Section S8E - Program Effectiveness
Quality Management System Planning Document

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Permit No.: WAR04-4503

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Seattle Public Utilities
Seattle , Washington

This document is part of the Science Information Quality System providing in one place a clear, concise, and complete plan for environmental data management and its quality objectives, and for identifying key project personnel.

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TITLE AND APPROVAL SHEET

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

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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 violations.

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Acronyms

BMP	Best Management Practice
CAR	Corrective Action Report
COC	Chain of Custody
CWA	Clean Water Act
DOC	Demonstration of Capability
DMP	Data Management Plan
DMRG	Data Management Reference Guide
DQI	Data Quality Indicator
DQO	Data Quality Objective
EPA	Environmental Protection Agency
GIS	Geographic Information System
MDL	Method Detection Limit
MQO	Measurement Quality Objective
NCR	Nonconformance Report
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
PO	Project Officer
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
QAS	Quality Assurance Specialist
QMP	Quality Management Plan
RPD	Relative Percent Difference
SIC	Science Information Catalog
SIMS	Science Information Management System
SLOC	Station Location Form
SOP	Standard Operating Procedure
WQI	Water Quality Indicator

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Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

This Quality Assurance Project Plan (Plan), prepared by Seattle Public Utilities for the City of Seattle, describes management of the *program effectiveness monitoring study* required under Section S8E of the Phase I Municipal Stormwater Permit, permit number WAR04-4503.

The permit, issued by the Washington Department of Ecology on January 17, 2007 with an effective date of February 16, 2007, under the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for discharges from Large and Medium Municipal Separate Storm Sewer Systems (Ecology 2007), requires three types of monitoring under section S8:

Stormwater characterization – field monitoring which is intended to characterize stormwater runoff quantity and quality to allow analysis of loadings and changes in conditions over time and generalization across the Permittees' jurisdiction.

Program effectiveness - monitoring which is intended to improve stormwater management efforts by evaluating at least two stormwater management practices that significantly affect the success of or confidence in stormwater controls.

BMP Effectiveness - full scale field monitoring to evaluate the effectiveness and operation and maintenance requirements of stormwater treatment and hydrologic management BMPs applied in their jurisdiction.

This Plan is the second of three that will be submitted to the Washington Department of Ecology (Ecology) to meet the permit requirements of Section S8 and covers the *Program effectiveness monitoring* component of section S8E. The City of Seattle submitted a "*Monitoring Approach Proposal*" to Ecology on October 7, 2007 and received an indication that the proposed approach would be acceptable to Ecology on December 12, 2007.

The primary goal of this Plan is to define procedures that assure the quality and integrity of the analyzed samples, the representativeness of the results, the precision and accuracy of the analyses, the completeness of the data, and ultimately delivers defensible products and decisions for *program effectiveness monitoring* described in Section S8E.

This document was developed with guidance from the Department of Ecology, Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (Ecology 2004). A cross-walk with the Environmental Protection Agency Quality Assurance Project Plan (QAPP) format is included in Table T-12.

This Plan 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. Study implementation 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 the specified criteria and will satisfy the project objectives and 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 history 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, and

Section 5 – Organization and Schedule.

3 BACKGROUND

In July 1995, Ecology issued three NPDES wastewater discharge general permits to regulate municipal stormwater discharges. These permits required development and implementation of stormwater management programs to reduce the discharge of pollutants to the maximum extent practicable. The permits expired on July 5, 2000. The Washington Department of Ecology (Ecology) administratively extended permit coverage until they issued the revised permit in January 2007.

Ecology combined the three current general permits for the Island/Snohomish, Cedar/Green, and South Puget Sound Water Quality Management Areas (WQMA) into a single statewide general permit. The general permit applies to all entities required to have permit coverage under current (Phase I) U.S. Environmental Protection Agency (EPA) stormwater regulations. This includes cities and unincorporated portions of counties whose populations exceed 100,000. The 1995 Phase I permittees include:

- King County
- Pierce County
- Snohomish County
- Clark County
- City of Seattle
- City of Tacoma

Phase I Secondary Permittees include:

- Port of Seattle
- Port of Tacoma

Seattle Public Utilities (SPU) completed the data collection phase of the “Seattle Street Sweeping Pilot Program” in July of 2007. This intensive data collection effort, undertaken at an approximate cost of $750,000, investigates the potential benefits to the City’s Stormwater Management Program if regenerative-air street sweepers are included as a source control measure.

Two major hypotheses will be tested in the pilot study:

- A targeted action - *Street sweeping will reduce the accumulation of sediment loading in catch basins and, thus, will reduce the frequency with which catch basins need to be cleaned*.

- A targeted outcome - *Street sweeping will increase the total amount of sediment removed from a catchment compared to the amount removed by catch basin cleaning alone*.

These hypotheses will be tested by comparing the quantity and quality of sediments accumulating in the catch basins and picked up by a street sweeper, using three pairs of drainage catchments located in Seattle. One catchment in the pair is cleaned every two weeks with a street sweeper (treatment) and one is not (control). The catch basins in treatment and control catchments will be cleaned at the beginning of the study.

The purpose of this *program effectiveness* study effort is to gather additional information needed to compare street sweeping costs and benefits to other ongoing stormwater management efforts so that the appropriate combination of street sweeping, other operations and maintenance programs, and capital improvement projects can be identified.

This study, implemented to meet the requirements of the permit, will build on the foundation established by the pilot study using archived samples collected during the last two quarters of 2006 and first two quarters of 2007 in combination with existing information about City drainage basins and conditions in the receiving water.

This study does not include the collection of any new data, but rather analysis of archived samples and modeling of results. See Seattle Public Utilities (2006) for additional information and study details. The study includes two components:

- Targeted action - R*egenerative-air street sweeping will provide comparable pollutant loading reduction to stormwater treatment.*

- Targeted outcome – *A model will serve as an effective tool to evaluate sweeping as an operational control versus capital improvement projects (i.e., stormwater treatment)*

A Schwarze Industries Model A8000 regenerative-air sweeper was used for all sweeping in the pilot study. The City is currently upgrading its street sweeping fleet to include regenerative-air sweepers as well as the mechanical broom sweeper used historically. The regenerative-air sweeper was previously reported to have pick-up efficiencies of over 99 percent under ideal conditions (i.e., picking up simulated street dirt deposited on a smooth concrete floor in an airplane hangar, with no time limit) (SPU 2006). The regenerative-air sweeper is being explored because it has been shown to be much more efficient at picking up small diameter particles typically associated with contaminants than the mechanical broom sweepers historically used.

3.1 The Problem

Section S5C, Stormwater Management Program, lists ten required components of the Stormwater Management Program (SWMP):

- Legal authority,

- Municipal Separate Storm Sewer System Mapping and Documentation,
- Coordination,
- Public Involvement and Participation,
- Controlling Runoff from New Development, Redevelopment, and Construction Sites,
- Structural Stormwater Controls,
- Source Control Program for Existing Development,
- Operation and Maintenance Program, and
- Education and Outreach Program.

