Tacoma

Section S8E - Program Effectiveness

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Permit No.: WAR04-4003

Revision: S8E-003 (Final)
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Prepared by:

City of Tacoma
Tacoma, Washington

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1 Title And Approval Sheet

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Internal Review and Approval

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Date: 8-17-09

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Acronyms

CIPP	Cured-in-place
CV	Coefficient of Variation
DQO	Data Quality Objective
EPA	Environmental Protection Agency
MDL	Method Detection Limit
MDRD	Minimum Detectable Relative Difference
MQO	Measurement Quality Objective
NPDES	National Pollutant Discharge Elimination System
OMMP	Operations, Maintenance and Monitoring Plan
QA/QC	Quality Assurance/Quality Control
QAM	Quality Assurance Manual
QAO	Quality Assurance Officer
QAPP	Quality Assurance Project Plan
RPD	Relative Percent Difference
SQO	Sediment Quality Objectives
SWMP	Stormwater Management Program
SOP	Standard Operating Procedure

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Abstract

This Quality Assurance Project Plan (Plan), prepared by City of Tacoma with assistance from Anchor Environmental LLC, describes management of the program effectiveness monitoring study required under Section S8E of the Phase I Municipal Stormwater NPDES Permit, Permit Number WAR04-4003 (Ecology 2007). The permit requires S8E 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.

This Plan is the third of four 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. This document is a companion to the Section S8 Program QAPP.

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.

3 BACKGROUND

Intensive source control investigation and storm flow monitoring from 2001-2006 show pipes tributary to Outfalls 254, 237A, 230 and 235 have been identified chemical of concerns in stormwater, baseflow and/or stormwater sediments. Some of these chemicals of concern concentrations are statistically significantly greater than those found in other Thea Foss Waterway outfalls. Source control investigations concentrated in portions of these basins concluded that sources of PAHs, phthalates, DDT, PCBs and/or mercury may be historic buildup of stormwater sediments within the municipal storm drain system.

City of Tacoma completed a pilot/demonstration project in Basins 254, 235 and 230. For each of these basins, the entire city-owned storm drain system, catch basins, laterals and pipe were cleaned and TVed. The first basin cleaned was 254. New procedures to safely clean pipe and collect cleaning water and curing water without discharge into the downstream receiving were developed to protect Thea Foss Waterway and the remediated sediments.

The video of the collection system in Tacoma's downtown area, which is approaching 100 years of use, showed defects (cracks, holes, etc.) in the aging system. These defects allow potentially contaminated groundwater and soil from historic "hot spots" to enter the system and ultimately discharge to the Thea Foss Waterway Superfund site and Commencement Bay.

To combat this problem, the City of Tacoma will retrofit and rehabilitate up to 17,807 feet of damaged stormwater pipe, by relining it with cured-in-place pipe (CIPP) technology. The project area focuses on the area tributary to Outfalls 230 and 235, which drain approximately 14 acres of the oldest area of downtown Tacoma.

When properly installed, the CIPP liner will result in continuous stormwater pipe segments with no joints (except for manhole connections), that are free of leaks associated with structural defects. Approximately 80% of the deteriorating pipes in the project area or 3.3 miles of pipe can be replaced with this project. There is another mile of pipe that will require full replacement through open trench construction; that will be initiated concurrent with the lining project. Starting in the spring of 2008, a fourth cleaning project was started in the 237A Basin.

Two major hypotheses will be tested in the pilot/demonstration project study:

- *Null Hypothesis S8D-1.* Stormwater concentrations before and after basin-wide cleaning are not significantly different.
- *Alternative Hypothesis S8D-1.* Stormwater concentrations after basin-wide cleaning are significantly lower than concentrations before cleaning.

and

- *Null Hypothesis S8D-2.* Average sediment concentrations for constituents of concern in the head of Thea Foss Waterway are above the SQOs (or biological effects levels).
- *Alternative Hypothesis S8D-2.* Average sediment concentrations for constituents of concern in the head of Thea Foss Waterway are significantly below the SQOs (or biological effects levels).

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 other measures for improving the quality of runoff have become increasingly important. Maintenance activities are believed to be one of the other measures that can improve the quality of runoff from older existing systems.

Cleaning and removing sediment buildup from storm systems can minimize the potential pollutant load conveyed from through the pipes 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.
Retrofitting and rehabilitating decaying pipe systems may improve water and sediment quality discharges to downstream receiving waters by removing the transport mechanism for historical contaminated groundwater or soil.

3.1.1 Driver

The permit requires selection of two specific aspects of the SWMP for evaluation: (1) to evaluate the effectiveness of a specific action and (2) to evaluate the effectiveness of achieving a targeted environmental outcome. The focus of this study is evaluation of maintenance practices for aging pipe systems. This includes the evaluation of cleaning and associated standard operating procedures for cleaning, and the possible subsequent retrofitting/rehabilitating decaying pipe systems. The City of Tacoma submitted this proposal to Ecology on July 12, 2007.

3.1.2 Decision-making

Source control investigations in Basins 230 and 235 have concluded that one possible source of chemicals of concern are historic sediment buildup within the aging pipe systems. In addition, it is believed that defects in aging and decaying pipes allow potentially contaminated groundwater and soil from historically contaminated areas to enter the system and ultimately discharge to receiving waters. Maintenance activities such as cleaning and/or retrofitting/rehabilitating decaying pipe systems may have the ability to improve stormwater and stormwater sediment quality concentrations by removing historic sediment or contaminated sources.

If these maintenance activities can be shown to yield such improvements, Tacoma will include these in its maintenance program for cleaning and rehabilitating aging and decaying systems. Basins would be prioritized for cleaning activites across the MS4 and include pipe, catch basins leads, and catch basins. Current practices are regularly cleaning catch basins and other areas only on an as needed basis. Retrofitting/rehabilitating decaying pipe systems, as identified through TV condition surveys of the pipeline, would be considered as another tool to improve stormwater and stormwater sediment quality concentrations.

3.2 Study Area

Three of the four basins that were cleaned, were selected for this study including:

- Outfall 235
- Outfall 230
- Outfall 237A

All these drainages discharge to Thea Foss Waterway (Figures 3-1 and 3-2). Table 3-1 summarizes the characteristics of the selected basins. Please refer to Tacoma (2008) for additional information.

Table 3-1. Project basin characteristics.

