Tacoma City of Tacoma
Public Works Department

November 25, 2009

Julie Lowe
Department of Ecology SWRO/WRU
P.O. Box 47775
Lacey, WA 98504-7775

Re: Phase I Municipal Stormwater NPDES Permit
Permit No.: WAR04-4003

Dear Ms. Lowe:

This letter transmits the City of Tacoma's Final Quality Assurance Project Plan (QAPPS) in accordance with Special Condition S8F of the Phase I Municipal Stormwater Permit including:

- Section S8F – Stormwater Treatment Best Management Practice Evaluation

If you have any questions, feel free to call Dana de Leon at (253) 502-2109. If you have comments or questions regarding analytical laboratory issues, feel free to call Chris Burke at (253) 502-2247.

Sincerely,

Lorna Mauren, P.E.
Assistant P.W. Division Manager

lm:dd:cb:crt

Enclosure: Section S8F - Stormwater Treatment Best Management Practice Evaluation

Cc: Dana de Leon
Chris Burke
Christopher Getchell
Rick Fuller

Section S8F - Stormwater Treatment Best Management Practice Evaluation

Quality Assurance Project Plan

Phase I Municipal Stormwater NPDES Permit

Permit No.: WAR04-4003

Revision: S8F-003 Final

Effective date: 11/30/2009

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

Assistant Division Manager Surface Water (Lorna Mauren, P.E.) — Approved On: Nov 23, 2009

NPDES Permit Manager (Lorna Mauren, P.E.) — Approved On: Nov 23, 2009

Program Manager (Dana de Leon, P.E.) — Approved On: Nov 20, 2009

QA Coordinator (Chris Burke) — Approved On: Nov 23, 2009

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.

Date: 11-30-09

Dan C. Thompson, Ph.D.
Acting Asst. Public Works Director/Environmental Services

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Acronyms

BMP	Best Management Practice
CAR	Corrective Action Report
COC	Chain of Custody
DQI	Data Quality Indicator
DQO	Data Quality Objective
EPA	Environmental Protection Agency
GIS	Geographic Information System
LID	Low Impact Development
MDL	Method Detection Limit
NCR	Nonconformance Report
NPDES	National Pollutant Discharge Elimination System
QA/QC	Quality Assurance/Quality Control
QAC	Quality Assurance Coordinator
QAPP	Quality Assurance Project Plan
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SMMWW	Stormwater Management Manual for Western Washington

2 TABLE OF CONTENTS

QAPP Element: Page No.

1. Title and Approval Sheet ii
2. Distribution List iv
Acronyms v
2. Table of Contents vi
Abstract 1
3. Background 2
3.1 The Problem 2
3.1.1 Driver 2
3.1.2 Decision-making 2
3.2 Study Area 2
3.3 Parameters of Concern 4
4. Project Description 15
4.1 Study Goals 15
4.2 Study Objectives 15
4.3 Information Requirements 16
4.4 Study Boundaries 16
4.4.1 Spatial Boundary 16
4.4.2 Temporal Boundaries 18
4.4.3 Target Population 18
4.4.4 Practical Constraints 18
5. Organization and Schedule 29
5.1 Study Deliverables 29
6. Quality Objectives 31
6.1 Data Quality Objectives 31
6.1.1 Step 1: State the Problem 31
6.1.2 Step 2: Identify the Decisions 31
6.1.3 Step 3: Identify Inputs to the Decision 32
6.1.4 Step 4: Define the Boundaries of the Study 34
6.1.5 Step 5: Develop Decision Rules 34
6.1.6 Step 6: Specify Limits on Decision Errors 34
6.1.7 Step 7: Optimize the Design 35
6.2 Measurement Quality Objectives 35
6.2.1 Representativeness 35
7. Sampling Process Design (Experimental Design) 38
7.1 Monitoring Strategy Overview 39
7.1.1 Parameters and Analytical Methods 39
7.1.2 Sampling Techniques and Types 39
7.1.3 Representative Sample Criteria 39
7.2 Site-Specific Sampling Design 40
7.2.1 Salishan Bioinfiltration Facilities 40
7.2.2 Biofiltration Facilities 57
7.2.3 Pervious Pavements - Landfill 73
7.3 Flow Monitoring Equipment Strategy 75
7.3.1 Salishan Bioinfiltration Facilities 75
7.3.2 Biofiltration Facilities 76
7.3.3 Pervious Pavements - Landfill 78

QAPP Element: Page No.

7.4 Water Quality Equipment Monitoring Strategy 79
7.4.1 Salishan Bioinfiltration Facilities 79
7.4.2 Biofiltration Facilities 80
8. Sampling Procedures 81
8.1 Sample Identification 81
8.2 Flow Monitoring 81
8.3 Water Quality Sampling 82
8.4 Sediment Sampling 84
8.4.1 Sediment Accumulation Monitoring 85
8.5 Soil Characterization 85
8.6 Controlled Infiltration Tests 85
8.6.1 Full-Scale Field Testing at East 46th & R Street Bioinfiltration Swale 85
8.6.2 Infiltrometer Measurements at East 44th Street Bioinfiltration Pond 86
9. Measurement Procedures 88
10. Quality Control 88
11. Data Management Procedures 88
12. Audits and Reports 88
13. Data Verification and Validation 88
14. Data Quality (Usability) Assessment 89
14.1 Data Quality Assessment Metrics 89
14.2 Data Analysis Methods 90
14.2.1 Summary Statistics 90
14.2.2 Treatment Efficiency Calculations 90
14.2.3 Graphical Data Presentation 91
14.2.4 Treatment of Non-Detected Values 92
14.2.5 Identification of Outliers 92
14.2.6 Statistical Distribution Testing 92
14.2.7 Pair Comparison Tests 93
14.2.8 Population Comparison Tests 93
15. Data Analysis and Presentation 94
15.1 Site Summary and Status 94
15.2 Comprehensive Data Summary 95
15.3 Quality Assurance/Quality Control Summary 95
References 96
List of Revisions 97

Appendix A Design Criteria for Selected BMPs
Appendix B Design Criteria for Pervious Pavement - Landfill
Appendix C National Stormwater BMP Database Requirements
Appendix D Field Equipment Specifications

List of Tables

Table 3-1. BMP effectiveness monitoring projects....3
Table 3-2. Required parameters to be measured in water....4
Table 3-3. Parameters to be measured in sediment....4
Table 4-1. Selected BMP effectiveness project – Bioinfiltration Facilities....17
Table 4-2. Selected BMP effectiveness projects – Biofiltration Facilities....17
Table 4-3. Selected BMP Flow Reduction Strategy – Pervious Pavement....18
Table 5-1. Study deliverable schedule....29
Table 6-1. Coefficients of variation in Tacoma stormwater....33
Table 6-2. Estimated sample size for BMP effectiveness monitoring....36
Table 7-1. Representative storm event criteria....40
Table 7-2. Representative sampler collection criteria....40

List of Figures

Figure 3-1. City of Tacoma BMP Projects Vicinity Map....5
Figure 3-2. Salishan Project Vicinity, Bioinfiltration Facilities....7
Figure 3-3. East 32nd Street Project Vicinity, Bioinfiltration Facilities....9
Figure 3-4. Trolley Court Bioswale Project Vicinity, Bioinfiltration Facilities....11
Figure 3-5. Location of Pervious Pavement Site, Tacoma Landfill....13
Figure 4-1. East 46th and R Street Bioinfiltration Facility Drainage Area....21
Figure 4-2. East 44th and T Street Bioinfiltration Facility Drainage Area....23
Figure 4-3. East 32nd Street Biofiltration Facility Drainage Area....25
Figure 4-4. Trolley Court Biofiltration Facility Drainage Area....27
Figure 7-1a. East 46th & R Street Bioinfiltration Facility Monitoring Locations....45
Figure 7-1b. East 46th & R Street Bioinfiltration Facility Monitoring Locations....47
Figure 7-1c. East 46th & R Street Bioinfiltration Facility Monitoring Locations....49
Figure 7-2a. East 44th Street Bioinfiltration Facility Monitoring Locations....51
Figure 7-2b. East 44th Street Bioinfiltration Facility Monitoring Locations....53
Figure 7-2c. East 44th Street Bioinfiltration Facility Monitoring Locations....55
Figure 7-3a. East 32nd Street Biofiltration Facility Monitoring Locations....61
Figure 7-3b. East 32nd Street Biofiltration Facility Monitoring Locations....63
Figure 7-3c. East 32nd Street Biofiltration Facility Monitoring Locations....65
Figure 7-4a. Trolley Court Biofiltration Facility Monitoring Locations....67
Figure 7-4b. Trolley Court Biofiltration Facility Monitoring Locations....69
Figure 7-4c. Trolley Court Biofiltration Facility Monitoring Locations....71
Figure 7-5a. Sampling Locations for Each Pavement Section – Tacoma Landfill....74
Figure 7-5b. Sampling Manholes and Curbing....74
Figure 7-5c. Flow Monitoring Setup for Pervious Pavement and Standard Asphalt Sites....79
Figure 7-5d. Flow Monitoring Setup for Surface Water Runoff from Pervious Pavement Sites....79

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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 *storm water treatment best management practices (BMPs) monitoring study* required under Section S8F of the Phase I Municipal Stormwater Permit, permit number WAR04-4003. 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 (Ecology 2007).

This Plan is the fourth of four that will be submitted to the Washington Department of Ecology (Ecology) to meet the permit requirements of Section S8 and covers the *BMP effectiveness monitoring* component of section S8F. This document is a companion to the Section S8 Program QAPP. The City of Tacoma submitted proposals to Ecology on July 12, 2007 and October 5, 2007 to monitoring the following treatment BMP types under S8F:

- Bioinfiltration facilities
- Biofiltration facilities, and
- Pervious pavements (flow reduction strategy).

The primary goal of this Plan is to define procedures that assure the quality and integrity of the collected 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 BMP and flow effectiveness monitoring described in Section S8F.

3 BACKGROUND

3.1 The Problem

Ecology (2006) has defined the problem to be addressed with the Best Management Practice (BMP) effectiveness monitoring as:

- "*Without the feedback loop, we haven't a good basis for altering design criteria in order to improve their performance.*
- *" We are overdue to perform studies to firm up our knowledge of the capabilities and limitations of the "best management practices" that we have been using to reduce the pollutant impacts of our developments."*

3.1.1 Driver

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 treatment BMPs. Treatment BMPs include ponds, swales, filtration, and infiltration devices that are designed to capture runoff and treat it using physical, biological, and/or chemical processes. The effectiveness and feasibility of treatment BMPs is variable, subject to some debate, and much remains to be learned (Ecology 2006).

The permit requires that each Phase I permittee select two treatment types that are standard technologies in their manuals, for detailed performance monitoring.

3.1.2 Decision-making

The results of this study are not intended for use in making specific decisions, but rather to provide a feedback loop to Ecology to improve their knowledge and understanding of the performance of treatment BMPs.

3.2 Study Area

As noted above, each permittee is required to select two treatment types that are standard technologies in their manuals, for detailed performance monitoring. The City of Tacoma has selected the following BMPs for evaluation monitoring (Figure 3-1):

- Two bioinfiltration facilities at the Salishan Hope VI Redevelopment (Salishan),
- Two biofiltration facilities, East 32nd Street and Trolley Court, and
- Three types of pervious pavement at the demonstration project located at the City of Tacoma Landfill (flow reduction strategy only).

These sites were selected based on a review of constructed BMPs within the City and the intent to meet the following criteria (Table 3-1):

- Listed in section S8F2 and S8F7,
- Meets design criteria of current Stormwater Management Manual for Western Washington (SMMWW),
- Meets design criteria of current Puget Sound Low Impact Development (LID) Manual which is referenced in the SMMWW,
- Technically feasible to monitor (access, drainage area, inlet concentration, other),

- Constructed and operable by 2009, and
- There are limited studies of the BMP within our region.

The selected bioinfiltration facilities provide enhanced treatment. The selected biofiltration facilities provide basic treatment. The selected pervious pavements provide a flow reduction strategy.

Table 3-1. BMP effectiveness monitoring projects.

BMP Type	BMP Project	On S8F2 List	Meets Ecology Design Criteria [1]	Meets PS LID Design Criteria [1]	2 of Each
1. Standard bioinfiltration	Salishan	Y'	Y'	Y'	Y
2. Standard biofiltration	East 32nd St. Trolley Court	Y'	Y'	Y'	Y
3. Pervious Pavement – 3 types	Tacoma Landfill	N	Y'	Y'	3 types & control

1 See Ecology (2005) for criteria.

BMP No. 1 – Bioinfiltration Facilities. The Salishan project is a residential redevelopment project consisting of over 1,200 housing units, single and multi-family (see Figure 3-2). During redevelopment, the existing stormwater conveyance system was replaced with new infrastructure including a system of biofiltration and bioinfiltration facilities. These facilities were designed to meet the requirements for basic and enhanced treatment as specified in the Tacoma Surface Water Management Manual (and 2005 Ecology Manual). Two bioinfiltration facilities were selected for this project, East 46th & R Street Swale and East 44th Street Pond. Design criteria for each of these bioinfiltration facilities are provided in Appendix A.

BMP No. 2 – Biofiltration Facilities. The East 32nd Street Improvement required treatment of the improved street runoff (see Figure 3-3). The land use in the area is residential on one side of the street and an office building with parking lot on the opposite side of the street. The East 32nd Street Improvement bioswale consists of two parallel bioswales that receive street runoff from catch basins along East 32nd Street through a pair of 12-inch pipes, one for each bioswale.

The Trolley Court development required treatment of the street, new residences, and one commercial building (see Figure 3-4). The land use in the area is residential and commercial. The Trolley Court bioswale is located at 1712 State St. It receives runoff from surrounding streets and residences through a 12-inch pipe.

These facilities were designed to meet the requirements for basic treatment as specified in the Tacoma Surface Water Management Manual (and 2005 Ecology Manual). Design criteria for each of these biofiltration facilities are provided in Appendix A.

BMP No. 3 – Pervious Pavements. At the Tacoma Landfill, a demonstration project, a 36,100 square foot paved area, was constructed using 3 types of pervious pavement systems and a control, standard asphalt (see Figure 3-5). There are several national studies on the effectiveness of pervious pavement. Tacoma is monitoring the effectiveness of this BMP for both water quality and flow reduction. Tacoma will continue to monitor flow reduction effectiveness at this facility.