While new development may have a large number of options for providing water quality treatment through structural controls, existing developed areas have limited choices for retrofitting their stormwater systems. Thus, source control and non-structural measures for improving the quality of runoff have become increasingly important. One of the non-structural measures that may be readily used throughout the city of Seattle is street sweeping.

Source control and non-structural approaches such as street sweeping can minimize the potential pollutant load conveyed from streets to the receiving environment. Sediment is a common component of stormwater and a pollutant in its own right. Excessive sediment can be detrimental to aquatic life (primary producers, benthic invertebrates, and fish) by interfering with photosynthesis, respiration, growth, and reproduction. In addition, the sediment can transport other pollutants that are attached to it, including nutrients, trace metals, and hydrocarbons.

3.1.1 Driver

The permit requires selection of two specific aspects of the stormwater management program for evaluation: (1) to evaluate the effectiveness of a specific action and (2) to evaluate the effectiveness of achieving a targeted environmental outcome.

Three basic control strategies exist for stormwater. First, prevent pollutants from coming into contact with stormwater by using source control best management practices (BMPs); second, apply treatment BMPs prior to discharge to surface or ground waters to reduce pollutants in the discharge; and third, control the flow rate of stormwater through flow control BMPs.

The focus of this study is evaluation of a source control BMP, street sweeping. Improvement in street sweeping technology over the last several decades has provided the potential opportunity to benefit the City's Stormwater Management Program. Table 1 summarizes the three common types of street sweepers and provides a range of expected performance from the literature (Zarriello, P.J. et al 2002). The two newer technologies, vacuum-assisted and regenerative-air provide significantly better performance than the conventional mechanical broom sweeper.

Table 1. Street sweeper types and ranges of performance.

Type	Mechanism	Solids removal range (%)	% Removal for particles <10 um	Street Dirt Yield (Selbig et al 2007)
Mechanical	lifts dirt off the street by a rotating broom and feed it to a hopper by a conveyor system. A water spray is often used to control dust. This is the most common type of sweeper, but typically	14-62	-7-to 8	20
Vacuum-	combines a mechanical sweeper (such	51-87	40-82	63

Type	Mechanism	Solids removal range (%)	% Removal for particles <10 um	Street Dirt Yield (Selbig et al 2007)
assisted	as a rotating broom) with a high-power vacuum. Some vacuum-assisted sweepers use a water spray to control dust and others operate completely dry with a continuous filtration system.			
Regenerative-air	combines a mechanical sweeper to loosen dirt with forced air to dislodge the remaining dirt. A high-power vacuum with a continuous filtration system captures the dirt and recycles the air.	43-71	31	76

3.1.2 Decision-making

Street sweeping has not been shown to cause a detectable reduction in stormwater quality concentrations (Selbig et al 2007). This may be due to many factors, including the ability to measure the reduction as well as the inherent variation in stormwater quality concentrations. However, street sweeping has many potential benefits that would contribute to an effective stormwater quality program. These may include:

- An effective source control measure in areas with space constraints, water table concerns, or an immediate need for sediment load reduction.
- An improvement in the cost-effectiveness of enhanced treatment structural controls by providing a significant pre-treatment function.
- A decrease in water quality impacts associated with flooding, particularly in the fall due to leaf drop.

If street sweeping can be shown to yield such benefits, Seattle may undertake a redesign of its current street sweeping program to achieve the multiple goals of aesthetics, economic vitality, and pollution prevention, thereby improving water quality and reducing maintenance costs.

3.2 Study Area

Three pairs of drainage catchments were selected for the Street Sweeping Pilot Study in the following basins:

- Southeast Seattle
- West Seattle
- Diagonal-Duwamish

Table 2 summarizes the characteristics of the selected basins. Please refer to SPU (2006) for additional information.

Table 2. Project basin characteristics.

	Southeast Seattle		West Seattle		Diagonal Duwamish	
Receiving Water Body	Lake Washington		Puget Sound		Duwamish River	
Predominant Land Use	Residential		Residential		Industrial	
Function	Treatment	Control	Treatment	Control	Treatment	Control
Subbasin Identifier	CCN	CCS	WSN	WSS	DDE	DDW
Catchment Area (acres)	34.8	41.5	24	28	23	23
Curb Miles	1.9	1.9	1.2	1.3	0.77	0.63
Street area (acres)	5.1	6.4	3.1	3.2	3.2	3.5

No. of Catch Basins Draining Street	35	38	16	18	16	17

3.3 Parameters of Concern

Impacts from stormwater are highly site-specific and vary geographically due to differences in local land use conditions, hydrologic conditions, and the type of receiving water.

There are many pollution sources that may contaminate stormwater, including 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 the storm sewers. Table 3 lists common stormwater pollutants with related potential sources. See Ecology (2006) for additional discussion on the impacts of stormwater pollutants.

Table 3. 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, dlown spouts, uncoated galvanized roofs, pipes, fencing)
Bacterial/Viral Agents	Domestic animals, septic systems, animal & manure transport
Nutrients	Sediments, fertilizers, domestic animals, septic systems, vegetative matter
Oil & Grease	Motor vehicles, illegal disposal of used oil
Organic Compounds	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
Temperature	Pavement runoff, loss of shading along streams

The sediment analytes identified as parameters of concern for the Street Sweeping Pilot are those that have a history of association with stormwater discharges, are found in urban environments, have a marine sediment quality standard, or that provide necessary support information (e.g., total organic carbon). The following list of the sediment parameters were analyzed in the pilot study.

- Grain size,
- Metals (arsenic, cadmium, chromium, copper, lead, silver, zinc),
- Total organic carbon,
- Petroleum hydrocarbons (diesel range & motor oil),
- Semi-volatile organic compounds, and
- Nutrients (Total Phosphorus and Total Kjeldahl Nitrogen).

The sediment analytes identified as parameters of concern for the *Targeted Action* study are those that would provide an increased knowledge and understanding of grain size distribution to aid in stormwater treatment improvements. These include:

- Metals (arsenic, cadmium, chromium, copper, lead, silver, and zinc), and
- Semi-volatile organic compounds if there is adequate archived sample volume.

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 Project Goals

The project goal is to comply with Section S8E of the permit. Ecology's purpose is to determine the effectiveness of the Stormwater Management Plan (SWMP) at controlling a stormwater related problem directly addressable by targeted actions in the SWMP. Ecology has indicated a feedback loop for adaptive management of the City of Seattle's stormwater management programs and the municipal stormwater permit is needed to determine which strategy, or combination of strategies, is the most cost-effective at managing stormwater.

The stormwater management program effectiveness monitoring component will answer one of each type of the following questions:

a. The effectiveness of a targeted action (or narrow suite of actions), and

b. The effectiveness of achieving a targeted environmental outcome.