Basin Name	OF235	OF230	OF237A
Predominant Land Use	commercial	commercial	Ind/comm/res
Area (acres)	180	513	2,794

3.3 Parameters of Concern

The chemicals of concern for Thea Foss Waterway identified as having the greatest potential to affect receiving water sediment quality following the cleanup action are PAHs and phthalates. These chemicals have a history of association with stormwater discharges, are found in urban environments, and have a marine sediment quality standard. The analytes identified as parameters of concern for this study are:

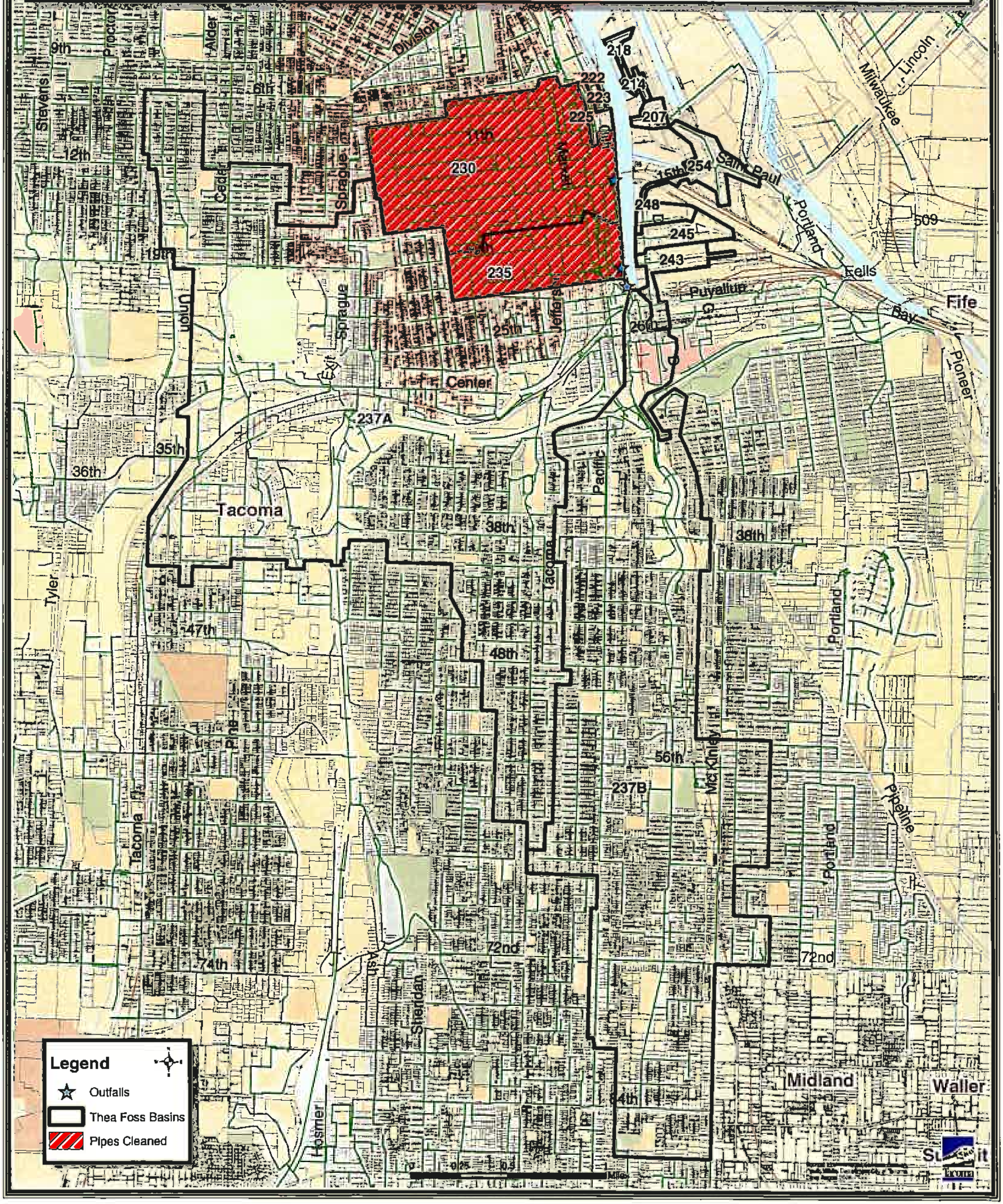
- Mercury,
- PAHs,
- Phthalates, and
- PCBs.

The chemicals of concern for each basin as identified in Tacoma (2008) are as follows:

- OF235 – PAHs and phthalates
- OF235 - Mercury, PAHs, Phthalates, and PCBs.
- OF237A - Mercury, PAHs, Phthalates, and PCBs

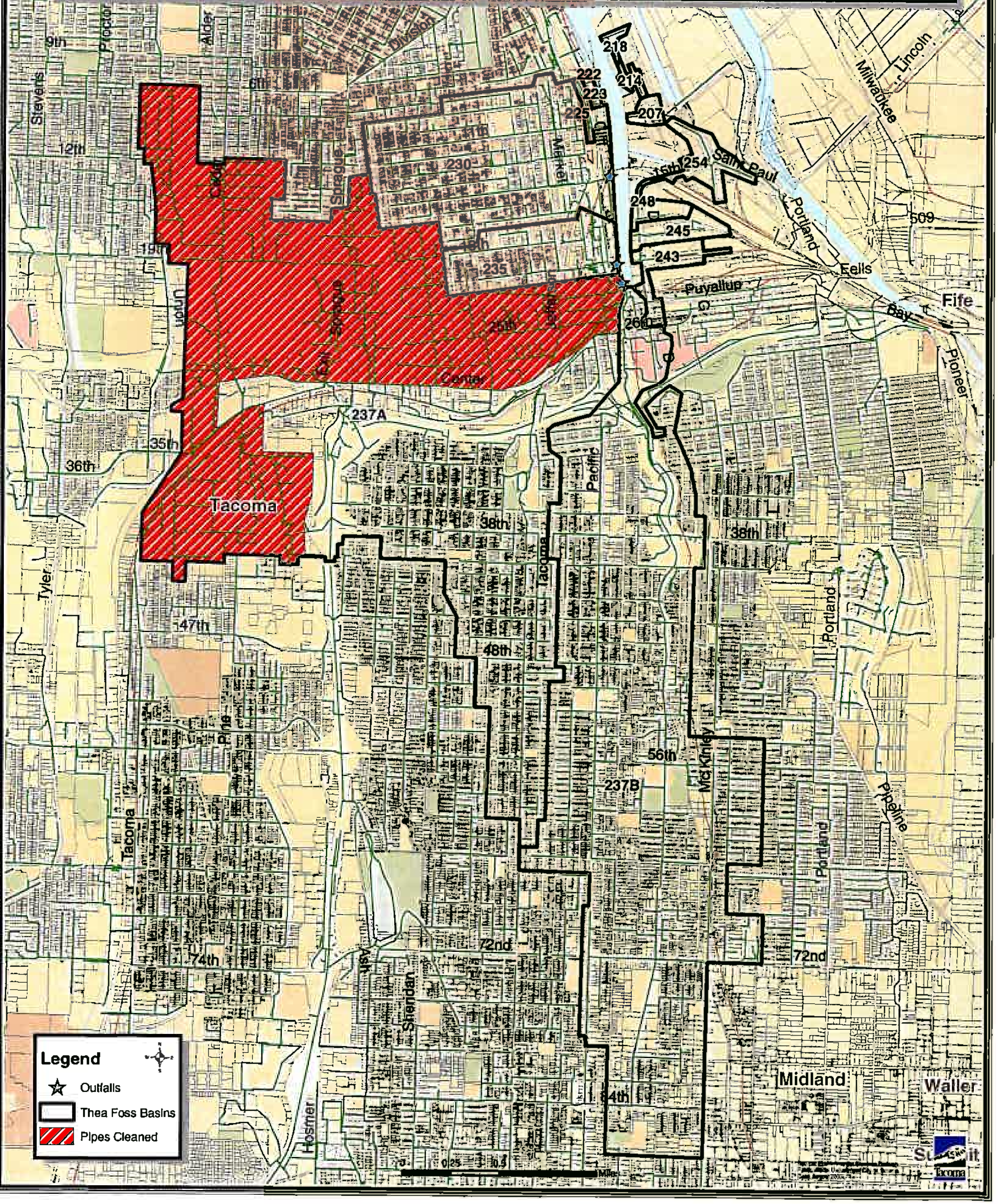
Thea Foss Basin 230 and 235 Pipe Cleaning Project