The City of Tacoma submitted a proposal to Ecology on July 12, 2007 and follow-up information on October 5, 2007 in regards to monitoring the pervious pavements at the Tacoma Landfill. Additional information regarding Ecology questions on the pervious pavements site are provided in Appendix B.

3.3 Parameters of Concern

The water analytes identified as parameters of concern by Ecology are those that will provide information regarding the effectiveness of basic and enhanced treatment BMPs (Table 3-2).

Table 3-2. Required parameters to be measured in water.

Analyte Group	Parameter
Conventional	Hardness
	pH
	Particle Size Distribution (PSD)
	TSS
Metals (dissolved & total)	Cadmium[1]
	Copper
	Lead[1,2]
	Zinc
	Mercury [2]
Nutrients	Orthophosphate
	Total phosphorus
Organics	PAHs and phthalates [2]

1 These parameters aren't required under NPDES Permit S8F.5.a.
2 These parameters are included as chemicals of concern for Thea Foss Waterway Recontamination Evaluation and are not a required parameter under S8F.

The sediment analytes identified as parameters of concern by Ecology are those that will provide information regarding the effectiveness of basic and enhanced treatment BMPs (Table 3-3).

Table 3-3. Parameters to be measured in sediment.

Analyte Group	Parameter
Conventional	Total solids
	Grain size
	Total Volatile solids
	Total organic carbon [2]
Metals, total recoverable	Cadmium
	Copper
	Lead
	Zinc
	Mercury [2]
Nutrients	Total phosphorus
Total Petroleum Hydrocarbons (TPH)	Diesel Range Organics (DRO)
Organics	PAHs and phthalates [2]
	PCBs [2]

2 These parameters are included as chemicals of concern for Thea Foss Waterway Recontamination Evaluation and are not a required parameter under S8F.

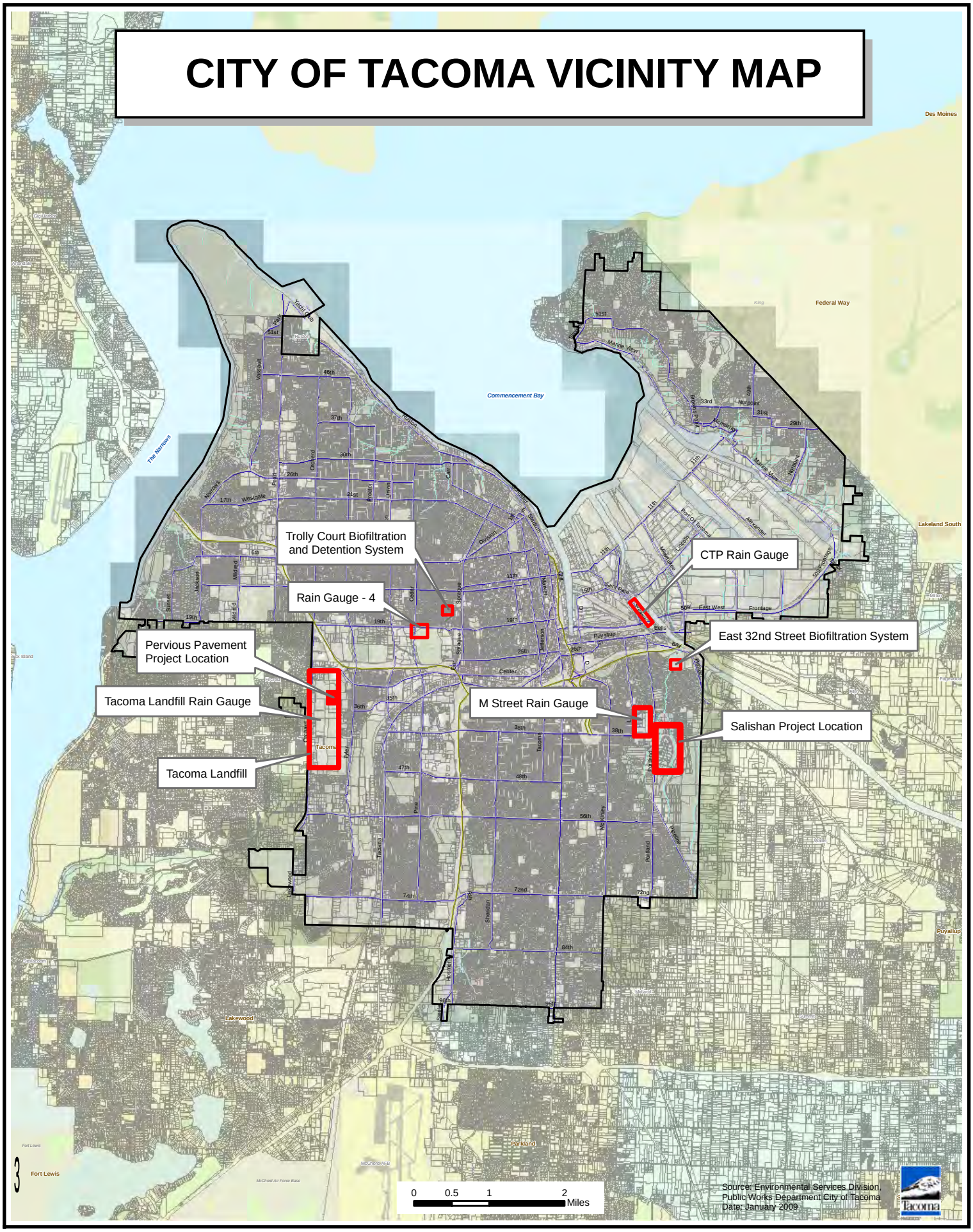


Figure 3-1 City of Tacoma BMP Projects Vicinity Map

Salishan Redevelopment Project

Source: Environmental Services Division,
Public Works Department City of Tacoma
Date: July 2008

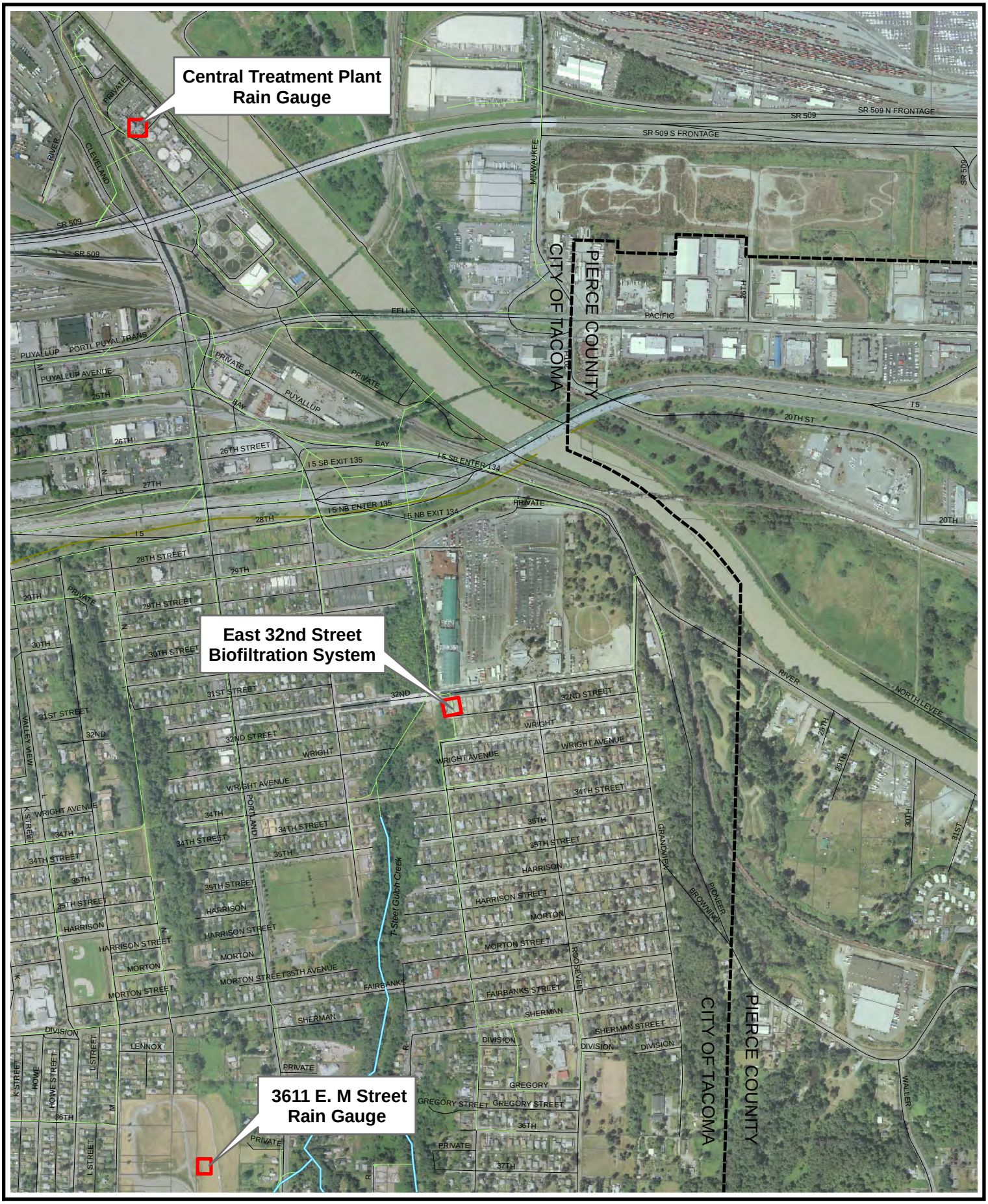
Streams and Creeks

City Limits

0 0.125 0.25 0.5 Miles

Figure 3-2
Salishan Project Vicinity

Bioinfiltration Facilities:
East 44th & R St.
East 46th & R St.



Salishan Redevelopment Project

Source: Environmental Services Division,
Public Works Department City of Tacoma
Date: January 2009

Streams and Creeks

City Limits

0 0.125 0.25 0.5 Miles

Figure 3-3
East 32nd Street Project Vicinity

Biofiltration Facilities

Salishan Redevelopment Project

Source: Environmental Services Division,
Public Works Department City of Tacoma
Date: January 2009

Streams and Creeks

City Limits

0 0.125 0.25 0.5 Miles

Figure 3-4
Trolley Court Bioswale Project Vicinity

Biofiltration Facilities:
17th & State St.

Approximate Scale 1" = 125'

Figure 3-5 Location of Pervious Pavement Site, Tacoma Landfill

4 PROJECT DESCRIPTION

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

4.1 Study Goals

The study goal is to comply with Section S8F of the permit. Ecology's goal is to provide a performance feedback loop so they can confirm which BMPs perform best for certain pollutants. The Fact Sheet (2006) states:

"*though most of these treatment types have been recommended and in common use for many years, we have only incomplete information about their pollutant removal capabilities. We have some confidence that they are based on sound engineering concepts, but we do not know how well they perform in relation to one another. Without a feedback loop of performance, we cannot confirm which BMP's perform best for certain pollutants."*

4.2 Study Objectives

Flow and water quality monitoring will be performed within each BMP in order to meet the following objectives:

- Quantify the treatment performance of each BMP for reducing both pollutant concentrations and loads.
- Determine the effectiveness of each BMP at treating the applicable water quality design flow.
- Determine if the treatment performance of each BMP varies in relation to storm event characteristics and/or other operational considerations.

In addition to the flow and water quality monitoring described above, sediment monitoring will be performed within each BMP in order to meet the following objectives:

- Quantify sediment accumulation rates within each component of the BMP for determining maintenance requirements.
- Evaluate the grain size distribution of accumulated sediment within each component of the BMP for use in assessing overall system performance.
- Evaluate pollutant concentrations in accumulated sediment within each component of the BMP.

4.3 Information Requirements

The sampling design for stormwater monitoring under S8F contains three primary activities that will be conducted at each monitoring site:

- Stormwater Sampling
- Sediment Sampling
- Flow Monitoring

General information that will be collected during these activities is described below. In addition, paragraph S8F4 requires "Permittees ... must collect information pertinent to fulfilling the 'National Stormwater BMP Data Base Requirements' in section 3.4.3. of that document." This information includes National Stormwater BMP Database requirements for:

- All BMPs (Table C-1),
- Structural BMPs(Table C-2), and
- Individual structural BMPs (Table C-3).

Influent, effluent and bypass monitoring stations will be established for two Salishan bioinfiltration facilities, two biofiltration facilities, and Landfill's pervious pavement lot.

Stormwater sampling. Automatic flow-weighted composite sampling methods will be used to collect stormwater samples from qualifying storm events (Section 7.1.3 Representative Sample Criteria). Stormwater samples collected during each storm event will be analyzed for a suite of parameters that are identified in the Phase I Municipal Stormwater Permit for evaluating basic and enhanced treatment performance (Table 3-1).

Hydrologic monitoring will involve measurements of discharge (water level or water level and velocity for estimating discharge using a primary measuring device), as well as precipitation depth. Discharge data will be used to characterize the peak discharge rate, the runoff volume, and the flow duration at each station. Precipitation data will be used to characterize the storm event antecedent dry period, total rainfall distribution during the sampled events, inter-event dry period, and rainfall average and peak intensity during the sampled storm events.

Sediment sampling. Sediment samples collected will be analyzed for a suite of parameters that are identified in the Phase I Municipal Stormwater Permit for evaluating basic and enhanced treatment performance (Table 3-2).

4.4 Study Boundaries

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

4.4.1 Spatial Boundary

The spatial boundary defines the geographic area within which all decisions will apply and the physical area to be studied and from where the samples will be taken. Ecology may apply any decisions resulting from this study within the Phase I permittees' jurisdictions.

The five projects are located within Tacoma (Figure 3-1). Tables 4-1 through 4-3 summarize the geographic information for the selected projects. Figures 4-1 through 4-4 and Figure 3-5 show the geographic drainage area for each project.

Table 4-1. Selected BMP effectiveness project – Bioinfiltration Facilities.