4.2 Project Objectives

The primary objectives of the study are:

(1) Targeted action - *Determine if regenerative-air street sweeping provides comparable pollutant loading reduction to stormwater treatment by measuring the distribution of pollutants removed by particle grain size fractions.*

(2) Targeted outcome – *Provide a tool to evaluate sweeping as an operational control versus capital improvement projects (i.e., stormwater treatment)*

A targeted action results in improvements in stormwater quality or quality of sediments in stormwater discharges. Additional analytical analysis will be performed to increase our understanding of the distribution of contaminants in varying size fractions for each waste stream; street dirt, sweeper waste, and catch basin sediment (Table 4).

Table 4. Targeted action component summary.

Study Element	Description
Significance	The application of street sweeping in highly built out urban areas has the potential to be an effective non-structural BMP that may significantly reduce pollutant loading to nearby receiving water bodies from potentially toxic transport-derived contaminants.
Hypothesis to be tested	Regenerative-air sweepers are effective at reducing the stormwater load from metals associated with a particle size less than fine sand and regenerative-air sweepers are effective at removing the bulk of the stormwater metals loading.
Parameters to be measured	Archived samples of street dirt, street sweeper waste, and catch basin sediment will be analyzed for metals (arsenic, cadmium, chromium, copper, lead, silver, and zinc) to determine

Study Element	Description
	the distribution of selected contaminants in four size fractions (gravel, medium-to-coarse sand, fine sand, and silt/clay).
Management actions	When feasible, consider regenerative-air street sweeping as an alternative to structural controls for stormwater management.
Temporal Scale	The study will be conducted during the permit cycle but the results may be implemented over the next several decades.
Feasibility Issues	There may not be adequate sample volume archived to analyze the smallest size fraction. The archived samples have been frozen. To ensure this does not bias the study results the smallest size fraction to be analyzed is less than fine sand. Holding times for grain size have been exceeded.

A targeted outcome reduces discharge of certain pollutants below a targeted annual load amount. A tool will be developed to predict a relative targeted annual load reduction for varying conditions, such as sweeping frequency, road surface condition, and parking enforcement compliance (Table 5). Existing data and a parking compliance survey will be used as a basis for the tool.

Table 5. Targeted outcome component summary.

Study Element	Description
Significance	The application of street sweeping in highly built out urban areas has the potential to be an effective non-structural BMP that may significantly reduce pollutant loading to nearby receiving water bodies from potentially toxic transport-derived contaminants. Street sweeping effectiveness can generally be attributed to the sweeper's efficiency and the sediment deposition rate. A model that describes this relationship will allow prioritizing and optimizing a street sweeping program with the intent of providing the highest value.
Hypothesis to be tested	Street sweeping effectiveness can be described by a model that accounts for (1) sweeping efficiency, a function of the sweeper frequency, utilization, and availability, and (2) sediment deposition rate, a function of pollutant build up and wash off.
Parameters to be modeled	Sweeper efficiency; frequency; utilization due to holidays, equipment breakdowns, communication failures; availability due to incomplete sweeping of streets from no parking violators; pavement roughness and street slopes; precipitation intensity and frequency.
Management actions	The model output, $/kg pollutant removed, may be used to prioritize streets within the City to be selected for street sweeping, and as a comparison with structural controls for Capital Improvement Projects when structural controls are under consideration.
Temporal Scale	The study will be conducted during the permit cycle but the results may be implemented over the next several decades.
Feasibility Issues	There may be inadequate data to calibrate the model. The results will be relative.

4.3 Information Requirements

The sampling effort to provide the data for the Street Sweeping Pilot Study included three monitoring components:

- Catch basin sediment monitoring,
- Street sweeper contents monitoring, and
- Street dirt monitoring.

Development of the information requirements for the *Targeted Action* can be found In the Data Quality Objective Process - Step 3. Identity the Inputs to the Decision, page 27.

The information requirements for the *Targeted Outcome* are described below in Table 6.

Table 6. Targeted outcome information requirements.

Input	Category	Description
Basin Information	Catchment Characteristics	Catchment size, land use, % impervious, slope, water table, space constraints
	Drainage System	Combined, separated, partially separated
	Road system	Curb miles, street area, street type, street slope, street condition, curb and gutter status
	Predicted runoff concentrations by land use and source	International Database -predicted TSS, copper, and zinc concentration in runoff
	Average annual water quality design volume (acre-feet)	from WWHM3 using historical precipitation records
Basin Sweeper Performance Efficiency	availability factor, E_{ss},	in the range of 80% (USGS 2002b) to account for incomplete sweeping of streets due to parking violations and mechanical availability.
	performance factor, E_{pf},	in the range of 85% to account for removal efficiencies affected by pavement roughness, slope, and curb/gutter status.
	washoff factor, E_{wo}	in the range of 20 to 60% to account for "wash off" between sweepings. A function of the sweeping frequency and meteorological conditions.
Typical Sweeper Performance	availability factor, E_{ss},	in the range of 80% (USGS 2002b) to account for mechanical availability.
	Utilization factor, E_u	To account for the utilization of the sweeper due to scheduling, labor availability, and travel time to and from the job site.
	Average travel velocity – sweeping (miles per hour)	A slower velocity may have improved performance.

The outcomes of the *targeted outcome* model may include:

- The investment cost, a function of the number of sweepers per basin needed at a given sweeping frequency, mechanical availability, utilization, and sweeping rate and the cost of a purchasing a regenerative-air sweeper.

- The performance, measured as mass of contaminant removed per year from the basin. This applies the sweeper performance efficiency factor against the basin load estimated from the product of the average annual water quality volume (acre-feet) from WWHM3 and the predicted TSS, copper, and zinc concentration in runoff.

- The operating cost, the present value of the series of annual costs measured as $/kg contaminant removed per year.

Once the outcomes are generated for selected basins, they may be utilized to determine the most cost-effective method to deliver water quality services to Seattle Public Utilities' ratepayers.

4.4 Target Populations

The *Targeted Action* study focus is street dirt and associated pollutants that can be removed by a regenerative-air sweeper in four particle sizes; gravel, medium-to-coarse sand, fine sand,

and particles sized less than fine sand. The *Targeted Outcome* study focus is the performance of a regenerative-air street sweeper, measured as mass of pollutant removed per year, and the cost-effectiveness of a regenerative-air street sweeper, measured as $/kg pollutant removed per year.

5 ORGANIZATION AND SCHEDULE

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

5.1 Roles & Responsibilities

The team consists of representatives from key groups with a role in data collection or use, and often those with a critical interest or stake in the problem. This section includes the names, duties, and responsibilities of all key team participants. This includes internal and external team members. The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for the field investigation.

The roles of key individuals involved in the study are provided in Table 7. A detailed description of the lines of authority and reporting between these individuals and organizations is presented in Figure 1 and the responsibility associated with each role is outlined in Table 8.