Figure 3-1



Thea Foss Basin 237A Pipe Cleaning Project

Figure 3-2



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. Please refer to Sections 6.1.1 through 6.1.4 for further information.

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 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 Tacoma's SWMPs and the municipal stormwater permit is needed to determine which strategy, or combination of strategies, is the most cost-effective at managing stormwater.

The SWMP 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 - To what extent does basin-wide cleaning of storm sewers and catch basins contribute to improvements in stormwater quality (i.e., reductions in contaminant concentrations)?
(2) Targeted outcome – Is the basin-wide cleaning of storm sewers and catch basins in key drainages, combined with other facets of Tacoma's multi-pronged source control program, helping to protect sediment quality in Thea Foss Waterway?

A targeted action results in improvements in baseflow, stormwater and/or stormwater sediments quality. The targeted environmental outcome results in improvements in sediment quality in the head of Thea Foss Waterway which tends to accumulate the highest contaminant concentrations in the waterway.

4.3 Information Requirements

The ongoing sampling effort to provide the data for the Pilot/Demonstration Study includes four monitoring components from the Thea Foss Stormwater Monitoring and Source Control Programs:

- Sediment-trap monitoring,
- Baseflow monitoring,
- Stormwater monitoring, and
- Waterway sediment monitoring.

Information requirements for the Pilot/Demonstration Study can be found In Section 6.1.3.

4.4 Target Populations

The *Targeted Action* study focus is historic sediments, groundwater infiltrations and soil and associated pollutants that can be removed by a cleaning and/or rehabilitating the storm pipes. The *Targeted Outcome* study focus is the effect of these maintenance activities on the sediment quality in the head of Thea Foss Waterway.

5 ORGANIZATION AND SCHEDULE

This section describes the roles and responsibilities of the study team, the study timeline and schedule. Please refer to S8 Program QAPP, Section 5.0 "Organization and Schedule" for roles, responsibilities and study timeline/schedule.

5.1 Study Deliverables

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, including 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 5-1 provides a schedule of activity and deliverables for the study. It is anticipated that reports will be submitted annually, each year will incorporate that years' analytical data from the Thea Foss Programs.

Table 5-1. Study schedule timeline.

Activity	Date of Initiation	Anticipated Date of Annual Completion	Deliverable[1]	Deliverable Due Date
Thea Foss Stormwater and Source control Program Reports	08/01/2001	08/30/2008	Thea Foss Stormwater & Source Control Program Reports	Annual, March 31
Targeted Action	08/16/2009	09/30/2010	Stormwater Monitoring Report	Annual, March 31
Targeted Outcome	08/16/2009	9/30/2010	Stormwater Monitoring Report	Annual, March 31

1 Submitted with Annual Report

6 QUALITY OBJECTIVES

This section describes the data quality objectives (DQOs) and measurement quality objectives (MQOs) for the stormwater monitoring program (i.e., the type and quality of data needed to meet the program goals and objectives). DQOs are qualitative and quantitative statements that define the objectives of the project, identify the most appropriate types of data and data collection procedures, and specify acceptable error limits for decision-making.
Once established, the DQOs become the basis for the MQOs that are used to assess analytical performance. MQOs are quantitative measures of performance using data quality indicators such as precision, bias, representativeness, completeness, comparability, and sensitivity. Data that meets the QAPP-specified MQOs is considered acceptable for use in project decision making.

6.1 Data Quality Objectives

The DQOs for this project were developed in general accordance with USEPA Guidance for Data Quality Objectives Process, EPA QA/G-4 (USEPA, 2000). The DQO process for Tacoma's stormwater monitoring program is presented below.

6.1.1 Step 1: State the Problem

The two components of Program Effectiveness Monitoring are (1) monitoring the effectiveness of a targeted action and (2) monitoring the effectiveness of achieving a targeted environmental outcome.

Targeted Action. The targeted action is a comprehensive cleaning of the sewer lines and catch basins in three major drainage basins to the Thea Foss Waterway (Outfalls 237A, 235, and 230). Improvements in stormwater quality that result from this basin-wide source control action will be monitored at these three outfalls to Thea Foss Waterway. Basin-wide cleaning was completed in 2007 for Outfalls 230 and 235, and cleaning is expected to be completed in 2008 for Outfall 237A.

Targeted Environmental Outcome. The targeted environmental outcome that will be monitored is the sediment quality in the head of Thea Foss Waterway which tends to accumulate the highest contaminant concentrations in the waterway. Outfalls 237A and 235 contribute 50% of the suspended sediments and 7.8 to 32.6% of the stormwater loadings to the head of the waterway. Therefore, basin-wide cleaning of these drainage systems may have a measurable effect on the sediment quality in the head of the waterway.