	Salishan Bioinfiltration Facilities	
Project	*E. 46th St. & E. R St. Swale (see Figure 4-1)*	*East 44th St. Pond (see Figure 4-2)*
Land use	Residential	Residential
Estimated Project Basin (acres)	2.04	13.9
Treatment Area (acres)	0.611	8.2
Rain gage	CTP - Tacoma No. 1 at 2201 Portland Ave and MST - 3611 E M Street	
Discharge only stations	RSTOUTB	44OUTB
Water quality & discharge stations	RSTIN RSTOUT	44IN 44OUT
Sediment quality stations	RSTSED	44SED

Table 4-2. Selected BMP effectiveness projects – Biofiltration Facilities.

Project	*32nd St. Swale (see Figure 4-3)*	*Trolley Court Swale (see Figure 4-4)*
Land use	3.9 acres Residential 2.6 acres Commercial	Residential
Estimated Project Basin (acres)	6.5	2.27
Treatment Area (acres)	5.23	1
Rain gage	CTP - Tacoma No. 1 at 2201 Portland Ave and MST - 3611 E M Street	RG-4 at S. Cedar St. and Tacoma Landfill
Discharge only stations	32INB1 32INB2 32OUTB	--
Water quality & discharge stations	32IN1 32IN2 32OUT	TCIN TCOUT
Sediment quality stations	32SED1 32SED2	TCSED

Table 4-3. Selected BMP Flow Reduction Strategy – Pervious Pavement.

	Tacoma Landfill Pervious Pavement *(see Figure 3-5)*			
Project	*Pervious concrete*	*Pervious pavers*	*Pervious asphalt*	*Standard Asphalt*
Land use	Commercial - Parking Lot			
Estimated Project Basin	9,028 sq ft	9,028 sq ft	9,028 sq ft	9,028 sq ft
Treatment Area	9,028 sq ft	9,028 sq ft	9,028 sq ft	NA
Rain gage	Tacoma Landfill			
Discharge only stations	Perv. Concrete: Infiltrated stormwater Perv. Concrete CB: Surface water runoff catch basin	Perv. Pavers: Infiltrated stormwater Perv. Pavers CB: Surface water runoff catch basin	Perv. Asphalt: Infiltrated stormwater Perv. Asphalt CB: Surface water runoff catch basin	Std. Asphalt: Surface water runoff

4.4.2 Temporal Boundaries

The temporal boundary defines the timeframe to which the decision applies and when data will be collected. Sample collection and reporting activities may extend beyond the current permit cycle (February 2007 – February 2012) by approximately 15 months, to May 2013.

Each station will be equipped with automated equipment to facilitate continuous monitoring of flows over the 2 year duration of this study (November 2009 – November 2011) and the collection of influent and effluent flow-weighted composite samples during discrete storm events over this period. The collection of flow-weighted composite samples will occur for 8-to-12 storm events in each year of the study to achieve a goal of obtaining up to 35 influent and effluent samples at each BMP by the end of the study period. After 2 complete years of data are collected, the sample numbers, completeness, and statistical power of the data will be reviewed to determine how well sampling objectives were met. If sampling objectives were not met, or statistical power is substantially less than expected, an extension of the monitoring program for a third year may be proposed to Ecology at that time.

4.4.3 Target Population

The characteristics that define the population of interest are: enhanced treatment performance of bioinfiltration facilities from the Salishan project; basic treatment performance of the biofiltration facilities, and flow reduction performance of pervious pavements from the Tacoma Landfill project, within the City of Tacoma.

4.4.4 Practical Constraints

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

1. Sampling design assumptions and requirements;
2. Installation of equipment in time to meet the permit deadline to begin sampling; and
3. Typical logistical challenges associated with the difficult task of monitoring stormwater.

Please refer to S8 Program QAPP, Section 4.1 "*Practical Constraints*" for general information related to stormwater sampling. Site specific constraints are discussed in the following paragraphs.

Sampling design – Both bioinfiltration and biofiltration facilities are located in residential and residential/business areas with an expected TSS concentration in the low end of the acceptable range. At the Landfill Project, the four fully-separated pavement cells (three pervious pavement and one standard pavement) collect runoff from a parking lot surface.

Construction schedule – Salishan's Phase 2 residential housing is currently being constructed. The utilities and streets in Phase 2 were completed in early 2008. The bioinfiltration were constructed and vegetated by July 2008. Most of the housing are rental units and are expected to be fully occupied by November 2009. We anticipate vegetation would be adequately established for monitoring by November 2009.

General maintenance on the biofiltration facilities were completed before August 2009. Unwanted vegetation (trees, shrubs, etc.) in the swales was removed.

The Landfill parking lot was constructed in 2007 and was maintained in October 2008. The parking lot and all sampling locations are currently active.

Fig. 4.1

East 46th and R-Street Bio-Infiltration Facility Drainage Area

Created by GPS Crew for City of Tacoma Environmental Services

2005 Ortho-Photo does not reflect current site conditions
Drainage includes street runoff from Salishan Hope VI Redevelopment

0 50 100 200 300 400 Feet

Fig. 4.2

East 44th and T-Street Bio-Infiltration Facility Drainage Area

2005 Ortho-Photo Does not reflect current site conditions
Drainage includes street runoff from Salishan Hope IV development

Created by GPS Crew for City of Tacoma Environmental Services

0 45 90 180 270 360 Feet

Fig. 4.3

East 32nd St. Bio-Filtration Facility Drainage Area

2005 Ortho-Photo Does not reflect current site conditions

Created by the GPS Crew for City of Tacoma Environmental Services

0 80 160 320 480 640 Feet

Fig. 4-4

Trolley Court Bio-Filtration Facility Drainage Area

2005 OrthoPhoto does not reflect current site conditions.
Drainage includes residential lots.

Feet
0 25 50 100 150 200

Created by the GPS Crew for City of Tacoma Environmental Services

5 ORGANIZATION AND SCHEDULE

This section describes the roles & 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.

The Landfill lot is an active monitoring site. By August 16, 2009, the flow monitoring equipment was set to measure flow continuously. Rainfall at this site is currently monitored continuously.

5.1 Study Deliverables

This section describes the study deliverables. Section 14.2 of this QAPP provides additional details describing the procedure and method for developing the deliverables. Refer to Section 11 of the S8 Program QAPP for documentation and records supporting development of the deliverables and Section 15 of this QAPP for a discussion of the content. Table 5-1 presents the study timeline and schedule as well as study deliverables. It is anticipated that sampling will continue for 2 complete monitoring years. After 2 complete years of data are collected, the sample numbers, completeness, and statistical power of the data will be reviewed to determine how well sampling objectives were met. If sampling objectives were not met, or statistical power is substantially less than expected, an extension of the monitoring program for a third year may be proposed to Ecology at that time.

The study results will be presented in an annual report. Each annual report will include all monitoring data collected during the preceding water year (October 1 – September 30). The first annual monitoring report submitted will include data from a partial water year, November 30, 2009 through September 30, 2010. 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:

1) A summary including BMP type location, land use, drainage area size, and hydrology for each site.
2) The status of implementing the monitoring program,
3) A comprehensive data and QA/QC report including an explanation and discussion of the results of each monitoring study, and
4) Performance data.

Table 5-1. Study deliverable schedule.

Performance Monitoring Period	Anticipated No. of Events	Anticipated Date of Initiation	Anticipated Date of Annual Completion	Deliverable and Due Date
Water Year 2009	0		09/30/2009	Stormwater Monitoring Status [2] March 31, 2010
Water Year 2010	7-9	10/01/2009	09/30/2010	Stormwater Monitoring Report[2] March 31, 2011
Water Year 2011	8-12	10/01/2010	09/30/2011	Stormwater Monitoring Report[2] March 31, 2012
Water Year 2012	2-5	10/01/2011	09/30/2012	Study Monitoring Report[2] March 31, 2013

1 After 2 complete years of data are collected, the sample numbers, completeness, and statistical power of the data will be reviewed to determine how well sampling objectives were met. If sampling objectives were not met, or statistical power is substantially less than expected, an extension of the monitoring program for a third year may be proposed to Ecology at that time.

2 Submitted with NPDES 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 overall objective of the BMP effectiveness monitoring program is to quantify the reductions in flow, contaminant concentrations and loads that result from full-scale field demonstrations of stormwater BMPs. Tacoma is proposing to monitor the following two types of stormwater BMPs:

- Pervious pavement (for hydrologic control)
- Bioinfiltration and biofiltration facilities (for pollutant control)

The objectives of the BMP effectiveness monitoring program are described in more detail in Section 4.2.

6.1.2 Step 2: Identify the Decisions

In accordance with MS4 Permit requirements, Tacoma's BMP effectiveness monitoring program is designed to answer the following questions:

- To what extent does pervious pavement help to improve the quantity (i.e., reduced flow and volume) in stormwater runoff?
- To what extent do bioinfiltration and biofiltration facilities help to improve the quality (i.e., reduced contaminant concentrations) in stormwater runoff?

These questions are developed into the following testable statistical hypotheses:

- *Null Hypothesis S8E-1.* Pervious pavement causes no significant reductions in stormwater flow (peak or average flow) or volume compared to impervious pavement.
- *Alternative Hypothesis S8E-1.* Pervious pavement results in significant reductions in stormwater flow and volume.

- *Null Hypothesis S8E-2.* The contaminant concentrations in stormwater from biofiltration facilities ("effluent") are not significantly different than concentrations in untreated overland stormwater runoff ("influent").
- *Alternative Hypothesis S8E-2.* Treatment of stormwater through biofiltration facilities helps to attenuate contaminant concentrations.
- *Null Hypothesis S8E-3.* The contaminant concentrations in infiltrated stormwater beneath bioinfiltration facilities ("effluent") are not significantly different than concentrations in untreated overland stormwater runoff ("influent").
- *Alternative Hypothesis S8E-3.* Infiltration of stormwater beneath bioinfiltration facilities helps to attenuate contaminant concentrations.

Sufficient data will be collected in the BMP effectiveness monitoring program to be able to test these hypotheses with an appropriate level of statistical confidence and power.

6.1.3 Step 3: Identify Inputs to the Decision

Tacoma has been monitoring stormwater quality under a Consent Decree with EPA in seven of the largest municipal drainages in the Thea Foss watershed since August 2001. Existing data on stormwater and storm sediment quality is compiled and summarized in Tacoma's annual stormwater monitoring reports (see Tacoma 2008).

The MS4 Permit requires analysis of the following parameters in the influent and effluent streams for each BMP:

- TSS
- Particle size distribution
- pH
- Total and ortho-phosphorus
- Total and dissolved copper and zinc

Of these parameters, TSS, zinc, and pH have been part of Tacoma's existing stormwater monitoring program. Summary statistics for TSS, zinc, and other representative analytes in various municipal outfalls are presented in Table 6-1. This table includes the arithmetic mean concentrations and coefficients of variation (CV) over the six-year monitoring period. 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 zinc range from 0.45 to 0.77. pH will be used as an index field parameter rather than a quantitative performance metric. It is assumed that the quality and statistical variability of the influent stormwater to the BMPs will be similar to these existing stormwater monitoring data, which are derived from a variety of mixed land uses (residential, commercial, and industrial). It is further assumed that the new Permit-required analytical parameters for the BMP effectiveness monitoring program, as listed above, will be characterized by CVs similar to those shown in Table 6-1, but this assumption will need to be confirmed with a few initial rounds of monitoring data.

Table 6-1. Coefficients of Variation in Tacoma Stormwater

Analyte	Outfall 237A		Outfall 237B		Outfall 230		Outfall 235		Outfall 245	
	Arithmetic Mean	Coefficient of Variation (%)	Arithmetic Mean	Coefficient of Variation (%)	Arithmetic Mean	Coefficient of Variation (%)	Arithmetic Mean	Coefficient of Variation (%)	Arithmetic Mean	Coefficient of Variation (%)
Conventionals in mg/L										
TSS	50	0.45	76	0.72	61	0.70	101	0.77	84	0.60
Metals in mg/L										
Lead (Total)	14	0.47	18	0.73	29	0.68	95	0.60	15	0.59
Zinc (Total)	118	0.47	91	0.58	137	0.71	164	0.58	183	0.62
Lead (Diss.)	0.9	0.63	0.8	0.56	1.6	0.87	7.9	0.76	1.0	0.87
Zinc (Diss.)	72	0.59	34	0.66	70	0.65	54	0.68	79	0.75
Organics in µg/L										
DEHP	3.8	0.60	4.2	0.64	5.8	0.71	9.7	1.37 [1]	5.2	1.12 [2]
Phenanthrene	0.16	0.85	0.11	1.08	0.18	0.82	0.18	0.75	0.13	1.74 [3]
Pyrene	0.40	0.76	0.26	0.92	0.37	0.74	0.35	0.68	0.17	1.09

Notes:

Data from City of Tacoma 2008; Annual Stormwater Monitoring Report, 2001-2007, Appendix F

[1] High CV for DEHP in Outfall 235 caused by one extreme outlier in Monitoring Year 2

[2] High CV for DEHP in Outfall 245 caused by two extreme outliers in Monitoring Year 2

[3] High CV for Phenanthrene in Outfall 245 caused by extreme outliers in Monitoring Years 3 and 4

6.1.4 Step 4: Define the Boundaries of the Study

Geographic Boundaries. The geographic boundaries of the BMP monitoring sites include relatively small controlled drainage areas. The pervious pavement study area includes four 0.21-acre plots in an employee parking lot at the Tacoma Landfill. The plots are situated on engineered cover material at a closed cell of the landfill, consisting of clean fill with underdrains on an impervious hydrologic and geochemical barrier. Stormwater runoff flowrates will be measured in sampling ports in the underdrains and in catch basins collecting any resulting surface water runoff. The four experimental plots include standard impervious asphalt, pervious asphalt, pervious concrete, and pervious interlocking blocks.

The bioinfiltration facilities' study areas are 2 acres for the 46th and R Street Swale and 14 acres for the 44th Street Pond. Surface water runoff is collected from surrounding streets of the multi-family Salishan Development and directed into the bioinfiltration facilities. Stormwater "effluent" will be collected from sampling ports in the underdrains of these facilities. The biofiltration facilities' study areas are 6.5 acres for the East 32nd Street Swale and 2.3 acres for the Trolley Court Swale. Surface water runoff is collected from surrounding streets of the residential and commercial areas (residential only for Trolley Court) and directed into the biofiltration facilities. Stormwater "effluent" will be collected from sampling ports in the surface flow discharging from these facilities.