Table 7. Study Team

Role	Name	Organization	Telephone No.
NPDES Permit Coordinator (Business Area Representative)	Kevin Buckley	SPU	206.733.9195
NPDES Monitoring Lead (Principle Investigator)	Shelly Basketfield	SPU	206.386.1127
QA Coordinator	Amy Minichillo	SPU	206.684.0974
Data Steward	To be determined.	SPU	
Contract Laboratory PM	Mark Harris	Analytical Resources Inc.	206.695.6200

In general, the Principle Investigator (PI), reporting to the Business Area Representative (NPDES Permit Coordinator), is assigned to manage the monitoring program. In this role, he/she provides technical expertise, coordinates sampling activities with the laboratory and field team, and reports the status and results of the monitoring program to the Business Area Representative.

The Business Area Representative provides direction to the PI and communicates with regulatory officials.

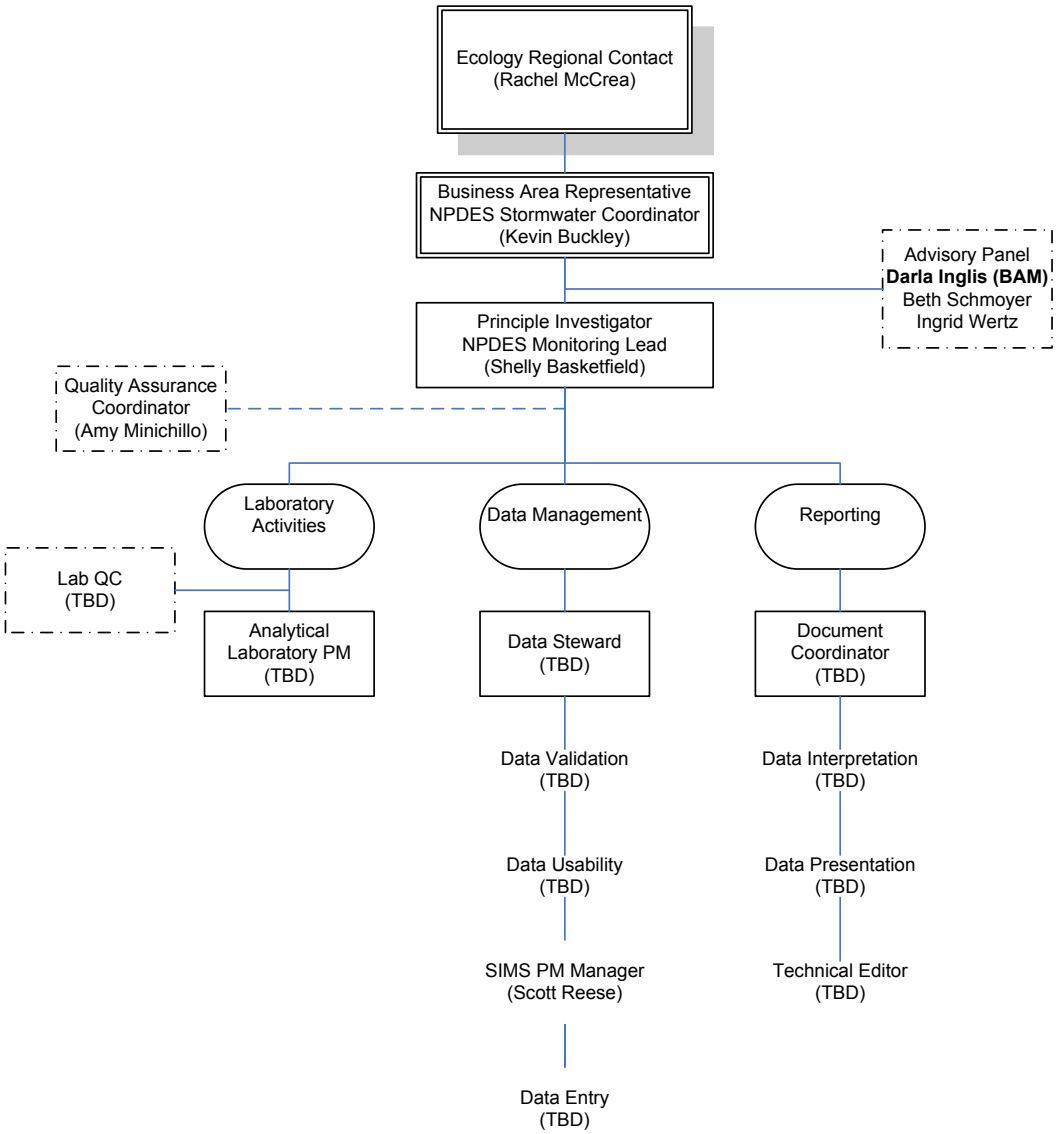

Figure 1. Organization chart with lines of communication.

A description of the detailed responsibility of each role is outline below in Table 8.

Table 8. Roles & responsibilities

Roles & responsibilities
Advisory Panel The Advisory Panel attends intermittent meetings for review process of the overall program in order to confirm or refute whether the objectives are being met. The group may make suggestions for changing specific procedure or overall organization in the event that the program design fails to meet the stated goals.
Business Area Manager Responsible for overall monitoring program including fiscal resources and personnel. Approves QAPP.
Business Area Representative Carries out needs and requirements set by the Business Area Manager. 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. Establish procedures to ensure that all personnel are free from any undue internal or external commercial, financial, and other pressures or influences that may adversely affect the performance and quality of their work. Ensure that the staff has the necessary education, experience, and/or training to perform their stated duties.

Principle Investigator 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 QAO and the organization. Responsible for: maintaining records of QAPP distribution, including appendices and amendments; maintaining written records of sub-tier commitment to requirements specified in this QAPP; identifying, receiving, and maintaining study quality assurance records; for coordinating with the QAO to resolve QA- related issues. Notifies Permit Coordinator of particular circumstances which may adversely affect the quality of data derived from the collection and analysis of samples. Enforces corrective action.
Quality Assurance Coordinator Reports to the Principle Investigator 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 and noting inconsistencies, and signing-off on the QA plan and reports.
Document Coordinator Responsible for on-schedule completion of assigned writing, editing, and data interpretation work. Directs all reporting activities, including in-house and outside review, editing, printing, copying, and distributing or journal submission.
Data Steward Responsible for the acquisition, verification, and transfer of data to the SPU database. Oversees data management for the study. Ensures data are submitted according to work plan specifications. Responsible for validation and verification of data collected. Provides the point of contact to resolve issues related to the data.
Laboratory 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 task performed and/or supervised. Responsible for oversight of all operations, ensuring that all QA/QC requirements are met, and documentation related to the analysis is completely and accurately reported. Enforces corrective action, as required. Develops and facilitates monitoring systems audits.
Laboratory QAO Monitors the implementation of the QAM and the QAPP within the laboratory to ensure complete compliance with QA objectives as defined by the contract and in the QAPP. Conducts internal audits to identify potential problems and ensure compliance with written SOPs. 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 contractor. ensures that all QA reviews are conducted in a timely manner from real-time review at the bench during analysis to final pass-off of data to the QA officer.

5.2 Timeline/study schedule

This section specifies the available resources and relevant deadlines for the study.