Sediment quality in the head of the Thea Foss Waterway has been monitored since April 2004. This corresponds to the initial starting concentration as well as Years 1 through 4 following the remedial action in the waterway which consisted of a sand cap over the contaminated sediments. Time-series graphs for four key constituents (phenanthrene, pyrene, dibenz[a,h]anthracene, and DEHP) are presented on Figure 6-1. As part of the Program Effectiveness Monitoring, Tacoma is proposing to collect sediment samples in Year 5 (May 2009) and Year 7 (May 2011) and compare the sediment concentrations to Commencement Bay SQOs (EPA 1989).

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Figure 6-1 Time Series

6.1.2 Step 2: Identify the Decisions

Program Effectiveness Monitoring is designed to answer the following questions:

- To what extent does basin-wide cleaning of storm sewers and catch basins contribute to improvements in stormwater quality (i.e., reductions in contaminant concentrations)?
- Is the basin-wide cleaning of storm sewers and catch basins in key drainages, combined with other facets of Tacoma's multi-pronged source control program, helping to protect sediment quality in Thea Foss Waterway?

These questions are developed into the following testable statistical hypotheses:

- *Null Hypothesis S8D-1.* Stormwater concentrations before and after basin-wide cleaning are not significantly different.
- *Alternative Hypothesis S8D-1.* Stormwater concentrations after basin-wide cleaning are significantly lower than concentrations before cleaning.

and

- *Null Hypothesis S8D-2.* Average sediment concentrations for constituents of concern in the head of Thea Foss Waterway are above the SQOs (or biological effects levels).
- *Alternative Hypothesis S8D-2.* Average sediment concentrations for constituents of concern in the head of Thea Foss Waterway are significantly below the SQOs (or biological effects levels).

Sufficient data will be collected in support of Program Effectiveness Monitoring to be able to test these hypotheses with an appropriate level of statistical confidence and power. If Alternative Hypothesis S8D-1 is found to be true, then Tacoma will prioritize its drains, based on their pollutant loading potential, and begin to perform basin-wide cleaning in other drains, starting with the top priorities. If Alternative Hypothesis S8D-2 is found to be true, then Tacoma will assess the relative contribution of stormwater to the observed sediment quality impact, compared to other non-stormwater sources, and if appropriate, step up its source control efforts for the constituent(s) of concern in the adjacent drainage basins.

6.1.3 Step 3: Identify Inputs to the Decision

Tacoma has been monitoring stormwater quality under its EPA Consent Decree in seven of the largest municipal drainages in the Thea Foss watershed since August 2001. Because these monitoring data were collected using methods comparable to those proposed herein, they will be used to help characterize stormwater quality at Outfalls 237A, 235, and 230 prior to basin-wide cleaning. Existing data on stormwater quality is compiled and summarized in Tacoma's annual stormwater monitoring reports (see Tacoma 2008). Existing data on Thea Foss Waterway sediment quality is compiled in annual reports of the Operations, Maintenance, and Monitoring Plan (OMMP) for the head of the Thea Foss Waterway (Tetra Tech 2006, 2007).

The following parameters will be monitored in stormwater and sediment as part of the targeted action and targeted environmental outcome.

- TSS (stormwater only)
- Metals (lead and zinc)
- Semivolatile organic compounds (PAHs and phthalates).

These parameters were selected because they are considered the most critical monitoring parameters for protecting sediment quality in the recently remediated Thea Foss Waterway. These parameters have been monitored in municipal stormwater since August 2001, and in waterway sediment since April 2004.

The variability of Tacoma's existing stormwater and sediment data will support the design of a statistically based sampling program. Summary statistics for representative stormwater monitoring parameters in municipal outfalls 237A, 235, and 230, and sediment monitoring parameters in the head of Thea Foss Waterway (i.e. south of the SR-509 bridge) are presented in Table 6-1. This table includes the arithmetic mean concentration and coefficient of variation (CV) over the six-year monitoring period for stormwater, and the mean and CV of the most recent monitoring event for sediments. The CV is a measure of sampling and analytical variability and will be used to evaluate the relationship between sample size and statistical power (see Section 6.1.7 below). The CVs for TSS and metals concentrations in stormwater appear to be somewhat lower overall than those for organic contaminants such as phthalates and PAHs. The CVs for sediments appear to be generally lower than those for stormwater.

Table 6-1. Thea Foss Data Arithmetic Mean and CVs.

Analyte	Outfall 237A		Outfall 230		Outfall 235		Thea Foss Sediments[1]	
	Arithmetic Mean	CV (%)	Arithmetic Mean	CV (%)	Arithmetic Mean	CV (%)	Arithmetic Mean	CV (%)
Conventionals in ppm								
TSS	50	0.45	61	0.70	101	0.77	NA	NA
Metals in ppm								
Copper	NM	NM	NM	NM	NM	NM	NM	NM
Lead (Total)	14	0.47	29	0.68	95	0.60	47	0.58
Mercury (Total)	NC	NC	NC	NC	NC	NC	NM	NM
Zinc (Total)	118	0.47	137	0.71	164	0.58	120	0.59
Lead (Diss.)	0.9	0.63	1.6	0.87	7.9	0.76	NA	NA
Mercury (Diss.)	NC	NC	NC	NC	NC	NC	NA	NA
Zinc (Diss.)	72	0.59	70	0.65	54	0.68	NA	NA
Organics in ppb								
DEHP	3.8	0.60	5.8	0.71	9.7	1.37 [2]	2,790	0.35
Phenanthrene	0.16	0.85	0.18	0.82	0.18	0.75	690	0.70
Pyrene	0.40	0.76	0.37	0.74	0.35	0.68	1,330	0.53

Notes:
Stormwater data from City of Tacoma 2008; Annual Stormwater Monitoring Report, 2001-2007, Appendix F
NM = Not measured; NA = Not Applicable
NC = Not calculated due to predominance of undetected results
[1] Metals data from TetraTech 2006; Organics data from TetraTech 2007
[2] High CV for DEHP in Outfall 235 caused by one extreme outlier in Monitoring Year 2

6.1.4 Step 4: Define the Boundaries of the Study

Targeted Action. The geographic boundaries of the monitoring program for the targeted action include municipal Drainage Basins 237A, 235, and 230. The temporal boundaries of the monitoring program are based on the date of completion of basin cleaning activities and adherence to water year schedules, as listed below:

Outfall	Pre-Cleaning Period	Post-Cleaning Period
237A	Oct-01 to Sep-08	Oct-08 to Sep-10
235	Oct-01 to Sep-07	Oct-07 to Sep-10
230	Oct-01 to Sep-07	Oct-07 to Sep-10

Targeted Environmental Outcome. The geographic boundaries of the monitoring program for the targeted environmental outcome include sediments in the head of Thea Foss Waterway south of the SR-509 bridge. The top 10-centimeter layer of the sediments is the depth of compliance according to the Commencement Bay Record of Decision (EPA 1989). The temporal boundaries of the program include sediment quality monitoring events in May 2009 (post-remediation Year 5) and May 2011 (post-remediation Year 7).