Two water years will be monitored at the BMP sites. The monitoring period will extend from November 30, 2009 through November 30, 2011 (see Table 5-1). After 2 complete years of data are collected, the sample numbers, completeness, and statistical power of the data will be reviewed to determine how well sampling objectives were met. If sampling objectives were not met, or statistical power is substantially less than expected, an extension of the monitoring program for a third year may be proposed to Ecology at that time.

6.1.5 Step 5: Develop Decision Rules

The stormwater monitoring data will be evaluated in accordance with the following decision rules:

1. If it can be shown with statistical significance that Null Hypothesis S8E-1 is false, then a difference in stormwater flow (average and/or peak flow) or volume will have been demonstrated in the pervious pavement areas relative to standard asphalt. By understanding the characteristics of the response hydrograph on these relatively small engineered plots, the results may be scaled up to larger drainage areas.

2. If it can be shown with statistical significance that Null Hypothesis S8E-2 is false, then the biofiltration facilities are able to filter and attenuate contaminant concentrations during stormwater flow through the grass-lined swale channel.

3. If it can be shown with statistical significance that Null Hypothesis S8E-3 is false, then the bioinfiltration facilities are able to filter and attenuate contaminant concentrations during stormwater infiltration and percolation through subsurface soils.

6.1.6 Step 6: Specify Limits on Decision Errors

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

Minimum Detectable Relative Difference (MDRD). A MDRD between mean influent and effluent concentrations is specified at 50 percent. The monitoring program should be able to detect with statistical significance a 50 percent reduction in stormwater concentrations representing treatment by the BMP. A MDRD of 50 percent is consistent with the minimum level of pollutant reduction that is considered acceptable in Ecology's TAPE guidance (Ecology 2008).

Statistical Confidence and Power. The MS4 Permit specifies goals of 90 to 95 percent statistical confidence and 75 to 80 percent statistical power for BMP effectiveness monitoring (S8F4). 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 pairs of influent-effluent samples that should be collected to achieve the data quality objectives specified for the BMP effectiveness monitoring program. The number of samples required 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):

$$N = (Z_{\alpha} + Z_{2\beta})^2 (CV/MDRD)^2$$

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 percent reduction between influent and effluent stormwater concentrations as a function of CV is provided in Table 6-2. A range of acceptable confidence levels (alpha = 0.05 to 0.10) and power levels (beta = 0.20 to 0.25) is presented. Depending on the particular analyte and its CV, no more than 20 pairs of samples would be needed to reach 90 percent confidence and 80 percent power, even for the more erratic constituents. At a sampling rate of 10 samples per year, these control limits would be achieved within one to two monitoring years.

It should be noted that the sample sizes estimated in Table 6-2 are based on an assumption of normal distributions, whereas much Tacoma's stormwater data are better described by lognormal distributions (Tacoma 2008). The statistical power may be reduced if the data are log-transformed. The statistical power will be verified at the end of the two-year monitoring period, and if the data provide less power and confidence than was expected, the City will consult with Ecology to determine whether to extend the monitoring program for a third year.

6.2 Measurement Quality Objectives

Please Refer to Section 6.2 of the S8 Program QAPP.

6.2.1 Representativeness

The representativeness of the data is dependent on 1) the sampling locations, 2) the flow regime during sample collection 3) the number of years sampling is performed, and 4) the sampling procedures. Site selection and sampling of pertinent media (i.e., water) and use of only approved analytical methods will assure that the measurement data represents the population being studied at the site.

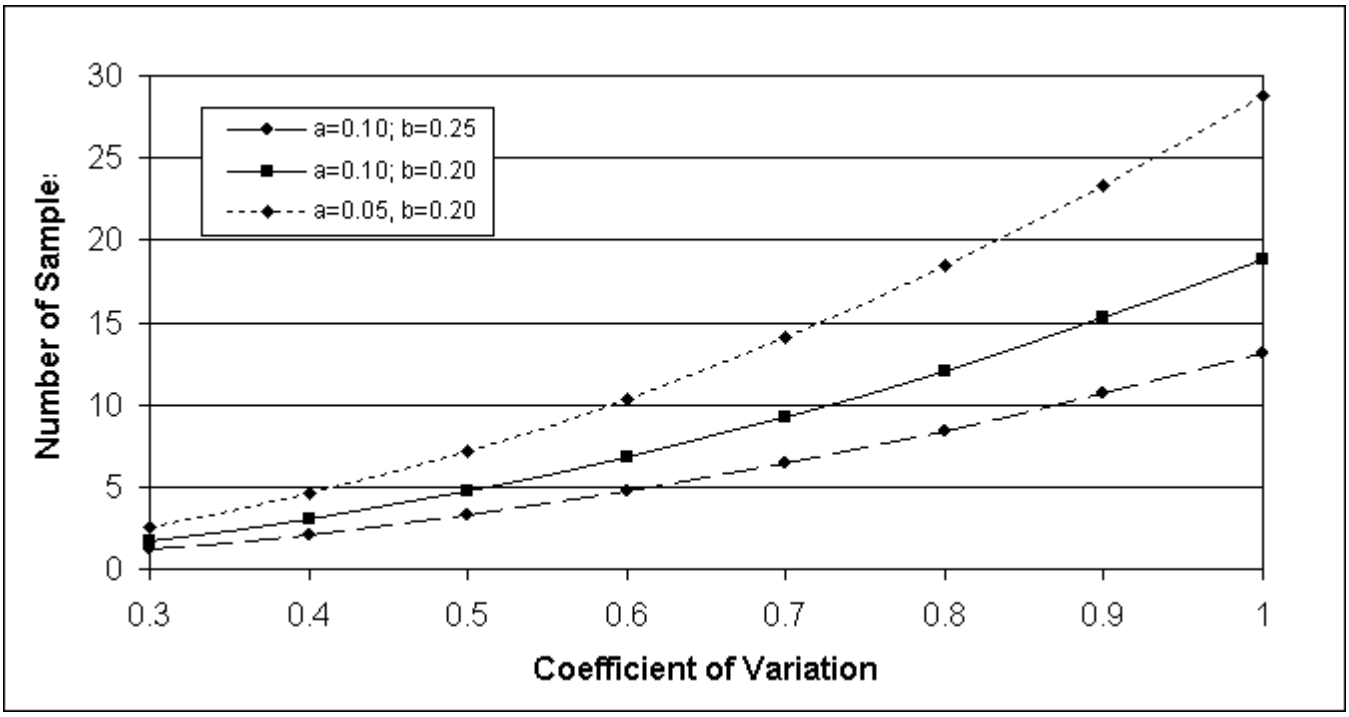
The representativeness of the water quality data to be collected through this study will be ensured by targeting representative storms for sampling based on the criteria (Table 7-1 and Table 7-2*)*: that were derived from the Phase I Municipal Stormwater Permit (Ecology 2007) and recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Storm water Treatment Technologies: Technology Assessment Protocol – Ecology (TAPE).*

The representativeness of the sediment and soil quality data to be collected through this study will be ensured by employing consistent and standard sampling procedures. In addition, the representativeness of these data will be ensured by selecting sampling locations that take into account the physical processes that 1) influence location and rate of sediment accumulation within stormwater treatment BMPs (bioinfiltration and biofiltration facilities).

Table 6-2. Estimated Sample Size for BMP Effectiveness Monitoring.

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:

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

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

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

7 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

The sampling process design to be used for monitoring is described herein. The sampling process design was developed based on monitoring requirements identified in the Phase I Municipal Stormwater Permit (Ecology 2007) and recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Storm water Treatment Technologies: Technology Assessment Protocol Ecology (TAPE).*

The sampling process design to be used for monitoring the pervious pavements lot for the Tacoma Landfill project, is herein. That is, continuous flow monitoring for a period of one year in order to evaluate pervious pavement systems as a flow control strategy.

As described previously, the specific objectives of this monitoring study are as follows:

- Quantify the treatment performance of each bioinfiltration and biofiltration BMP for reducing both pollutant concentrations and loads.
- Determine the bioinfiltration and biofiltration effectiveness of each BMP at treating the applicable water quality design flow.
- Determine if the treatment performance of each bioinfiltration and biofiltration BMP varies in relation to storm event characteristics and/or other operational considerations.
- Quantify the flow reduction performance of each pervious pavement section in comparison to standard asphalt.

In addition to the flow and water quality monitoring described above, sediment monitoring will be performed within each bioinfiltration and biofiltration BMP in order to meet the following objectives:

- Quantify sediment accumulation rates within each component of the BMP for determining maintenance requirements.
- Evaluate the grain size distribution of accumulated sediment within each component of the BMP for use in assessing overall system performance.
- Evaluate pollutant concentrations in accumulated sediment within each component of the BMP.

A short discussion of the monitoring strategy is followed by the detailed sampling design for each project along with the flow and water quality monitoring equipment selection.

7.1 Monitoring Strategy Overview

A discussion of the stormwater monitoring strategy developed to meet the requirements of Section S8F and the recommended procedures from Ecology (2008) in *Guidance for Evaluating Emerging Storm water Treatment Technologies: Technology Assessment Protocol Ecology (TAPE)* is presented below and includes:

- Selection of parameters and analytical methods,
- Selection of sampling techniques and types; and
- Selection of sampling frequency and criteria to ensure representative samples.

7.1.1 Parameters and Analytical Methods

Monitoring parameters were selected by Ecology as those expected to meet basic and enhanced treatment goals and their known presence in stormwater, their potential for adverse impacts, or their value in providing necessary supporting information (see Section 3.3 for additional information). Tables 6-5 and 6-6, in the S8 Program QAPP, present the analytical methods and minimum reporting limits.

7.1.2 Sampling Techniques and Types

Sampling techniques and types to be used include automatic flow-weighted composite sampling of stormwater and manual grab collection of sediment samples. Samples collected in water will be collected using automatic flow-weighted composite sampling. Sediment and soil samples will be collected using manual grab procedures.

7.1.3. Representative Sample Criteria

The TAPE protocol (Ecology 2008) defines “representative” storms that must be monitored when ascertaining performance of treatment BMPs. Storm event criteria are established to: (1) ensure that adequate flow will be discharged; (2) allow some build-up of pollutants during the dry weather intervals; and (3) ensure that the storm will be “representative,” (i.e., typical for the area in terms of intensity, depth, and duration).

Collection of samples during a storm event meeting these criteria ensures that the resulting data will accurately portray the most common conditions for each site. Ensuring a representative sample requires two considerations: (1) the storm event must be representative, and (2) the sample collected must represent the storm event. Table 7-1 lists the qualifying storm event criteria to ensure the storm event sampled is representative. It is anticipated that sampling will continue for 2 complete monitoring years. After 2 complete years of data are collected, the sample numbers, completeness, and statistical power of the data will be reviewed to determine how well sampling objectives were met (see Section 6.1.7 for additional details). If sampling objectives were not met, or statistical power is substantially less than expected, an extension of the monitoring program for a third year may be proposed to Ecology at that time. The maximum number of samples needed to be representative is estimated to be 35.

Table 7-1. Representative storm event criteria.

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

Table 7-2 describes the criteria to ensure the composite sample collected is representative of the storm event sampled.

Table 7-2. Representative sampler collection criteria.

Storm Storm event event duration	<24 hours	>24 hours
Minimum storm volume to sample	75 percent of the storm event hydrograph	75 percent of the hydrograph of the first 24 hours of the storm
No. of Aliquots	At least 10 flow-weighted sub-samples (or aliquots) must be collected during the duration of the event. If fewer than 10, but seven or more aliquots are collected, than the sample will be considered valid only if all other sampling criteria have been met.	
Maximum time period for sample collection (hours)	36	36

7.2 Site-specific Sampling Design

The following subsections provide a more detailed description of the sampling process design that will be used for the Salishan bioinfiltration facilities, East 46th & R Street Swale and East 44th Street Pond, and the biofiltration swales, East 32nd St and Trolley Court. The actual sampling procedures to be implemented in connection with this sampling process design are described in Section 8. A detailed description of the flow monitoring process design that will be used for the pervious pavements at the Landfill is also provided.

7.2.1 Salishan Bioinfiltration Facilities

The East 46th & R Street Swale is approximately 80 feet long and runs west to east at the intersection of East 46th Street & R Street (see Figures 4-1 and 7-1a). The second bioinfiltration facility, the East 44th Pond, is approximately 155.5 feet long and runs south of East 44th Street parallel to T-Street Gulch (see Figures 4-2 and 7-2a). The bioinfiltration facilities have four primary components: a vegetated planting strip, an engineered soil layer, a gravel drain layer, and a perforated under-drain pipe (see Appendix A for details).

During operation, stormwater runoff from the surrounding drainage basin enters the planting strip via the inlet pipe where it is retained for a sufficient period of time to allow infiltration to the underlying engineered soil layer (see Figures 7-1a, 7-1b, 7-2a and 7-2b). Absorption, filtration, retention and evapotranspiration processes within the engineered soil layer then provide water quality treatment and serve to attenuate stormwater runoff rates and volumes. Under saturated conditions, stormwater infiltrates from the engineered soil layer down to the gravel drain layer. The gravel drain layer provides additional storage for attenuating stormwater runoff flow rates and volumes. Overflow from the gravel drain layer is first collected in the perforated under-drain pipe which subsequently discharges to the first bypass structure (see Figures 7-1c and 7-2c). A solid-walled pipe within the outlet structures then conveys the overflow water to the primary stormwater conveyance system for the Salishan neighborhood.

During larger storm events when the infiltration capacity is exceeded, the water depth in the swale/pond will rise until stormwater begins to overflow (or bypass) the swale/pond via two beehive structures (see Figures 7-1c and 7-2c). The elevations of the two overflow (or bypass) beehive structures' are staggered, one lower and one higher. This overflow (or bypass) also connects to the primary stormwater conveyance systems for the Salishan neighborhood.

During larger storm events when the water quality treatment design flowrate is exceeded for the East 44th Street Pond, the upstream flow bypasses the East 44th Street Pond via the flow splitter (see Structure A in Figure 7-2b). The bypassed flow continues to discharge downstream in the primary stormwater conveyance system for the Salishan neighborhood (see Figure 7-2a).