Key dates include:

February 16, 2008	Summary description of the study and Quality Assurance Project Plans submitted to Ecology.
August 16, 2008	Final QAPPs approved.
February 16, 2009	Full implementation of the study.
March 31, 2010	First Annual report due covering the period February 16, 2009 through September 30, 2009.
March 31, 2011	Second annual report due covering first complete water year, from October 1, 2010 through September 30, 2011.

This section describes the study deliverables, which will be presented in the annual permit report. Each annual report will include all monitoring data collected during the preceding water year (October 1 – September 30), provided the first annual monitoring report submitted will include data from a partial water year. Each report shall also integrate data from earlier years

into the analysis of results, as appropriate. Reports shall be submitted in both paper and electronic form and shall include:

- A summary of the purpose, design, and methods of the study,
- The status of implementing the study,
- A comprehensive data and QA/QC report for each part of the study where applicable, with an explanation and discussion of the results of each study,
- An analysis of the results of each part of the study, ncluding any identified water quality problems or improvements or other trends in stormwater or receiving water quality, and
- Recommended future actions based on the findings.

Section 15 provides additional details describing the procedure and method for developing the deliverables. Table 9 provides a schedule of activity and deliverables for the study.

Table 9. Study schedule time line.

Activity	Anticipated Date of Initiation	Anticipated Date of Annual Completion	Deliverable[1]	Deliverable Due Date
Complete analysis of results from pilot study	10/01/2007	06/30/2008	Pilot Study Results Report	March 31, 2009
Targeted Action	2/16/2009	09/30/2009	Stormwater Monitoring Report	March 31, 2010
Targeted Outcome	10/01/2010	9/30/2010	Stormwater Monitoring Report	March 31, 2011

[1] Submitted with Annual Report

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, and

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

6 QUALITY OBJECTIVES

This section describes the study data quality and measurement quality objectives, which describe the type and quality of data needed to meet the study goals and objectives.

Data Quality Objectives (DQOs) are qualitative and quantitative statements developed using the data quality objectives process that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors. These will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Once established, DQOs become the basis for the measurement quality objectives (MQOs) that are used specifically to address analytical performance.

Measurement Quality Objectives (MQOs) are “acceptance criteria” for the quality attributes measured by the study data quality indicators (DQIs). During study planning, measurement quality objectives are established as quantitative measures of performance against selected data quality indicators, 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

This section addresses the DQOs process applied in development of this Plan. The DQO process is a systematic planning tool based on the Scientific Method for establishing criteria for data quality and for developing data collection designs. Establishing formal DQOs during the QAPP stage of a study allows clear and unambiguous definition of study objectives, decisions, and decision criteria so that data of sufficient type, quality, and quantity are generated to meet study objectives. The formal implementation of a DQO process brings structure to the planning process, resulting in defensible decision-making.

To achieve the required DQOs, this Plan is designed to assure that a sufficient number of samples will be collected using technically valid scientific procedures.

The Guidance for the Data Quality Objectives Process, EPA QA/G-4 (EPA, 2000) provided the basis for implementing the DQO process outlined in the Data Quality Objective Process - Step 5. Decision Rule, page 29. The decision statement resulting from the DQO process is:

Include street sweeping as an option whenever structural controls are considered:

(1) *if* regenerative-air street sweeping *provides comparable pollutant loading reduction for each grain size fraction, or*

(2) *if* regenerative-*air* street *sweeping provides comparable overall pollutant loading reduction.*

6.2 Measurement Quality Objectives

The MQOs are defined in terms of precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters. Utilization of the Plan requires implementation of procedures for obtaining and evaluating data in a manner that will result in a quantitative or qualitative representation of the five PARCC parameters.

- The parameters of precision, accuracy, and completeness provide a quantitative measure of the statistical significance of the data collected in this field program. The criteria for precision and accuracy are presented in Table 5 (SPU 2006).
- The parameters of representativeness and comparability utilize documentation of the site and laboratory procedures to qualitatively evaluate the data.

Following the collection and analysis of the samples, a determination will be made whether the MQOs established for this Plan were satisfied. Data that meets the criteria will be deemed acceptable. Data that do not meet the criteria will be reviewed on a case-by-case basis to ascertain usefulness.

7 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The Street Sweeping Pilot sampling design strategy was developed by Herrera Environmental Consultants (SPU 2006) and is summarized below in Table 10. This study will build upon the data collection and analysis efforts conducted during the pilot study.

Table 10. Study design for the Street Sweeping Pilot.

Sample Type	Sampling Procedure Summary	Sample Analyses
Catch Basins Sediment	Measure total volume of sediment in approximately 12 catch basins in each of 6 catchments (3 swept, 3 unswept) once every 4 weeks starting at Week 0 (before sweeping) for a period of 48 weeks, totaling 13 occasions and approximately 936 measurements per year. Collect one sample from each catch basin every 12 weeks starting at Week 0 (before sweeping) for a total of 5 sampling events and 360 samples. Composite all 12 samples from each of 6 catchments into one sample per catchment using equal portions from each catch basin. Analyze a total of 30 composite samples for all physical and chemical parameters. Convert volume measurements to dry weight using bulk density and moisture content data.	Percent debris >2cm Bulk density Moisture content Grain size Total organic carbon Total phosphorus Total nitrogen Arsenic, cadmium, copper, lead, mercury, zinc

Sample Type	Sampling Procedure Summary	Sample Analyses
Sweeper Waste	Measure wet weight of decanted sweeper waste in dumpster for each of 3 swept catchments once every 4 weeks starting at Week 4 for a period of 48 weeks, totaling 12 occasions and approximately 36 measurements per year. Collect one composite sample from each of 3 dumpsters once every 4 weeks starting at Week 4 for a period of 48 weeks, totaling 12 sampling events and approximately 36 samples, and archive samples for future analysis. Combine three composite samples collected during consecutive 4-week periods into one composite sample for each dumpster (catchment) representing a 12-week period for a total of 12 composite samples (4/catchment). Analyze a total of 12 composite samples for all physical and chemical parameters. Convert wet weight measurements to dry weight using moisture content data.	Total Petroleum Hydrocarbons Semivolatile organic compounds
Street Dirt	Collect one street dirt sample from the street area draining to each of the 12 monitored catch basins in each of the 6 catchments once every 4 weeks starting at Week 0 (before sweeping) for a period of 48 weeks, totaling 13 sampling events and approximately 936 samples per year. Measure weight of each collected street dirt sample and composite all samples from each catchment into one sample per event, and archive composite samples for future analysis. Combine three composite samples collected during consecutive 4-week periods into one composite sample for each catchment representing a 12-week period for a total of 12 composite samples (4 per catchment). Analyze a total of 12 per composite samples for all physical and chemical parameters. Convert wet weight measurements to dry weight using moisture content data.	

Element III. Sampling and measurement procedures

This element describes the sampling and measurement procedures needed to acquire those data necessary to meet the study goals and objectives and includes:

Section 8 – Sampling Procedures, and

Section 9 – Measurement Procedures.

8 SAMPLING (FIELD) PROCEDURES

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations and practices and specific sample collection were well planned and carefully implemented. Please refer to Section "Study Design and Monitoring Procedures" for additional information (SPU 2006).