6.1.5 Step 5: Develop Decision Rules

The Program Effectiveness Monitoring data will be evaluated in accordance with the following decision rules:

1. Targeted Action. If it can be shown with statistical significance that Null Hypothesis S8D-1 is false, then it will be demonstrated that basin-wide cleaning of major municipal drainages results in significant and measurable improvements in stormwater and/or or base flow quality. The hypothesis will be tested separately using storm flow and base flow data.
2. Targeted Environmental Outcome. If it can be shown with statistical significance that Null Hypothesis S8D-2 is false, then it will be demonstrated that the mean sediment concentration in the head of Thea Foss Waterway is significantly below the SQOs. The test statistic for this comparison will be the 90% upper confidence limit on the mean sediment concentration (90% UCL). Alternatively, the 90^{th} percentile concentration may be used as a nonparametric test statistic. The SQOs for PAHs and metals are the values established in the Commencement Bay Record of Decision (EPA 1989). However, recent bioassay testing has shown that the biological effects level for DEHP is significantly higher than the SQO originally issued in the Record of Decision (Tetra Tech 2006). No adverse effects were observed in three different bioassay tests at a DEHP concentration of 3,600 ug/kg, and a minor adverse effect was observed in one of three bioassay tests at a DEHP concentration of 4,600 ug/kg. Therefore, a biological effects level of ~4,000 ug/kg will be used for statistical comparisons in place of the SQO for DEHP.

6.1.6 Step 6: Specify Limits on Decision Errors

The stormwater monitoring program is designed to meet the following levels of statistical sensitivity, confidence, and power:

Minimum Detectable Relative Difference (MDRD). A MDRD of 50% is specified for evaluating differences in stormwater concentrations before and after basin-wide cleaning of the storm sewers. The monitoring program should be able to detect with statistical significance a 50% reduction in stormwater concentrations as a result of the source control action. A MDRD of 50% is consistent with the differences in stormwater quality that are typically evaluated using Ecology's TAPE guidance (Ecology 2008).

Because the CVs of sediment quality data are lower than the CVs of stormwater data, a smaller MDRD may be used. A MDRD of 25% is specified for evaluating differences between Thea Foss Waterway sediment concentrations and the SQOs. With a smaller MDRD, mean sediment concentrations that are close to but below the SQO may be more effectively differentiated as being significantly below the SQO.

Statistical Confidence and Power. As part of the BMP Effectiveness Monitoring program, the MS4 Permit provides goals of 90 to 95% statistical confidence and 75 to 80% statistical power [S8F(4)]. These same goals will be adopted in Program Effectiveness Monitoring. The associated alpha levels (0.05 to 0.10) and beta levels (0.20 to 0.25) are the complements of statistical confidence and power, respectively.

6.1.7 Step 7: Optimize the Design

This section provides an estimate of the number of stormwater and sediment samples that should be collected to achieve the data quality objectives specified for Program Effectiveness Monitoring. The number of samples required for the monitoring program may be estimated based on the desired MDRD, the acceptable levels of statistical confidence and power (see Section 6.1.6), and an estimate of the variability of the data as measured by the coefficient of variation, or CV (see Section 6.1.3 and Table 6-1).

The sample size analysis follows EPA (1998, section 9.3.3):

$$N = (Z_\alpha + Z_{2\beta})^2 \times 2(CV/MDRD)^2 \qquad \text{[Equation 6-1]}$$

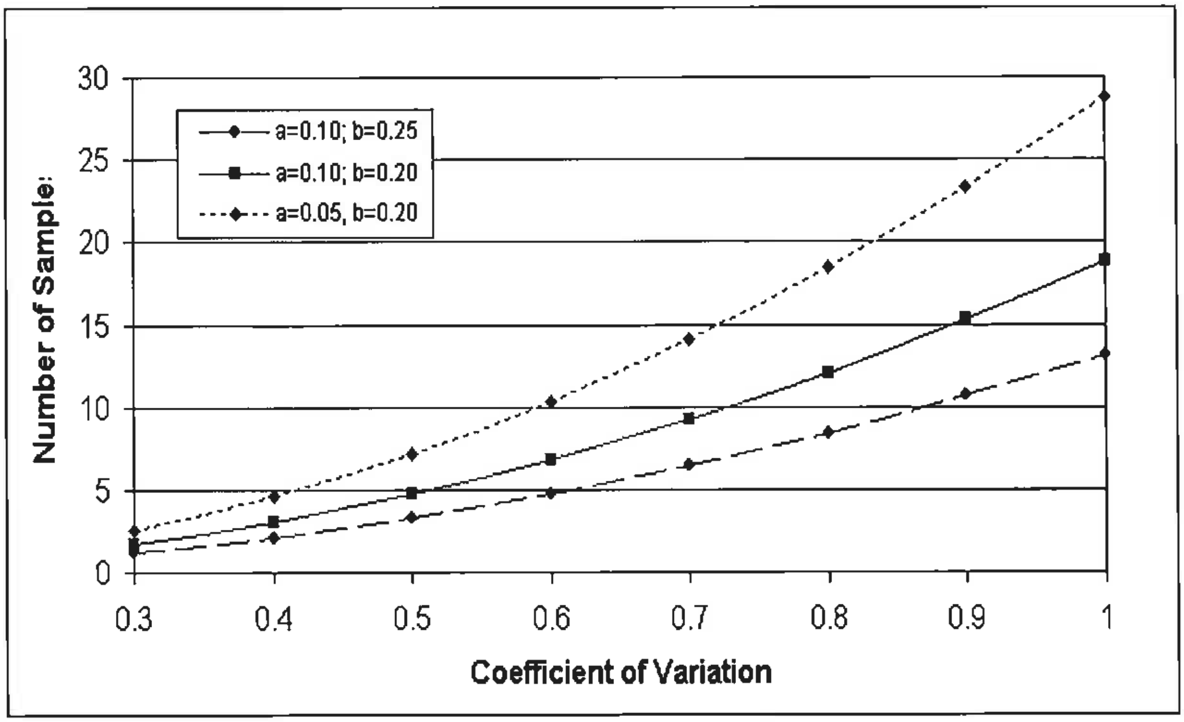
where [N] = number of samples, [Z_α and $Z_{2\beta}$] are Z statistics at the specified alpha and beta levels, [CV] is the coefficient of variation of stormwater data, and [MDRD] is defined in Section 6.1.6.