Two monitoring stations will be established in connection with each bioinfiltration facility to measure the quantity and quality of influent (IN) and effluent (OUT) stormwater. Figures 7-1a and 7-2a shows the inlet and outlets of each bioinfiltration facility, East 46th & R Street Swale and East 44th Pond. As noted on Figures 7-1b, 7-1c, 7-2b and 7-2c, the equipment will be secured and/or housed in an enclosure or manhole.

The influent stations are located in the inlet pipe to each of the bioinfiltration facilities (see Figures 7-1b and 7-2b). Similarly, the effluent station is located in the outlet pipe from each of the bioinfiltration facilities (see Figures 7-1c and 7-2c). The treatment performance of the bioinfiltration facilities will be evaluated based on comparisons of loads and concentrations measured at the IN and OUT stations, respectively, for each bioinfiltration facility. To facilitate interpretation of trends in the data from each of these stations, a rain gauge will continuously monitor precipitation near the study site.

The specific monitoring stations established in association with the bioinfiltration facilities will be use to measure:

- Influent quality as measured in the inlet outfall pipe
- Influent flow at the point of discharge to the swale/pond
- Bypassed flow
- Effluent quality as measured in the under-drain pipe
- Effluent flow at the point of discharge for the under-drain pipe

Influent flow to the swale/pond will be continuously monitored at the inlet stations. These stations are designated RSTIN in Figure 7-1a and 44IN in Figure 7-2a and described in Section 7.3.1). When the water quality treatment design flowrate is exceeded for the East 44th Street Pond, the upstream flow bypasses the East 44th Street Pond via the flow splitter. When the infiltration capacity of the swale/pond is exceeded, the water depth in the swale/pond will rise until stormwater begins to overflow (or bypass) the swale/pond via beehive structures. As described above, the bypassed stormwater is then discharged into a nearby storm drain (see Figures 7-1a and 7-2a). Therefore, stations 44INB, 44OUTB and RSTOUTB will also be used to continuously monitor the flow of bypassed stormwater (see detail in Figures 7-1c and 7-2c) and described in Section 7.3.1).

Flow monitoring stations (designated 44OUT and RSTOUT in Figures 7-1c and 7-2c) will also be established at the point of discharge for the under-drain pipes associated with the swale/pond. Both of these under-drain pipes discharge to the first overflow structure for each BMP. These stations will be used to continuously monitor flow rates of effluent stormwater that overflows from the gravel drain layer via these pipes. A schematic diagram showing equipment

configuration for these stations is provide in Figures 7-1c and 7-2c and discussed in more detail below under Section 7.3.1.

The flow monitoring equipment at 44IN, 44OUT, RSTIN and RSTOUT will also be used to pace an automated sampler to facilitate the collection of flow-weighted composite samples for characterizing influent and effluent quality to and from the swale/pond. A new rain gauge is installed at a Tacoma Water secured site, 3611 E M Street (designated MST) and will be used to continuously monitor precipitation for the project site. This rain gauge is approximately 0.8 miles from the Salishan swale/pond. As a backup location, an existing rain gauge (designated CTP in Figure 1) will also be used to continuously monitor precipitation for the project site. This rain gauge is approximately 2 miles from the Salishan swale/pond.

Hydraulic Residence Time and Treatment Efficiency. The bioinfiltration facilities may be classified as having an intermediate residence time. In smaller storms, it is expected that the water exiting the BMP in the underdrains will be residual pore waters generated during a previous storm or storms. For example, during a minimum rain event (0.2 inches), the total runoff volume is only about one-quarter to one-third of the detention volume in the void spaces of the soils beneath the facilities, as shown in the table below. During a moderate rain event, the total runoff volume is about the same magnitude as the void spaces. During the six-month storm (~1.4 inches), the total runoff volume is about 8 times the detention volume in the void spaces. Therefore, the bioinfiltration facilities are effectively short-term devices only during large storms (i.e., 6 month return period or greater) which have the ability to flush through several soil pore volumes.

Rain Depth (in)	Runoff Vol. (ft3)	Void Vol (ft3)	Runoff/Void Ratio
East 46th and R Street Facility			
0.2	240	870	0.28
0.5	1,210	870	1.4
1.4 (6 mo.)	6,640	870	7.6
East 44th Street Facility			
0.2	2,180	6,270	0.35
0.5	10,870	6,270	1.7
1.4 (6 mo.)	50,310	6,270	8.0

For small storms, the effluent sample is not expected to be derived from the same storm as the influent sample. As a result, the treatment efficiency for this device will not be analyzed using event-based data pairs, but instead the data will be pooled over many storms for general characterization purposes. Tacoma does not propose to monitor these facilities using a random sampling approach, as described in Ecology's draft TAPE for *Evaluating Stormwater Treatment Technologies with Long Detention Times*, because (1) storm-generated standing water in the swales sets up a hydraulic gradient in the subsurface soils that drives pore waters into the underdrain system, i.e., the hydraulic driving force for effluent flow occurs during storms, although the effluent hydrograph may be lagged and prolonged, and (2) the effluent flow is expected to be ephemeral, with prolonged dry periods between storms, and therefore not practical for random sampling due to the low probability of a successful sampling event. Therefore, Tacoma will monitor these facilities using a sampling approach that targets storm events.

The infiltration rate assumed for the bioinfiltration facilities is approximately 2.4 inches/hour, based on the characteristics of the amended soils. Considering the underdrains are installed to a depth of 3.5 to 4 feet below grade, and assuming a soil porosity of 0.25 to 0.33, the travel time of stormwater through the soil profile to the underdrains is estimated at 4 to 7 hours. Thus, there is likely to be a delay of several hours between the peaks of the influent and effluent hydrographs. Continuous flow data from a few test storms will be used to estimate the delay and pacing of the effluent samples, relative to the influent, and the shape and duration of the effluent tail-out.

Treatment efficiency for the bioinfiltration facilities will be evaluated by pooling influent and effluent concentrations across many storms, respectively. As described above, influent concentrations for both bioinfiltration facilities will be derived from flow-weighted composite samples that are obtained during discrete storm events. Effluent concentrations will be derived from flow-weighted samples that are obtained from the under-drain pipe of each bioinfiltration facility (i.e., 44OUT and RSTOUT). However, influent and effluent data will not be paired on an event-specific basis.

Treatment efficiency will also be assessed for Salishan swale and pond based on comparisons of annual pollutant loads measured in influent, effluent, and bypassed water for each swale. The specific procedures used to calculate these pollutant load estimates are as follows:

- **Influent Loads**: Annual influent flow volumes to the Salishan swale and pond will be obtained from continuously monitored stations 44IN and RSTIN and rainfall data obtained from stations MST and CTP for the year of interest. These volumes will then be multiplied by a flow-weighted average concentration derived from the influent water quality samples that were obtained from the 44IN and RSTIN stations.
- **Effluent Loads**: Annual effluent flow volumes for the Salishan swale and pond will be determined from data collected from continuously monitored stations 44OUT and RSTOUT, respectively, in the under-drains of each bioinfiltration facility. These volumes will then be multiplied by average effluent concentrations that were derived from flow-weighted samples collected in the under drain monitoring stations for each of the respective bioinfiltration facilities.
- **Bypass Loads**: Annual bypass flow volumes to the Salishan swale and pond will be determined from data collected from continuously monitored stations 44INB, 44OUTB and RSTOUTB, respectively, in each bioinfiltration facility. These volumes will then be multiplied by a flow-weighted average concentration derived from the influent water quality samples that were obtained from stations 44IN and RSTIN.

Additional details of treatment efficiency calculations are provided in Sections 14.2.7 and 14.2.8.

The flow control performance of the Salishan swale and pond will be assessed based on analysis of the timing and frequency bypass events to determine if the swale and pond are effective at treating storm events up to the WWHM3 water quality BMP design flowrate. Additional statistical analyses will also be performed to quantify the performance of each swale with regard to reducing runoff volumes, peak discharge rates, and flow durations.

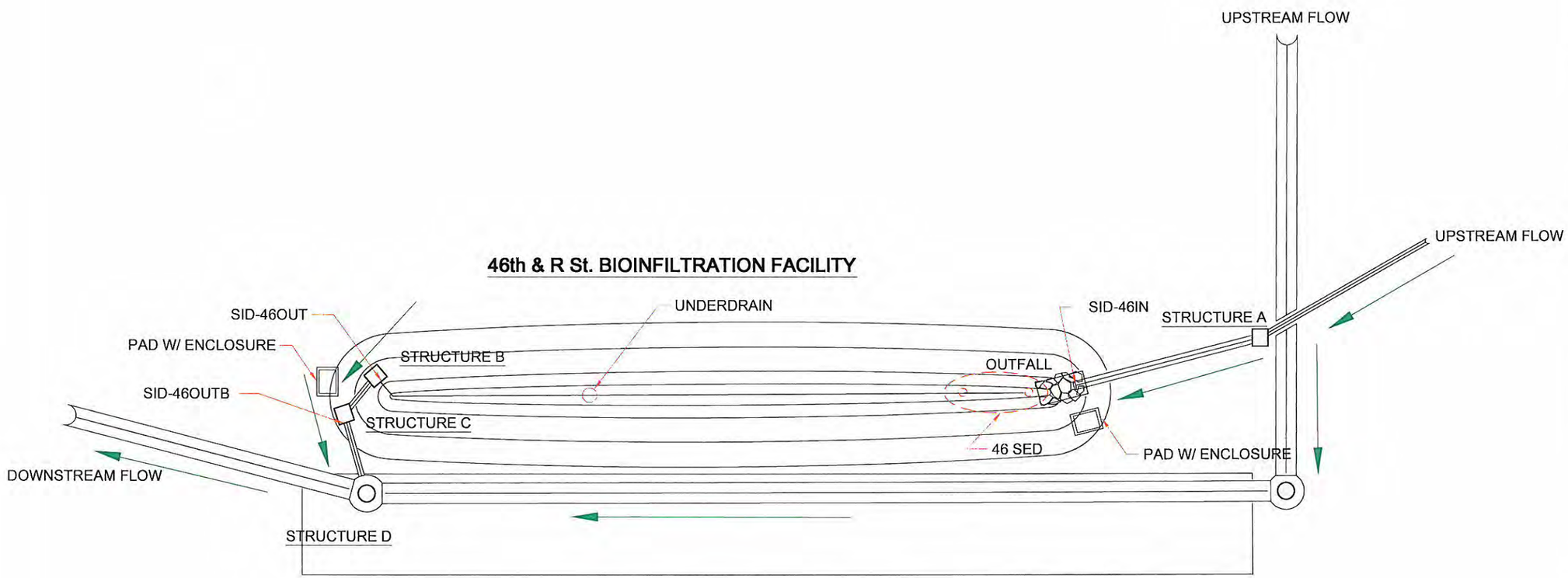
In addition to stormwater quantity and quality monitoring, sediment sampling will be conducted in the Salishan swale and pond on an annual basis. Figures 7-1a and 7-2a show the locations of sediment monitoring stations to be established in connection with the Salishan swale and pond.

A total of two monitoring stations (designated 44SED and RSTSED in Figures 7-1a and 7-2a) will be established, one in each bioinfiltration facility. Each station will consist of two sampling locations situated at the inlet pipe that allow stormwater to enter the facility and at the bottom of the swale/pond near the inlet pipe. The two samples from each BMP will be composited in the field resulting in one sample from each sediment monitoring station.

Soils in the Salishan swale and pond will be characterized to confirm the soil mixture installed at each site. Parameters to report include soil gradation, cation exchange capacity, organic content and depth.

Finally, controlled infiltration tests will be conducted on three occasions to measure surface infiltration rates in the Salishan swale and the pond. The first set of tests will be performed in November 2009 and follow-up tests will be performed in Fall 2010 and Fall 2011. In general, water will be introduced to maintain a constant water level in the swale (full-scale) or infiltrometer. After the flow rate has remained stable for 60 minutes, the water is turned off and the rate of infiltration (in inches per hour) is recorded until empty.

46th & R St. BIOINFILTRATION FACILITY



General Notes

1. FOR STRUCTURE A DETAIL REFER TO FIGURE 7-S.
2. FOR STRUCTURES B & C DETAILS REFER TO FIGURE 7-T.
3. FOR STRUCTURE D DETAIL REFER TO FIGURE 7-U.
4. FOR ALL INLET SAMPLING & MONITORING LOCATIONS DETAILS REFER TO FIGURE 7-S AND 7-U.
5. FOR ALL OUTLET SAMPLING & MONITORING LOCATIONS DETAILS REFER TO FIGURE 7-T.
6. FOR PAD AND ENCLOSURE DETAILS REFER TO FIGURE 7-S AND 7-T.
7. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
8. SID - SAMPLE IDENTIFICATION NUMBER.