Table 11 summarizes the analytical parameters, the analytical method, and the sample containers, holding times, and preservation technique to be used for the *Targeted Action*, which includes analysis of archived samples that were collected during the pilot study.

Table 11. Analytical parameters, sample containers, and holding times.

Parameter	Method [2]	Type [3]	Sample Container	Preservation Technique	Holding Time [4]
Grain size	PSEP	Sieve	16 oz. LP [5]	Refrigerate, 4°C	6 months
Metals [6]	EPA 6010	ICP	4 oz. Glass [7]	Refrigerate, 4°C Freeze, -18°C	6 months 2 years
Semivolatile organic compounds [8]	EPA 8270	GC-MS	16 oz. glass	Refrigerate, 4°C Freeze, -18°C	14 days; 40 days 1 year; 40 days

9 MEASUREMENT PROCEDURES

Targeted Action - Catch basin sediment, street dirt, and sweeper waste archived samples will be separated into four size fractions; gravel, medium-to-coarse sand, fine sand, and clay/silt. Each size fraction will be analyzed for metals and if adequate sample volume remains, for semi-volatile organic compounds. Table 11 presents the analytical methods to be used for this study.

Targeted Outcome – No analysis is required.

[2] PSEP, EPA, and Ecology approved methods in EPA 1986, Ecology 1997, and PSEP 1997.
[3] ICP – Inductively coupled plasma spectrometer. CVAA – Cold vapor atomic absorption. GC-MS – Gas chromatograph-mass spectrometer. GC-FID – Gas chromatograph-flame ionization detection.
[4] Separate holding times are required for extraction and analysis of the elutriate for organic compounds.
[5] LP – linear polyethylene.
[6] Metals include arsenic, cadmium, copper, lead, zinc.
[7] One container for metals for each sediment sample.

Element IV. Study Implementation QA/QC Procedures

This element describes the procedures to be followed during the study implementation phase and includes:

Section 10 – Quality Control, which discusses measures to be implemented in the analytical laboratory and field,

Section 11 – Data Management and Documentation, a quality assurance (QA) measure to ensure maintenance of accurate and complete records of all study activities, and

Section 12 – Audits and Reports, which ensures the QAPP is implemented as described in this Plan.

10 QUALITY CONTROL

The field and laboratory quality control samples are intended to provide information needed to evaluate method performance during analysis and to determine whether subsequent analytical results meet study MQO's. Please refer to Sections "Field Quality Control Procedures" and "Laboratory Quality Control and Data Quality Assessment Procedures" for additional information (SPU 2006).

11 DATA MANAGEMENT & DOCUMENTATION PROCEDURES

Study documentation includes field sampling notes, field testing notes, chain of custodies, laboratory results, and reports. Please refer to Section "Data Analysis and Reporting Procedures" for additional information (SPU 2006).

12 AUDITS AND REPORTS

This section ensures that the QAPP is implemented as prescribed and describes the activities for assessing the effectiveness of the implementation of the QAPP and its associated QA/QC program. Please refer to Section "Laboratory Quality Control and Data Quality Assessment Procedures" for additional information (SPU 2006).

[8] If adequate archived sample volume is available only.

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 & Verification,

Section 14, Data Quality (Usability) Assessment, and

Section 15 – Data Analysis and Presentation.

The result of sections 13 and 14 are data of known and documented quality; *are the data of sufficient quality and quantity to meet the use for which they are intended*.

13 DATA VERIFICATION AND VALIDATION

Please refer to "Appendix B, Quality Assurance Report" for a discussion of data review, verification, and validation methods (SPU 2006).

14 DATA QUALITY (USABILITY) ASSESSMENT

Data usability is described in SPU (2006).

15 DATA ANALYSIS & PRESENTATION

This section discusses the content of the Annual Stormwater Monitoring Report. Each Annual Stormwater Monitoring Report, which is an attachment to the Annual Report under the Phase I Permit, is required to include the following five elements:

1) A summary of the purpose, design, and methods of the study,
2) The status of implementing the study,
3) A comprehensive data and QA/QC report for each part of the study, with an explanation and discussion of the results of each study,
4) An analysis of the results of each part of the study, including any identified water quality problems or improvements or other trends in stormwater or receiving water quality, and
5) Recommended future actions based on the findings.

15.1 Study Summary

Provide a brief description of the more detailed information presented in this QAPP.

- Summarize the purpose, design, and methods of the study,
- Describe the study status at the end of the reporting period.
- Provide an updated completion schedule.

15.2 Comprehensive Report

The comprehensive report will include at a minimum:

- Table showing qualified analytical results.
- An analysis of the results of each part of the study. This analysis will include discussion of the two required questions (e.g., effectiveness of a targeted action and/or achieving a targeted environmental outcome).
- At the end of the study, recommended future actions based on the findings. If the analysis indicates an ineffective targeted action or failure to achieve a targeted outcome, identify possible future actions to address the problem.

15.3 Quality Assurance/Quality Control Report

The QA/QC report should include at a minimum:

- A data validation memo for the *Targeted Action* sample batch that includes: (a) a narrative analysis of appropriate *field quality control* procedures *data quality indicator results* and of any associated issues and corrections made and (b) a narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discussed, any associated issues and corrections made.
- An overall assessment of the usability and representativeness of the data analyzed for the *Targeted Action*.

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List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Review Status	Revised by	Revision Summary
R0D1	11/05/2007	Draft	Shelly Basketfield	Initial draft.
R0D2	02/12/2008	Draft	Shelly Basketfield	Include review comments and additions from Beth Schmoyer.

Tables

Table T-12. Quality assurance planning document cross-walk.

Washington Department of Ecology	Environmental Protection Agency
1. Title Page with Approvals	A1 Title and Approval Sheet
2. Table of Contents and Distribution List	A2 Table of Contents A3 Distribution List
I. Goals and objectives of the study	
3. Background	A5 Problem Definition/Background
4. Project Description	A6 Project/Task Description
5. Organization and Schedule	A4 Project/Task Organization
II. Type, quality, and quantity of data needed	
6. Quality Objectives	A7 Quality Objectives and Criteria for Measurement Data
7. Sampling Process Design (Experimental Design)	B1 Sampling Process Design (Experimental Design)
III. Sampling and measurement procedures to acquire those data	
8. Sampling Procedures	B2 Sampling Methods B3 Sample Handling and Custody
9. Measurement Procedures	B4 Analytical Methods
IV. Study implementation QA/ QC procedures	
10. Quality Control	B5 Quality Control B6 Instrument/Equipment Testing, Inspection, and Maintenance B7 Instrument/Equipment Calibration and Frequency B8 Inspection/Acceptance of Supplies and Consumables
11. Data Management Procedures	B10 Data Management
12. Audits and Reports	C1 Assessments and Response Actions C2 Reports to Management
IV. Assessment procedures to ensure that study objectives are met	
13. Data Verification and Validation	D1 Data Review, Verification, and Validation D2 Verification and Validation Methods
14. Data Quality (Usability) Assessment	D3 Reconciliation with User Requirements
15. Data Analysis and Presentation	

DQO Process – Targeted Action

Data Quality Objectives are qualitative and quantitative statements that clarify the study objective, define the most appropriate type of data to collect, and determine the most appropriate conditions under which to collect them. DQOs also specify the minimum quantity and quality of data needed by a decision-maker to make any decisions that will be based on the results for the project. The DQO process consists of seven steps, which are conducted in an iterative process.