The estimated sample size to detect a 50% reduction in stormwater concentrations due to basin-wide cleaning of the storm sewers as a function of CV is provided in Table 6-2A. A range of acceptable confidence levels (alpha = 0.05 to 0.10) and power levels (beta = 0.20 to 0.25) is presented. Tacoma proposes to collect 10 stormwater samples per year in each of the drainage basins after cleaning is completed, consistent with the intensity of past stormwater monitoring efforts under Tacoma's previous permit. At this rate of data collection, Table 6-2A indicates the specified levels of statistical confidence and power will be achieved within one to two monitoring years, depending on the CV of the stormwater data.

Table 6-2A Estimated Sample Size for Stormwater in OF237A, OF235 and OF230

Minimum Detectable Difference: 50%

Confidence (alpha)	Power (beta)	Stormwater Coefficient of Variation							
		0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.10	0.25	1	2	3	5	6	8	11	13
0.10	0.20	2	3	5	7	9	12	15	19
0.05	0.20	3	5	7	10	14	18	23	29



LEGEND:

Yellow: Sample sizes achieved after 1 monitoring year (minimum 10 samples/year)

Green: Sample sizes achieved after 2 monitoring years (minimum 10 samples/year)

The sample size calculation is modified slightly when a statistical population (i.e., sediment quality data from the waterway) is compared to a regulatory threshold (i.e., SQO), as opposed to the previous example where two statistical populations were compared (i.e., stormwater data before and after basin cleaning) (EPA 1998). The modified sample size analysis for comparing sediment quality data to a regulatory threshold is:

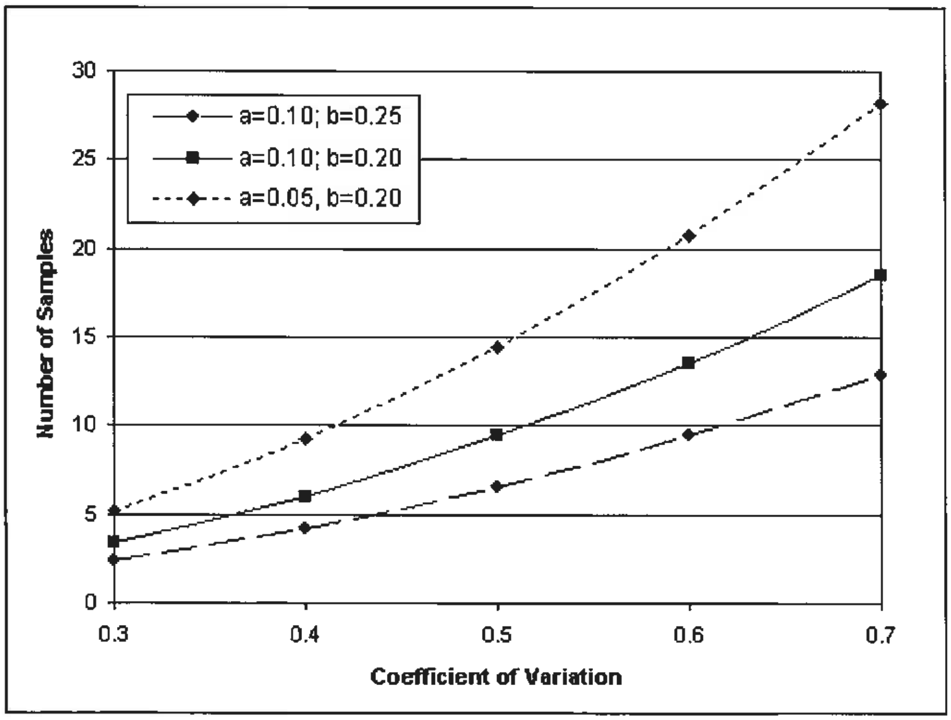
$$N = (Z_{\alpha} + Z_{2\beta})^2 \text{ x } (CV/MDRD)^2 \qquad \text{[Equation 6-2]}$$

The estimated sample size to detect a 25% difference between mean sediment concentrations for key constituents in the head of the Thea Foss Waterway and their associated SQOs is provided in Table 6-2B. Tacoma proposes to collect 10 surface sediment samples from the head of the waterway during each monitoring year, consistent with the intensity of past sediment quality monitoring efforts under the OMMP. At this rate of data collection, Table 6-2B indicates the specified levels of statistical confidence and power will be achieved within one to two monitoring years, depending on the CV of the sediment data.

Table 6-2B Estimated Sample Size for Surface Sediment in Thea Foss Waterway

Minimum Detectable Difference: 25%

Confidence (alpha)	Power (beta)	Surface Sediment Coefficient of Variation				
		0.3	0.4	0.5	0.6	0.7
0.10	0.25	2	4	7	9	13
0.10	0.20	3	6	9	14	18
0.05	0.20	5	9	14	21	28



LEGEND:

Sample sizes achieved after 1 monitoring year (10 samples/year)

Sample sizes achieved after 2 monitoring years (10 samples/year)

7 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The Thea Foss Waterway Stormwater Monitoring sampling design was developed by City of Tacoma (Tacoma 2001) and is summarized below in Table 7-1. This study conducts statistical calculations using data collected during the Thea Foss Waterway Stormwater Monitoring and Source Control Programs.

Table 7-1. Study design for the Thea Foss Waterway Stormwater Monitoring Program.

Sample Type	Sampling Procedure Summary	Sample Analyses
Sediment-trap sediments	At 19 locations in Basins 230, 235, 237A, sediment-traps are deployed annually from 8/27 through the wet season.	Analyze 19 samples for all physical and chemical parameters. Convert wet weight measurements to dry weight using moisture content data. Grain size, Total organic carbon, metals (lead, mercury, zinc), PAHs, phthalates, NWTPH, and PCBs.
Stormwater and baseflow	Collecting 10 storm event and 4 baseflow samples per year using automated compositing samplers at OF235, OF230,OF237A and OF237B.	Analyze water samples for chemical parameters: TSS, metals and hardness (lead, mercury, zinc), PAHs and phthalates.