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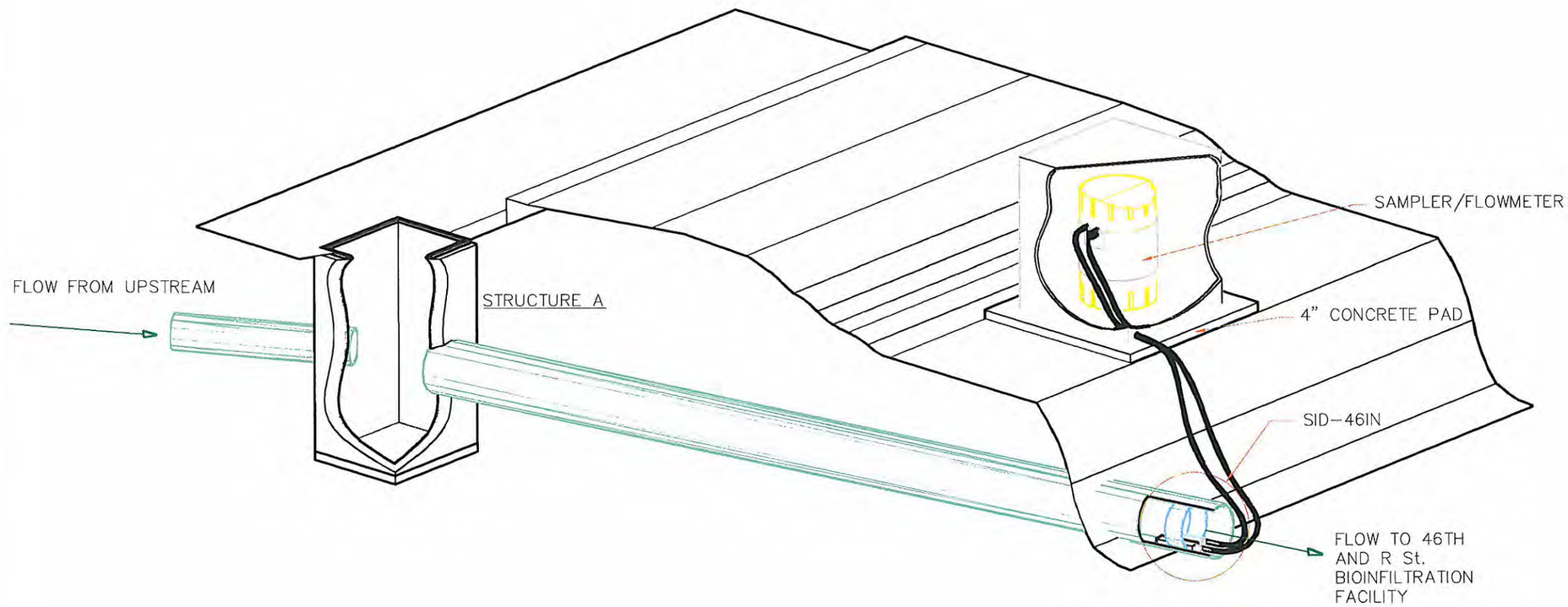
Tacoma

Project Name and Address

FIGURE 7-1A
46th & R St. BIOINFILTRATION FACILITY MONITORING LOCATIONS

Project N/A	Sheet 1 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

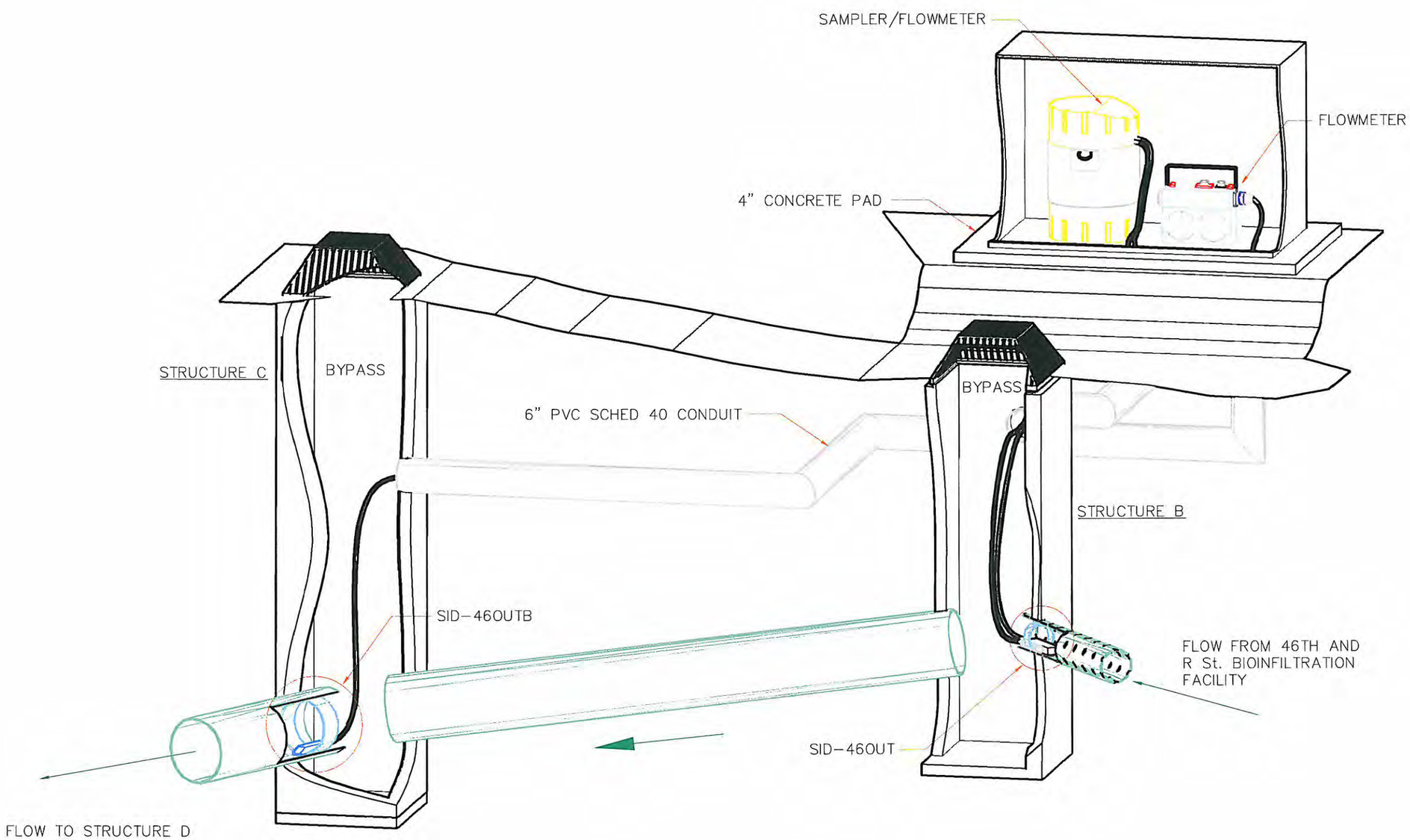
1. FOR STRUCTURE A LOCATION REFER TO FIGURE 7-R.
2. FOR ALL INLET SAMPLE LOCATIONS & MONITORING LOCATIONS REFER TO FIGURE 7-R.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address
CITY OF TACOMA
SCIENCE AND ENGINEERING
ENVIRONMENTAL COMPLIANCE

Project Name and Address
FIGURE 7-1B
INLET STATION FOR 46TH AND R St. BIOINFILTRATION FACILITY

Project N/A
Date JAN 9, 2009
Scale NTS
Sheet 2 OF 3



General Notes

1. FOR STRUCTURES B & C LOCATIONS REFER TO FIGURE 7-R.
2. FOR ALL OUTLET SAMPLING & MONITORING LOCATIONS REFER TO FIGURE 7-R.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
4. CONDUIT TO BE BURIED OR SURFACE MOUNTED DEPENDING ON CONDITIONS.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

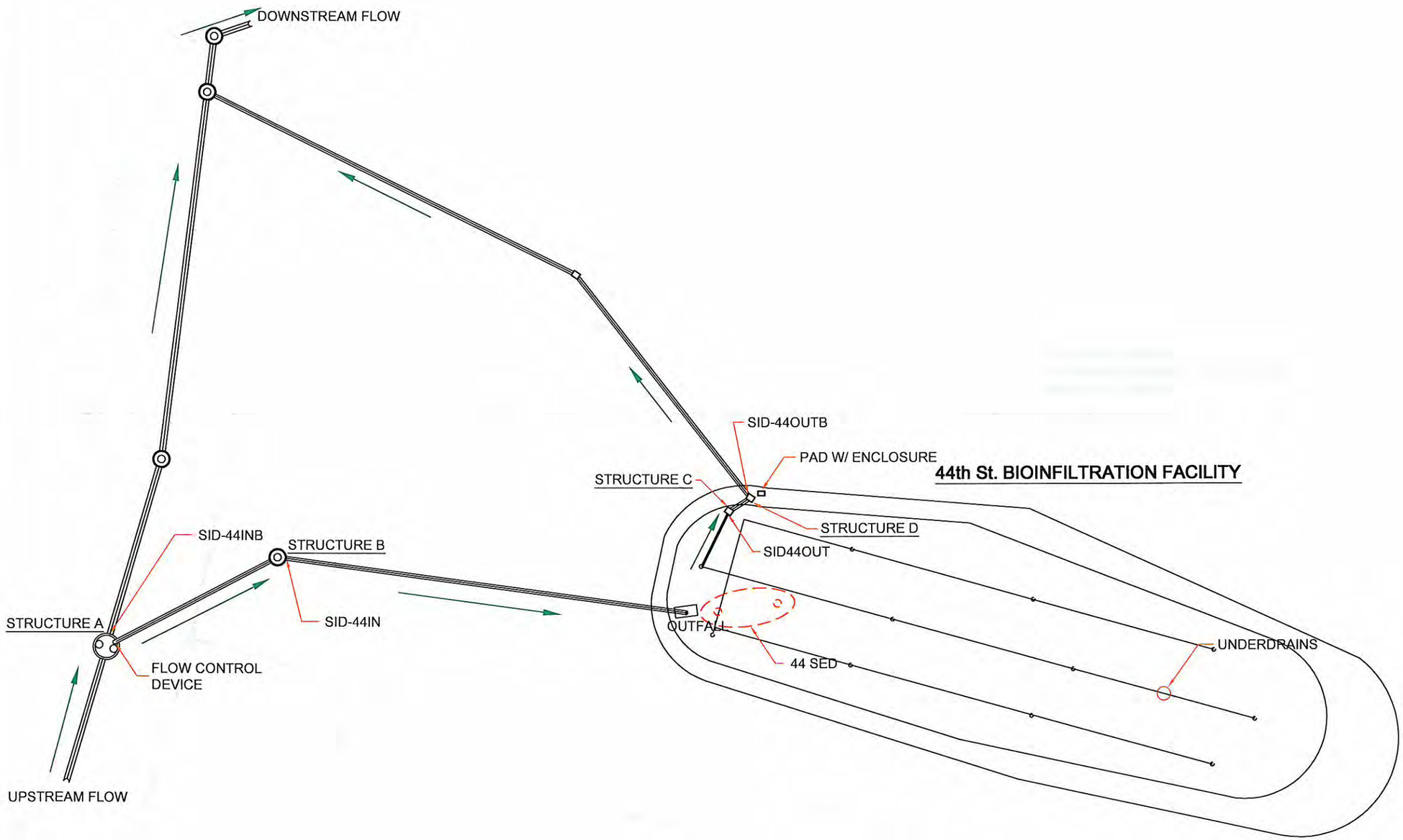
SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

Project Name and Address

FIGURE 7-1C
OUTLET STATIONS FOR 46TH AND R St. BIOINFILTRATION FACILITY

Project N/A	Sheet 3 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURES A & B DETAILS REFER TO FIGURE 7-B.
2. FOR STRUCTURES C & D DETAILS REFER TO FIGURE 7-C.
3. FOR ALL INLET SAMPLE LOCATIONS & MONITORING LOCATIONS DETAILS REFER TO FIGURE 7-B.
3. FOR ALL OUTLET SAMPLE LOCATIONS & MONITORING LOCATIONS DETAILS REFER TO FIGURE 7-C.
4. FOR PAD AND ENCLOSURE DETAILS REFER TO FIGURE 7-C.
5. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
6. SID - SAMPLE IDENTIFICATION NUMBER.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

