 5 percent of the total number of primary samples for each analytical method.

Field Split – A field split is collected to determine the variability of analytical results caused by the sampling equipment and procedures used, and assess the variability of the sample medium. Field split samples are two or more samples collected from a single environmental sample that has been homogenized to correct for sample heterogeneity. The samples equally represent as nearly as possible the medium being sampled, and may provide information of variance of constituents at a sampling location and the consistency of laboratory analytical techniques.

Replicate samples will be collected at the time of sample collection. Replicate samples will be sent to the laboratory. The final number of replicate samples collected and submitted for analysis to each laboratory will equal or exceed 5 percent of the total number of primary samples for each analytical method.

Grab Sample - A grab sample is a discrete, individual sample collected within a short period.

Interquartile Range (IQR) - The interquartile range (IQR) is the most commonly-used resistant measure of spread. It measures the range of the central 50 percent of the data, and is not influenced at all by the 25 percent on either end. The IQR is defined as the 75th percentile minus the 25th percentile.

The 75th, 50th (median) and 25th percentiles split the data into four equal-sized quarters. The 75th percentile (P.75), also called the upper quartile, is a value which exceeds no more than 75 percent of the data and is exceeded by no more than 25 percent of the data. The 25th percentile (P.25) or lower quartile is a value

that exceeds no more than 25 percent of the data and is exceeded by no more than 75 percent.

Laboratory Control Samples - Laboratory control samples (LCS) are well-characterized, laboratory-generated samples used to monitor the laboratory's day-to-day performance of routine analytical methods. Certain LCS are used to monitor the precision and accuracy of the analytical process, independent of matrix effects. Other LCS are used to identify any background interference or contamination of the analytical system which may lead to the reporting of elevated concentration levels or false positive measurements.

The results of the LCS are compared to well-defined laboratory acceptance criteria to determine whether the laboratory system is "in control." Controlling lab operations with LCS (as opposed to MS/MSD samples) offers the advantage of being able to differentiate low recoveries due to procedural errors from those due to matrix effects. One LCS should be analyzed for every set of 20 or fewer samples or with each sample preparation lot.

Laboratory (or Matrix) Duplicate - A laboratory duplicate is a split of an environmental sample, which is prepared and analyzed in a manner identical to that of the original sample. The results are used to evaluate the precision of the laboratory analyses. Results are expressed in Relative Percent Difference (percent RPD) between analytical results for the split and the original sample.

If more than five but less than 20 samples are submitted, at least one laboratory duplicate should be analyzed. A general rule is one laboratory duplicate for every batch of up to 20 samples analyzed together.

Matrix Spike - A matrix spike (MS) is an environmental sample to which known concentrations of analytes have been added. The matrix spike is taken through the entire analytical procedure and the recovery of the analytes is calculated. Results are expressed as percent recovery of the known amount spiked. The matrix spike is used to evaluate the effect of the sample matrix on the accuracy of the analysis.

One matrix spike sample should be analyzed for every set of 20 or fewer samples or with each sample preparation lot. The spike solution is added to samples prior to digestion. The sample that is chosen for spiking should be the same sample used for laboratory duplicate analysis. The amount of spike added to the sample should be 2 to 5 times the expected sample concentration or the IDL, whichever is greater.

Method Detection Limit (MDL) – The minimum concentration of an analyte that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero as determined by a specific laboratory method (40 CFR 136).

Method or Preparation Blank - A method blank consists of analyte-free media. The method blank is carried through each step of the analytical method. The method blank data will be used to detect any laboratory contamination during analysis.

A method blank is required for each batch of samples prepared for analysis, except in the case of volatile organic analyses, which should be analyze at least once every 12 hours.

Method Reporting Limit (MRL) – The concentration at which confidence in the reported value requires no qualifying remarks. The MRL should be 3-5 times the MDL. A standard is run at the MRL to verify acceptable data quality. The MRL may be affected by sample size, sample dilution, and matrix interference.

Outlier - Outliers are measurements that are extremely large or small relative to the rest of the data and, therefore, are suspected of misrepresenting the population from which they were collected.

Precision Objectives - Precision is the degree of agreement between a set of replicate measurements. Precision will be measured as the relative percent difference (RPD) between duplicate analyses for matrix spike duplicates, laboratory duplicates, and field duplicates.

Precision RPD for matrix spike duplicates and laboratory duplicates will be within limits specified in the QAPP. The %RPDs will be compared to the criteria specified in the QAPP and deviations from specified limits reported. If the objective criteria are not met, the laboratory will supply a justification of why the acceptability limits were exceeded and implement the appropriate actions. The percent RPDs will be reviewed during data validation, and deviations from the specified limits will be noted and the effect on reported data commented upon by the data reviewer.

Quality control objectives for field replicate precision have not been established by the USEPA. These analyses measure both field and lab precision; therefore, the results may also have more variability than lab duplicates which measure only lab performance.

Representativeness - Representativeness is the degree to which data accurately and precisely represent a characteristic of a population, parameter concentrations at a sampling point, or an environmental condition of a site. Representativeness is a function of sample site selection, sampling methods, and analytical techniques. The rationale for sample site selection and sampling methodology is provided in Section 7. Representativeness will be maintained by performing all sampling, sample handling, and analyses in compliance with the procedures described in this QAPP and the referenced analytical methods.

It is difficult to establish quantitative representativeness criteria. Representativeness of the analytical data may be determined by a comparison of the quality control data for the samples to established criteria, and by affirming that sampling and analytical methods conformed to established plans and methods.

Sample Type – Sample type refers to the kind of sample. Examples of this may include Primary Environmental Samples (PES), Field Duplicate Samples (FDS), Field Split Samples (FSS), Laboratory Control Samples (LCS), and others.

Sample Technique – Sample technique refers to the method by which a sample is actually collected. This may include information about whether it was manually collected or collected via automatic sampler. It may also include information on whether a sample was collected as a composite or a grab.