8 SAMPLING (FIELD) PROCEDURES

Sampling completed under Foss SAP and OMMP will be used to support the "targeted action" and "targeted environmental outcome" study objectives, respectively (Tacoma 2001, 2006 and 2008 and TetraTech 2006 and 2007).

9 MEASUREMENT PROCEDURES

Sampling completed under Foss SAP and OMMP will be used to support the "targeted action" and "targeted environmental outcome" study objectives, respectively (Tacoma 2001, 2006 and 2008 and TetraTech 2006 and 2007).

10 .QUALITY CONTROL

Sampling completed under Foss SAP and OMMP will be used to support the "targeted action" and "targeted environmental outcome" study objectives, respectively (Tacoma 2001, 2006 and 2008 and TetraTech 2006 and 2007). 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.

11 DATA MANAGEMENT AND DOCUMENTATION PROCEDURES

Sampling completed under Foss SAP and OMMP will be used to support the "targeted action" and "targeted environmental outcome" study objectives, respectively (Tacoma 2001, 2006 and 2008 and TetraTech 2006 and 2007). Study documentation includes field sampling notes, field testing notes, chain of custodies, laboratory results, and reports. Please refer to Thea Foss Waterway Sampling Analysis SAP Section 7.0, 9.1, 9.2 and 9.4 (Tacoma 2001), Stormwater Monitoring Report (Tacoma 2008), and Operation, Maintenance, and Monitoring Plans for Thea

Foss Waterway Remediation (TetraTech 2006 and 2007 and Tacoma 2006) for additional information.

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 Thea Foss Waterway Sampling Analysis SAP (Tacoma 2001), Stormwater Monitoring Report (Tacoma 2008) Section 5.0 "Recommendations for Foss 2001 SAP Revisions" and Operation, Maintenance, and Monitoring Plans for Thea Foss Waterway Remediation (TetraTech 2006 and 2007 and Tacoma 2006) for additional information.

13 Data Verification And Validation

Please refer to Thea Foss Waterway Sampling Analysis SAP Sections 9.1, 9.2, and 13 (Tacoma 2001), Stormwater Monitoring Report Sections 3.1-3.3 (Tacoma 2008), and Operation, Maintenance, and Monitoring Plans for Thea Foss Waterway Remediation (TetraTech 2006 and 2007 and Tacoma 2006) for additional information. Each year, field and laboratory QA/QC case narratives are reviewed. The field and hydrological data is reviewed to evaluate representativeness of individual storm events, storm types, and criteria goals (i.e., antecedent period, total precipitation, duration, etc.).

14 Data Quality (Usability) Assessment

Data usability is described in Thea Foss Waterway Sampling Analysis SAP (Tacoma 2001), Stormwater Monitoring Report Sections 3.1-3.3 (Tacoma 2008), and Operation, Maintenance, and Monitoring Plans for Thea Foss Waterway Remediation (TetraTech 2006 and 2007 and Tacoma 2006).

This section describes the process for assessing data usability, specifically, whether data of the right type, quality, and quantity have been collected to meet project objectives. The proposed methods for qualitative and quantitative data analysis are also described.

14.1 Data Quality Assessment Metrics

The data quality assessment process determines whether the sampling and analytical program has fulfilled the project objectives, including the DQOs established in Section 6.1, and whether the data can be used to support project management decisions with the desired level of confidence.

Data quality assessment is a professional judgment based on several lines of evidence:

- **Laboratory Data Validation Results.** This metric evaluates laboratory data quality, i.e., the extent to which MQOs for accuracy, precision, sensitivity, and bias have been met during laboratory analysis, as determined by the data validation process (see Section 13).

- **Field and Laboratory Completeness.** This metric evaluates data quantity, i.e., the extent to which the QAPP-specified number of valid field and laboratory measurements (i.e. 10 stormwater samples and 10 sediment samples per year) have been obtained and whether field and laboratory completeness goals have been achieved.

- **Sample Representativeness.** The degree to which the monitoring program provides a representative sample of the physical and chemical characteristics of municipal stormwater will be evaluated. We will assess whether the flow-weighted composite samplers have successfully captured the time-varying characteristics of individual storm events (i.e., representative sampling of the runoff hydrograph); whether a representative range of storm sizes, intensities, and seasons have been sampled; and how the rainfall and runoff observed during the monitored year(s) compares to an average or "normal" year. To ensure a representative sample of waterway sediments is collected, samples will be collected systematically from various habitats and geographic portions of the waterway (i.e., shallow and deep-water areas; left bank, right bank, and mid-channel areas).

- **Statistical Power**. The statistical variability of the stormwater and sediment monitoring data (specifically, the coefficient of variation) will be evaluated using the statistical power tables (Tables 6-2A and 6-2B) to determine whether the assumptions used to develop the sampling design are valid, and whether the sample sizes obtained are sufficient to meet the desired levels of statistical confidence and power.

14.2 Data Analysis Methods

14.2.1 Summary Statistics

For each detected chemical in each stormwater outfall, and for each detected chemical in waterway sediments, the following summary statistics will be calculated:

- Number of samples analyzed
- Number and percentage of samples with detected concentrations
- Arithmetic mean concentration
- Arithmetic standard deviation
- Coefficient of variation
- Minimum and maximum concentrations
- Median concentration (50^{th} percentile)
- 10^{th} and 90^{th} percentile concentrations

Stormwater summary statistics will be calculated for the entire monitoring period prior to basin cleaning, and the two- to three-year monitoring period following basin cleaning. Sediment quality summary statistics will be calculated separately for each monitoring year. Sediment quality data will not be pooled across monitoring years because time-trends in sediment quality are expected, as shown on Figure 6-1.

In addition, the following hydrologic parameters will be tabulated for each sampled storm event:

- Rain depth (inches)
- Average storm intensity (inches/hour)
- Antecedent dry period (hours)
- Event-average and peak flow (cfs)
- Total runoff volume (acre-feet)

14.2.2 Graphical Data Presentation

<u>Box-and-Whisker Plots</u>. Box-and-whisker plots will provide a qualitative graphic comparison of differences between stormwater quality before and after basin-wide cleaning. Paired ("before" and "after") box-and-whisker plots will be prepared for key monitoring parameters, including the following:

- Total suspended solids (TSS)

- Lead and zinc (total and dissolved)
- Polycyclic aromatic hydrocarbons (PAHs)
- DEHP

Box-and-whisker plots will also be plotted by water year to show annual changes over time, and to determine whether a systematic reduction in stormwater concentrations resulted from the basin-wide cleaning of the storm systems.