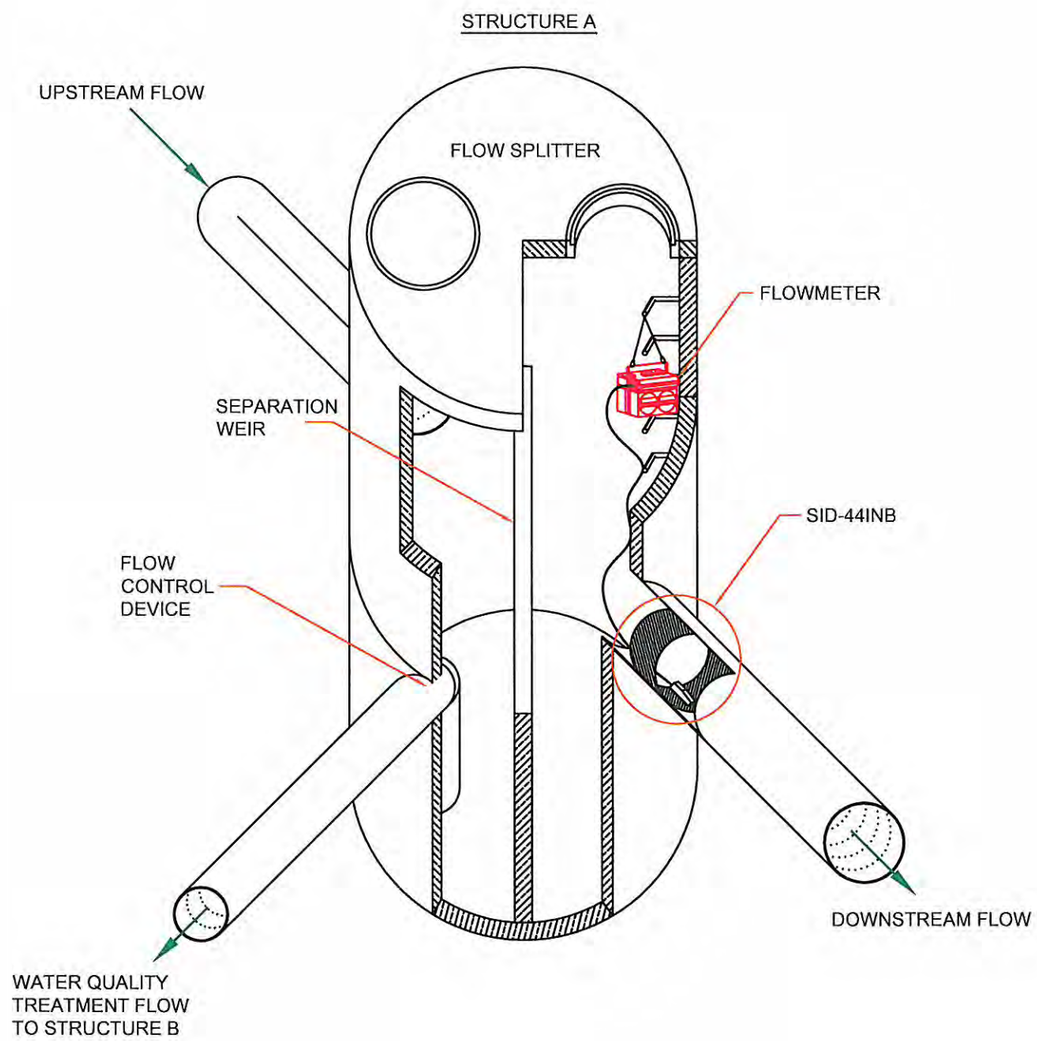
Tacoma

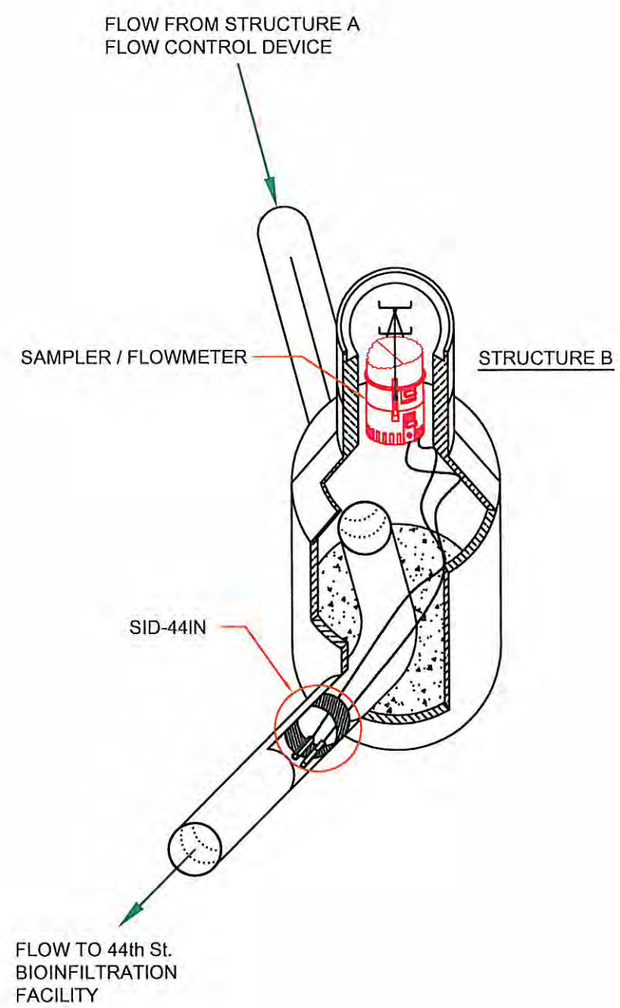
Project Name and Address

FIGURE 7-2A

44th St. BIOINFILTRATION FACILITY MONITORING LOCATIONS

Project: N/A	Sheet: 1 OF 3
Date: JAN 9, 2009	
Scale: NTS	





General Notes

1. FOR STRUCTURES A & B LOCATIONS REFER TO FIGURE 7-A.
2. FOR ALL INLET SAMPLE LOCATIONS & MONITORING LOCATIONS REFER TO FIGURE 7-A.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

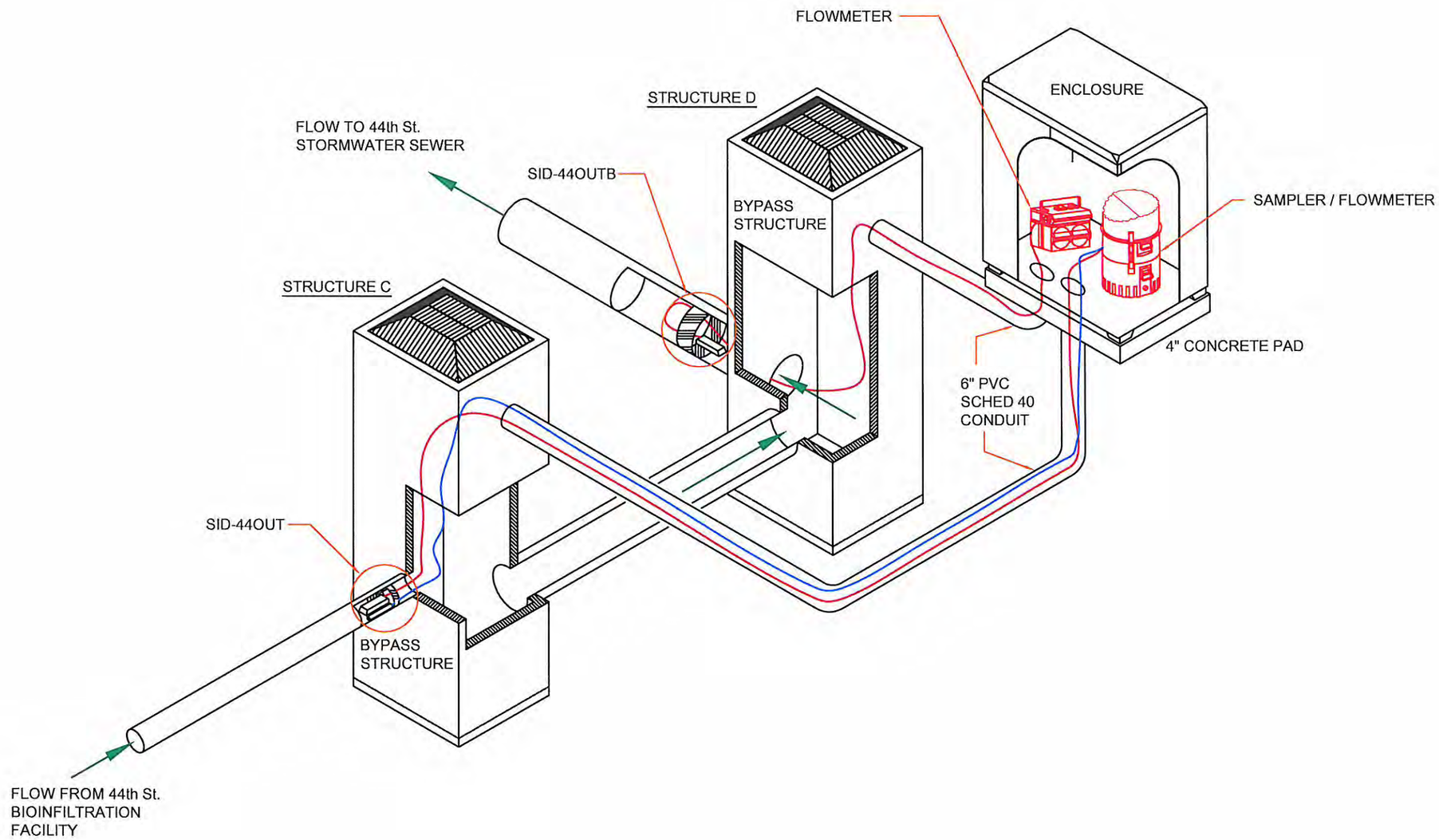
ENVIRONMENTAL COMPLIANCE

Project Name and Address

FIGURE 7-2B

INLET STATIONS FOR 44th St. BIOINFILTRATION FACILITY

Project N/A	Sheet 2 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURES C & D LOCATIONS INCLUDING MONITORING EQUIPMENT ENCLOSURE LOCATIONS REFER TO FIGURE 7-A.
2. FOR ALL OUTLET SAMPLING & MONITORING LOCATIONS REFER TO FIGURE 7-A.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
4. CONDUIT MAY BE EITHER BURIED OR SURFACE MOUNTED DEPENDING UPON GROUND CONDITIONS.

No.	Revision/Issue	Date

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CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

Tacoma

Project Name and Address

FIGURE 7-2C

OUTLET STATIONS FOR 44th St. BIOINFILTRATION FACILITY

Project N/A	Sheet 3 OF 3
Date JAN 9, 2009	
Scale NTS	

7.2.2 Biofiltration Facilities

The East 32nd Street Facility has two parallel swales that are approximately 120 feet long and run south of East 32nd Street parallel to T-Street Gulch (see Figures 4-3 and 7-3a). The second biofiltration facility, Trolley Court Swale, is approximately 186 feet long and is south of 17th at the intersection of State Street (see Figures 4-4 and 7-4a). The biofiltration facilities comprise of an inlet pipe, grass-lined channel, and an outlet structure (see Appendix A for details, Table A-3: Trolley Court and Table A-6: East 32nd Street Facility). During operation, stormwater runoff from the surrounding drainage basin enters a grass-lined channel via an inlet pipe where it disperses across the width of the channel and flows down the length of the channel to allow filtration via the grasses.

The East 32nd Street Swale consists of two parallel inlets, grass lined channels, and outlets (see Figure 7-3a). The two outlet pipes convey water to a single manhole structure and then to a downstream dispersion facility that disperses the treated water to a downstream wetland in T Street Gulch. During larger storm events, design inlet flows greater than the 100 % 6 month 24 hour flowrate bypasses the biofiltration facility to the primary stormwater conveyance system. In addition, outlet flows greater than 6-month, 24-hour flowrate (see Appendix A, Table A-6) bypasses the dispersion facility to the primary stormwater conveyance system.

Two monitoring stations will be established in connection with each inlet to measure the total quantity and quality of influent (IN) stormwater. Figures 7-3a and 7-3b shows the inlets to East 32nd Street Swale. As noted on Figure 7-3b, the equipment will be secured and housed in an enclosure. One monitoring station will be established downstream of the single manhole structure to measure the quantity and quality of effluent (OUT) stormwater. Figures 7-3c shows the single manhole structure. The equipment will be secured and housed in a manhole.

The Trolley Court Swale has a single inlet, grass lined channel, and a beehive outlet (see Figure 7-4a). The outlet pipe conveys water to a manhole structure and then to a detention facility that discharges to the primary stormwater conveyance system. Two monitoring stations will be established in the Trolley Court Swale to measure the quantity and quality of influent (IN) and effluent (OUT) stormwater. Figures 7-4a shows the inlet(s) and outlet(s) of this biofiltration facility. As noted on Figures 7-4b and 7-4c, the equipment will be secured and/or housed in an enclosure (OUT) or manhole (IN). The influent station is located in the inlet pipe to the biofiltration facility (see Figure 7-4b). Similarly, the effluent station is located in the outlet pipe from the biofiltration facility (see Figure 7-4c).

The treatment performance of the biofiltration facilities will be evaluated based on comparisons of loads and concentrations measured at the IN and OUT stations, respectively, for each biofiltration facility. To facilitate interpretation of trends in the data from each of these stations, a rain gauge will continuously monitor precipitation near the study site.

The specific monitoring stations established in association with the biofiltration facilities will be use to measure:

- Influent quality as measured in the inlet outfall pipes
- Influent flow at the point of discharge to the swales
- Bypassed flow (East 32nd Street Swale only),
- Effluent quality as measured in the outlet pipes
- Effluent flow at the point of discharge from the swales

Influent flow to the swales will be continuously monitored at the IN stations. These stations are designated 32IN1 and 32IN2 in Figure 7-3a and TCIN in Figure 7-4a and described in Section

7.3.2). When the treatment flow of the East 32nd Street swale is exceeded, the excess stormwater volumes begin to overflow (or bypass) the swale inlets via the inlet manhole structures. As described above, this stormwater is then discharged into a nearby storm drain (see Figures 7-3a and 7-3b). Therefore, stations 32INB1 and 32INB2 will also be used to continuously monitor the flow of bypassed stormwater and described in Section 7.3.2).

Flow monitoring stations (designated 32OUT and TCOUT in Figures 7-3c and 7-4c) will also be established at the point of discharge for the outlet pipes associated with the swales. These stations will be used to continuously monitor flow rates of effluent stormwater that flows from the channel to the outlet structures. A schematic diagram showing equipment configuration for these stations is provide in Figures 7-3c and 7-4c and discussed in more detail below under Section 7.3.2.

The effluent stormwater of the East 32nd Street swale flow discharges to a downstream dispersion facility to a wetland. To protect the dispersion facility and wetland, excess stormwater volumes begin to overflow (or bypass) the swale outlet manhole structure. As described above, this stormwater is then discharged into a nearby storm drain (see Figures 7-3a and 7-3c). Therefore, station 32OUTB will also be used to continuously monitor the flow of bypassed stormwater and description in Section 7.3.2).

The flow monitoring equipment at 32IN1, 32IN2, 32OUT, TCIN, and TCOUT will also be used to pace an automated sampler to facilitate the collection of flow-weighted composite samples for characterizing influent and effluent quality to and from the swales. An existing rain gauge (designated CTP in Figure 3-3) will be used to continuously monitor precipitation for the project site. This rain gauge is approximately 0.8 mile from the East 32nd Street swale. As a backup location, a new rain gauge may be installed at a Tacoma Water secured site, 3611 E M Street (designated MST) and will also be used to continuously monitor precipitation for the project site. This rain gauge is approximately 0.8 mile from the East 32nd Street swale.

An existing rain gauge (designated RG-4 in Figure 3-4) will be used to continuously monitor precipitation for the Trolley Court swale. This rain gauge is approximately 0.5 mile from the Trolley Court swale. As a backup location, existing rain gauge at the Tacoma Landfill will also be used to continuously monitor precipitation for the project site. This rain gauge is approximately 2 miles from the Trolley Court swale.

Hydraulic Residence Time and Treatment Efficiency. The biofiltration facilities are flow-through BMPs with hydraulic residence times estimated at 10 to 20 minutes. As a result, these may be classified as short-term stormwater treatment facilities, and the effluent flow is reasonably assumed to be derived from the same storm as the influent. Treatment efficiency for the biofiltration facilities may therefore be evaluated based on statistical comparisons of paired influent and effluent concentrations during individual storm events. As described above, influent concentrations for both biofiltration facilities will be derived from flow-weighted composite samples that are obtained during discrete storm events. Effluent concentrations will be derived from flow-weighted samples that are obtained from the outlet pipes of each biofiltration facility (i.e., 32OUT and TCOUT).