Step 1. State the Problem

The first step is the identification of the problem that has initiated the study, and that requires new environmental data. There are four basic activities in this step:

1a. Identify members of the planning team. Key members are identified in Section 5.1 for the main body of the QAPP.

1b. Identify the primary decision maker of the planning team and define each member's role and responsibility during the DQO process. Roles and responsibilities are identified in Section 5.1 of the main body of the QAPP. The main decision-makers are the Business Area Manager and the Business Area Manager Representative.

1c. Develop a concise description of the problem. Seattle Public Utilities is charged with managing the City of Seattle's stormwater. Stormwater management encompasses a number of different elements including operations and maintenance of City-owned infrastructure, constructing stormwater capital improvement projects (e.g., regional stormwater treatment facilities and code-driven projects), and pollution prevention/source control efforts. The key to a successful program is identifying the best combination of the above tools to meet the needs of the City's watersheds. In the past, SPU has focused on certain operational tools (e.g., catch basin cleaning) and has recently implemented a number of capital improvement projects to improve stormwater quality (e.g, natural drainage system projects). Although Seattle has an active street sweeping program, managed by the Seattle Department of Transportation (SDOT), the existing program mainly focuses on removing litter and debris for aesthetic purposes in the central business district and along major arterials.

SPU would like to evaluate how the street sweeping program could be modified to improve benefits to area receiving water bodies. In 2006-2007, SPU and SDOT completed a street sweeping pilot test to measure its effectiveness in reducing pollutant loads and to evaluate operational issues, such as parking. To incorporate street sweeping as an element of an overall stormwater management program, SPU must be able to evaluate sweeping in the context of other stormwater management efforts. Understanding the distribution of contaminants within different particle size fractions and the effectiveness of regenerative-air street sweeping at removing different sized particles will support this evaluation.

1d. Specify the available resources and relevant deadlines for the study. Section 5.2 discusses the project deliverables and the anticipated schedule.

Step 2. Identify the Decisions

The second step in the process is to define the decision statement that the study will attempt to resolve. There are four basic activities in this step:

2a. Identify the principal study question. *Does regenerative-air street sweeping provide comparable pollutant loading reduction to stormwater treatment?*

2b. Define the alternative actions that could result from resolution of the principal study question.

Alternative Action (if yes) – When feasible, consider regenerative-air street sweeping as an alternative to structural controls for stormwater management.

Alternative Action (if no) – Continue use of structural controls.

2c. Combine the principal study question and the alternative actions into a decision statement. Determine if regenerative-air street sweeping provides comparable pollutant loading reduction to stormwater treatment and if so modify the Stormwater Management Plan (SWMP) to include street sweeping as an option whenever structural controls are considered.

2d. Organize multiple decisions. Only one decision is being evaluated.

Step 3. Identity the Inputs to the Decision

In this step, the planning team identifies the different types of information needed to resolve the decision statement. There are four activities in this step:

3a. Identify the information that will be required to resolve the decision statement.

We want to determine if regenerative-air street sweeping provides comparable pollutant loading reduction to stormwater treatment by measuring the distribution of pollutants removed by particle grain size fractions.

We will measure concentrations of metals (arsenic, cadmium, chromium, copper, lead, silver, and zinc) in four size fractions for three different sources and two land use types in three basins (Table 13). There is potentially enough archived sample available to analyze three samples for each source, land use, and size fraction. Sampling in the industrial basin did not begin until the fourth quarter 2006, so a sample from the third quarter 2006 for the industrial basin is not available. The residential basins may not have adequate sample to analyze from the fourth quarter 2006. In addition to metals, the samples will be analyzed for semi-volatile organic compounds if sample volume is available.

Table 13. Targeted action Information needs summary and number of samples.

Source (Swept Basin)	Land Use	Basin	Wentworth class and particle size fraction (microns)			
			Gravel (>2000)	Coarse to medium sand (250-to-2000)	Fine sand (75 -to-250) [9]	Silt and clay (<75) [9]
Catch Basin	Residential	Southeast Seattle	3	3	3	3
		West Seattle	3	3	3	3

[9] The Wentworth class uses 62.5 microns.

Source (Swept Basin)	Land Use	Basin	Wentworth class and particle size fraction (microns)			
			Gravel (>2000)	Coarse to medium sand (250-to-2000)	Fine sand (75 -to-250) [9]	Silt and clay (<75) [9]
	Industrial	Duwamish	3	3	3	3
Street Dirt	Residential	Southeast Seattle	3	3	3	3
		West Seattle	3	3	3	3
	Industrial	Duwamish	3	3	3	3
Sweeper Waste	Residential	Southeast Seattle	3	3	3	3
		West Seattle	3	3	3	3
	Industrial	Duwamish	3	3	3	3

3b. Determine the sources for each item of information identified.

(1) For each archived sample, the metals concentration will be analyzed by Analytical Resources, Inc. using the methods described in SPU (2006) for four size fractions.

(2) For each land use and size fraction the method of Selbig and Bannerman (2007) will be used to estimate the street dirt yield. This information was collected during the pilot study.

$$P = \frac{\sum_{i=1}^{n}\left[\left(\frac{M}{WxN}\right)xL_{ft}\right]}{\sum_{i=1}^{n} L_{mi}}$$

Where:

P is the mass of dirt on a street, in kilograms per curb-mile;
n is the total number of streets in each basin;
i is an index to each street sampled in a study basin;
M is the total mass of sampled street-dirt, in kilograms;
W is the width of the vacuum nozzle, in feet;
N is the number of individual strips vacuumed per street;
Lft is the length of each street, in feet; and
Lmi is the length of each street, in miles.

(3) For each Street Dirt Yield value, estimate the Street Dirt Yield load for each metal using the concentration measured in item one and the street dirt yield estimated in item two.

(4) For each land use, metal concentration measured in item one, and size fraction mass measured during the pilot study, estimate the sweeper waste load removed.

(5) For each land use and size fraction estimate the removal efficiency using the loads estimated in item three and four and the following relationship:

$$RE(\%) = \frac{SweeperWasteLoad(kg/curb-mile))}{StreetDirtYieldLoad(kg/curb-mile)}$$

3c. Identify the information needed to establish the action level. The action level determines which alternative action will be taken. The action level for the decision will be based on (1) whether the regenerative-air street sweeper reduces metals loading from particles smaller than fine sand and (2) whether the regenerative-air sweeper removes the bulk of the metals loading.

3d. Confirm that appropriate analytical methods exist to provide the necessary data. The appropriate methods exist to provide the necessary data (See SPU 2006).