Box-and-whisker plots will be generated using *Data Analysis for Microsoft Excel* (Berk & Carey 2000) or a suitable substitute. These plots will display the following characteristics of the data distributions:

- Interquartile range, or IQR (data between the 25th and 75th percentile)
- Median and arithmetic mean
- Moderate outliers (more than 1.5 x IQR above the 75th percentile, or below the 25th percentile)
- Extreme outliers (more than 3 x IQR above the 75th percentile, or below the 25th percentile)

<u>Time-Series Graphs</u>. The time-series graphs shown on Figure 6-1 will be updated with sediment quality data collected in May 2009 (Year 5) and May 2011 (Year 7). Individual sampling results will be plotted as well as the arithmetic mean concentration for each monitoring year. Model predicted sediment curves are also shown on the graphs (see Tacoma 2008). These curves show that sediment concentrations are expected to increase after remediation (starting in Year 0 with clean cap material) and rise asymptotically to a concentration in equilibrium with current source loads to the waterway. These graphs will be inspected to determine whether long-term trends in mean sediment concentrations are consistent with model predictions, or whether observed sediment concentrations are higher or lower than expected.

14.2.3 Treatment of Non-Detected Values

The analytical laboratory will be required to report estimated values for any detections between the Method Detection Limit (MDL) and the reporting limit (RL), with appropriate data qualifiers (e.g. J-flags). For general summary statistics, undetected values will be substituted at one-half the MDL.

For higher-level statistical analyses, other treatment methods are available for evaluating constituents with a high percentage of undetected values (i.e., >15% non-detects). Such constituents will likely include the organic constituents of interest in the Thea Foss Waterway (e.g., PAHs, phthalates). The primary methods for evaluating data sets with a high percentage of non-detects (i.e., "censored" data sets) include: (1) use of nonparametric statistical methods, and (2) extrapolation of data distributions into the undetected region through the use of probability plot regressions (see Ecology 1993).

14.2.4 Identification of Outliers

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. It should be noted, however, that lognormal data distributions can tolerate relatively extreme high values, and nonparametric tests are relatively insensitive to the magnitude of the outlier concentration. Thus it may be possible to select statistical tests that minimize the impacts from outliers.

Moderate outliers (deviations greater than 1.5 times the IQR) and extreme outliers (deviations greater than 3 times the IQR) will initially be identified in the box plots described in Section 14.2.2. Other types of outlier tests may be selected based on the recommended methods in Section 4.4 of the EPA document "Guidance for Data Quality Assessment" (EPA/600/R-96/084).

Outliers will not be removed from any data set unless there is supporting information to indicate the outlier was caused by an unusual and unrepresentative event. Such events could include acts of nature (e.g. fire, landslide) or man-made events, such as extensive land disturbance from an unexpected construction activity. The impact the outlier has on the statistical processing of the data will be evaluated. The information will be discussed with Ecology before any decisions are made whether to include or exclude any outlier data points.

14.2.5 Statistical Distribution Testing

To verify the appropriateness of using parametric statistical tests, conformance of stormwater and sediment data with standard statistical distributions (e.g., normal or lognormal distributions) should be demonstrated. Parametric statistical procedures that may be used for data analysis include t-tests to compare two stormwater populations, and calculating upper confidence limits on mean sediment concentrations. Statistical distribution testing will generally follow *Statistical Guidance for Ecology Site Managers* (Ecology 1992, 1993) using the *MTCAStat* program.

For constituents with mostly detected concentrations (e.g., TSS and most metals), numerical distribution tests may be used (Shapiro and Wilk 1965; Gilbert 1987). For more highly censored data (e.g., PAHs and phthalates), probability plot regression methods will be used to help estimate the characteristics of the data distribution below the detection limit (Ecology 1993).

Lognormal test results for Tacoma's stormwater monitoring data from 2001 through 2007 showed excellent conformance to lognormal distributions (Tacoma 2008b). These results indicate Tacoma's stormwater data are likely to be lognormal in character, and that parametric statistical tests may be appropriate.

14.2.6 Testing for Effectiveness of Targeted Action

Parametric Test. The effectiveness of the targeted action (i.e., comprehensive sewer line cleaning) will be evaluated using the two-sample t-test. The data will be split into two groups – one collected "before" the targeted action and the other collected "after" the targeted action. Any existing monitoring data dating back to October 2001 will be used to characterize the "before" condition. A minimum two years of monitoring data will be used to characterize the "after" condition. T-tests will be used to determine whether the stormwater concentrations in the "after" data are significantly lower than the "before" data, thus demonstrating the effectiveness of the targeted action.

Nonparametric Alternative. A nonparametric alternative to the t-test is the Mann-Whitney U test (aka the Wilcox on rank-sum test). This test is similar to performing a t-test on the data after ranking over the combined samples from both groups. If a significant difference is observed between the "before" and "after" group, the Hodges-Lehman estimator is a nonparametric procedure for estimating the difference in central tendency between the two groups of data; more specifically, this procedure calculates the median difference between all possible sample pairs between the two groups. The difference may then be used to calculate a percent reduction resulting from the targeted action.

14.2.7 Testing for Effectiveness of Environmental Outcome

Parametric Test. The effectiveness of the targeted environmental outcome (i.e., compliance with SQOs in waterway sediments) will be tested by comparing the 90% UCL of the arithmetic mean sediment concentration in the head of Thea Foss Waterway to the SQO (or biological effects level in the case of DEHP). The 90% UCL will be calculated using standard statistical methods, as presented in Gilbert (1987) and Ecology (1992, 1993). Different equations are used to calculate the 90% UCL depending on whether the data are normally or log normally distributed.

Nonparametric Alternative. For skewed and censored data, the calculation of the 90% UCL often tends to "blow up" and in many instances will even exceed the range of measured concentrations, especially for relatively small data sets. In these situations, the 90th percentile sediment concentration will be compared to the SQOs as a nonparametric measure of compliance instead of the parametric 90% UCL.

15 Data Analysis And 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 is provided in the Thea Foss Waterway Stormwater Monitoring Report (Tacoma 2008b).

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List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Revised by	Revision Summary
S8E-001	08/11/2008	Dana de Leon, Chris Burke and Todd Thornburg	Initial draft.
S8E-002	01/15/2009	Dana de Leon, Chris Burke and Todd Thornburg	Redline
S8E-003	08/16/2009	Dana de Leon and Chris Burke	Final