Step 4. Define the Study Boundaries

In this step, the planning team defines the spatial and temporal boundaries of the problem. There are five activities in this step:

4a. Specify the characteristics that define the population of interest. Key attributes of the population of interest are the concentration of metals (arsenic, cadmium, chromium, copper, lead, silver, zinc) in street dirt, CB sediments, and sweeper waste for four particle sizes and two land use types (Table 13).

4b. Define the spatial boundary of the decision statement. The decision will be applied within the City of Seattle city limits, in street areas that are owned and/or controlled by the City, have curb and gutter, and drain to the storm system.

4c. Define the temporal boundary of the problem. The time-frame in which the decision may be applied will be for Capital Improvement Program planning from fiscal year 2010 onward. Samples were collected from July of 2006 through June of 2007 and will be analyzed in 2008.

4d. Scale of decision-making. The decision-making will be applied at the SWMP level, to guide the overall program as well as at a project-by-project level as an alternative for consideration during the asset management process.

4e. Practical constraints on data collection. The most important practical consideration that could interfere with the study is inadequate archived sample for each source, land use, and size fraction. Another concern is the holding time.

Step 5. Decision Rule

The purpose of this step is to define the parameter of interest, specify the action level, and integrate previous DQO outputs into a single statement that describes a logical basis for choosing among alternative actions. This step includes the development of logical "if…then.." statements that define the conditions that would cause the decision-maker to choose among alternative actions.

In this step, the planning team summarizes the attributes of the problem and how the information collected will guide the team to choose a course of action that will solve the problem. There are four main elements to the decision rule: the parameter of interest, the scale of decision-making, the action level, and the alternative actions.

The three activities involved in this step are as follows:

5a. Specify the statistical parameter that characterizes the population (the parameter of interest). The planning team is interested in the true median pollutant loading reduction for four grain size fractions; gravel, coarse-to-medium sand, fine sand, and silt/clay.

5b. Specify the action level for the study. The action level for the decision will be based on the detection of a significant difference in pollutant reduction between the four size fractions (gravel, coarse-to-medium sand, fine sand, and silt/clay).

5c. Develop a decision rule. Include street sweeping as an option whenever structural controls are considered:

(3) if regenerative-*air* street *sweeping provides comparable pollutant loading reduction for each grain size fraction, or*

(4) *if* regenerative-*air* street *sweeping provides comparable overall pollutant loading reduction.*

Step 6. Tolerable Limits on Decision Error

The decision maker's tolerable decision error rates are based on a consideration of the consequences of making a decision error. There are four activities in this step:

6a. Determine the possible range of the parameter of interest. The removal efficiency of street waste may range from zero to 80 percent, depending on the metal of interest, the concentration, season, and other factors.

6b. Identify the decision errors and choose the null hypothesis. There are two decision errors: (i) deciding that the regenerative-air sweeper is effective at removing particles smaller than fine sand when it is not and (ii) deciding that the regenerative-air sweeper is not effective at removing particles smaller than fine sand when it truly is. The true state of nature for decision error (i) is that the regenerative-air sweeper is not effective at removing particles smaller than fine sand. The true state of nature for decision error (ii) is that the regenerative-air sweeper is effective at removing particles smaller than fine sand.

The consequences of deciding that the regenerative-air sweeper is effective at removing particles smaller than fine sand when it is not will be that the smaller particles will be washed off the street surface, enter the storm drain system, and ultimately the receiving water.

The consequences of deciding that the regenerative-air sweeper is not effective at removing particles smaller than fine sand when it truly is are: (1) unrecognized benefits from street sweeping and (2) the potential for higher stormwater management costs to Seattle Public Utilities' ratepayers because the opportunity to implement street sweeping as an option to structural controls, which have higher life-cycle costs, will not be realized.

Decision error (ii) has the more severe consequences. Even though street sweeping may be ineffective at removing the particles smaller than fine sand, it may remain effective at removing a considerable mass of pollutants of larger particles size which would otherwise be transported to the receiving environment.

The baseline condition of null hypothesis (H_o) is "the regenerative-air sweeper is effective at removing particles smaller than fine sand."

The alternative hypothesis (H_a) is "the regenerative-air sweeper is not effective at removing particles smaller than fine sand."

The false positive decision error occurs when the null hypothesis is rejected when it is true; when the decision maker decides the regenerative-air sweeper is not effective at removing particles smaller than fine sand when it truly is. The false negative decision error occurs when the null hypothesis is not rejected when it is false; when the decision maker decides that the regenerative-air sweeper is effective at removing particles smaller than fine sand when it is not.

A tentative strategy for testing the hypothesis uses pairing; we make inferences about the difference between the two populations using the paired data set and analyze the data as a single sample. This approach is valid where the assumption of independence is not valid between the samples when data is obtained from two populations (see USFHA 2002).

Each size fraction (gravel, medium-to-coarse sand, fine sand, and silt/clay) will have eleven removal efficiency values. We will obtain a paired difference by subtracting the removal efficiency from one size fraction with the corresponding removal efficiency for each of the other size fractions for each sample. The null hypothesis (Ho) and alternative hypotheses (H_a) are specified below:

$$H_o: \mu_d = 0$$
$$H_a: \mu_d > 0$$

where μ_d is the mean of the paired differences. If the paired differences are assumed to follow a normal distribution, a t-statistic can be computed for a one-sample t test:

$$t = (x - \mu_d)/(s/\sqrt{n})$$

where x is the mean of observed differences, s is the standard deviation of observed differences, and n is the number of observations. We reject the null hypothesis if the t statistic is greater than the critical value ($t_{\alpha,n-1}$). We will determine the level of significance, α, the error rate we are willing to accept to ascertain if the regenerative-air sweeper is effective at removing particles smaller than fine sand after examination of the level of significance needed to meet H_a: $\mu_d > 0$ for the larger sized fractions.

If the assumption of a normal distribution is not felt to be valid, the equivalent nonparametric test (Wilcoxon signed rank one-sample test) can be conducted on the paired differences.

Step 7. Optimize Design for Obtaining Data

This step of the DQO process describes the approach to collecting new data necessary to address the decisions identified in Step 2.

The quantity of new data has been optimized so that an appropriate quantity of new data is collected, providing the information required to assess the baseline condition.

7a. Review the DQO outputs and existing environmental data. The DQO outputs will be reviewed by a statistician. Based on the pilot study data, the sweeper waste varies from season and with land use.

7b. Develop general data collection design alternatives. The data collection design is described in SPU (2006).

7c. For each data collection design alternative, select the optimal sample size that satisfies the DQOs. Eleven samples were collected based on the previous sampling design.

7d. Select the most resource-effective data collection design that satisfies the DQOs. A significant investment has been made in the Street Sweep Pilot Study ($750,000). Analyzing all available samples is the most resource-effective design.

7e. Document the operational details and theoretical assumptions of the selected design in the Quality Assurance Project Plan. The DQO process is included as part of the QAPP.