Treatment efficiency will also be assessed for the swales based on comparisons of the combined annual pollutant loads measured in influent, effluent, and bypassed water for each swale. The specific procedures used to calculate these pollutant load estimates are as follows:

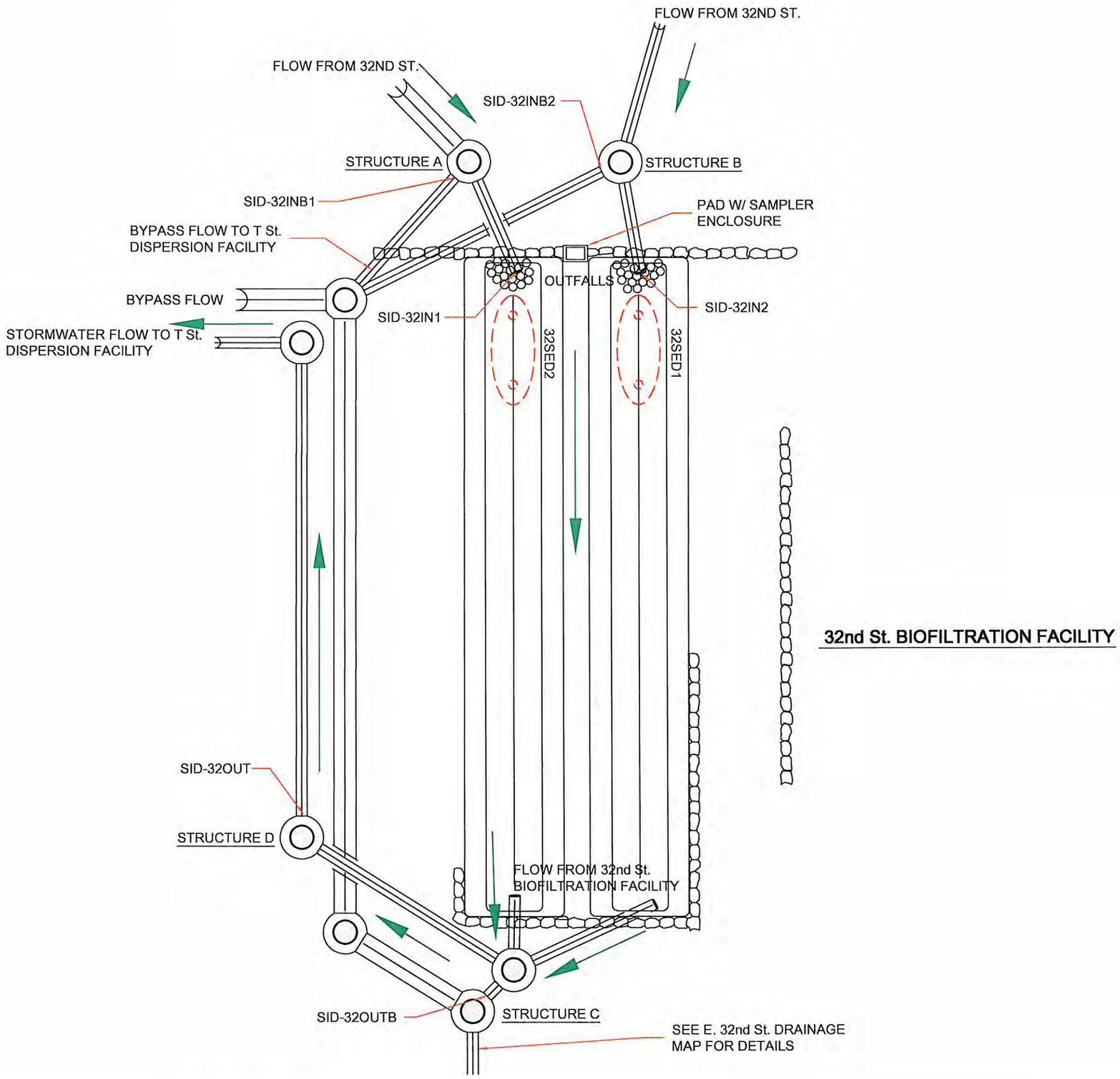
- **Influent Loads**: Annual influent flow volumes to the swales will be obtained from inlet stations 32IN1, 32IN2, and TCIN and rainfall data obtained from the respective stations (MST, CTP, RG-4 and Tacoma Landfill) for the year of interest. These volumes will then be multiplied by a flow-weighted average concentration derived from the influent water quality samples that were obtained from the 32IN1, 32IN2, and TCIN stations, respectively.
- **Effluent Loads**: Annual effluent flow volumes for the swales will be determined from data collected from monitoring stations 32OUT and TCOUT, respectively, in the outlets of each biofiltration facility. These volumes will then be multiplied by average effluent concentrations that were derived from flow-weighted samples collected in the outlet monitoring stations for each of the respective bioinfiltration facilities.
- **Bypass Loads**: Annual bypass flow volumes to the swales will be determined from data collected from monitoring stations 32INB1, 32INB2, and 32OUTB, respectively, in 32nd Street swale. These volumes will then be multiplied by a flow-weighted average concentration derived from the influent and water quality samples that were obtained from stations 32IN1, 32IN2 and 32OUT.

Additional details of treatment efficiency calculations are provided in Section 14.2.7.

The flow control performance of the swales will be assessed based on analysis of the timing and frequency bypass events to determine if the swale and pond are effective at treating storm events up to the 6-month, 24-hour design storm for the East 32nd St Swale and up to the WWHM2 water quality BMP design flowrate for Trolley Court Swale. Additional statistical analyses will also be performed to quantify the performance of each swale with regard to reducing runoff volumes, peak discharge rates, and flow durations.

In addition to stormwater quantity and quality monitoring, sediment sampling will be conducted in the swales on an annual basis. Figures 7-3a and 7-4a show the locations of sediment monitoring stations to be established in connection with the swales. A total of three monitoring stations (designated 32SED1, 32SED2 and TCSED in Figures 7-3a and 7-4a) will be established, one with each inlet to the biofiltration facility. Each station will consist of two sampling locations situated at the inlet pipe that allow stormwater to enter the facility and at the bottom of the swale mid channel near the inlet pipe. The two samples from each swale will be composited in the field resulting in one sample from each sediment monitoring station.

Finally, a detailed description of the vegetation cover in both swales will be completed including the species types growing in the swale bottom and side slopes, as well as an estimate of the percentage of the swale covered in vegetation.



General Notes

1. FOR STRUCTURES A & B DETAILS REFER TO FIGURE 7-Y.
2. FOR STUCTURES C & D DETAILS REFER TO FIGURE 7-Z.
3. FOR INLET SAMPLING AND METERING DETAILS REFER TO FIGURE 7-Y.
4. FOR OUTLET SAMPLING AND BYPASS METERING REFER TO FIGURE 7-Z.
5. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
6. SID-SAMPLE IDENTIFICATION NUMBER.

No.	Revision/Issue	Date

Firm Name and Address

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SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

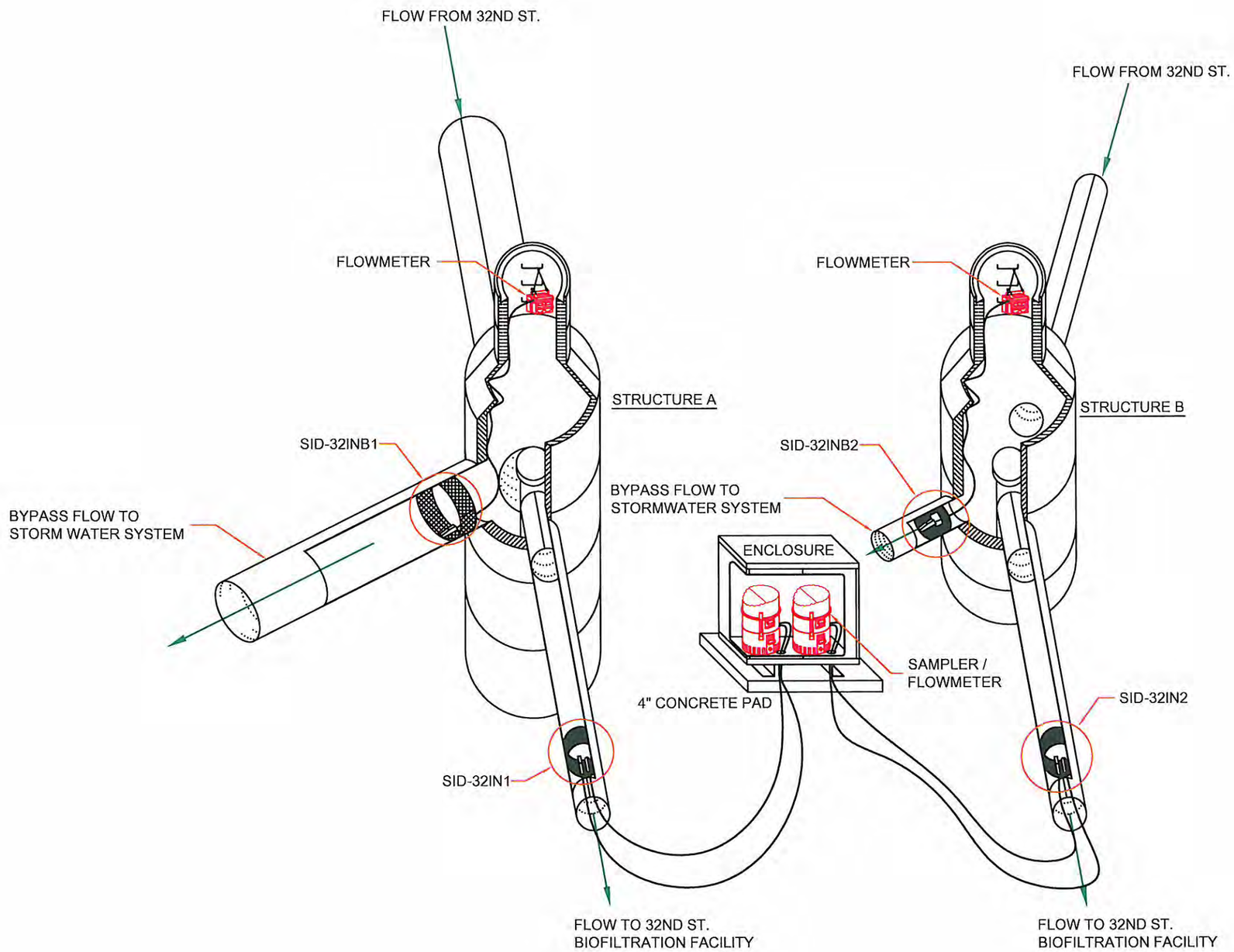
Tacoma

Project Name and Address

FIGURE 7-3A

32nd St. BIOFILTRATION FACILITY MONITORING LOCATIONS

Project N/A	Sheet 1 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURES A & B, ALL SAMPLE LOCATIONS & MONITORING LOCATIONS INCLUDING ENCLOSURE LOCATIONS REFER TO FIGURE 7-X.
2. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

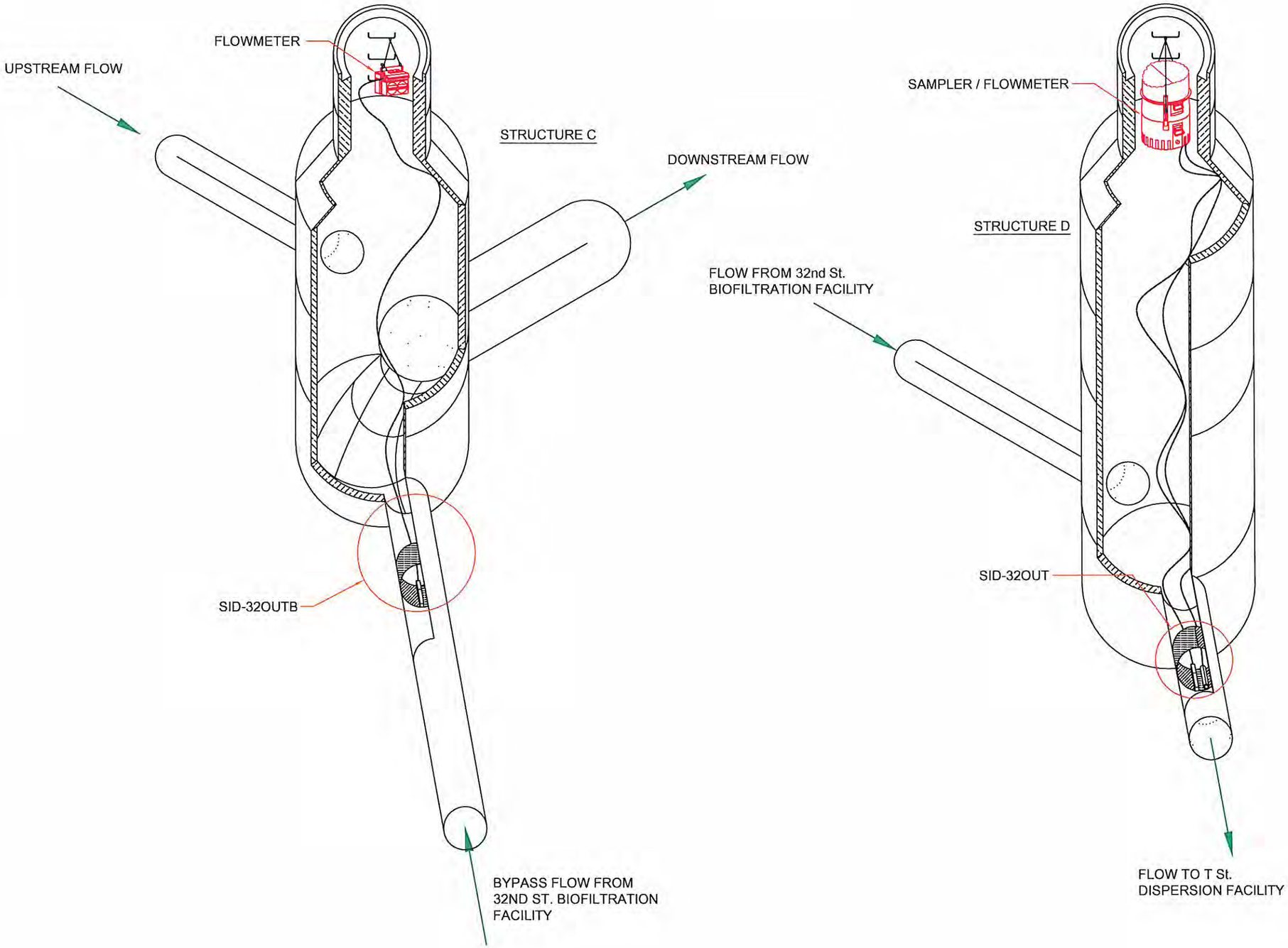
Tacoma

Project Name and Address

FIGURE 7-3B

INLET STATIONS FOR 32nd St. BIOFILTRATION FACILITY

Project N/A	Sheet 2 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURES C & D AND ALL SAMPLE AND METERING LOCATIONS REFER TO FIGURE 7-X.
2. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

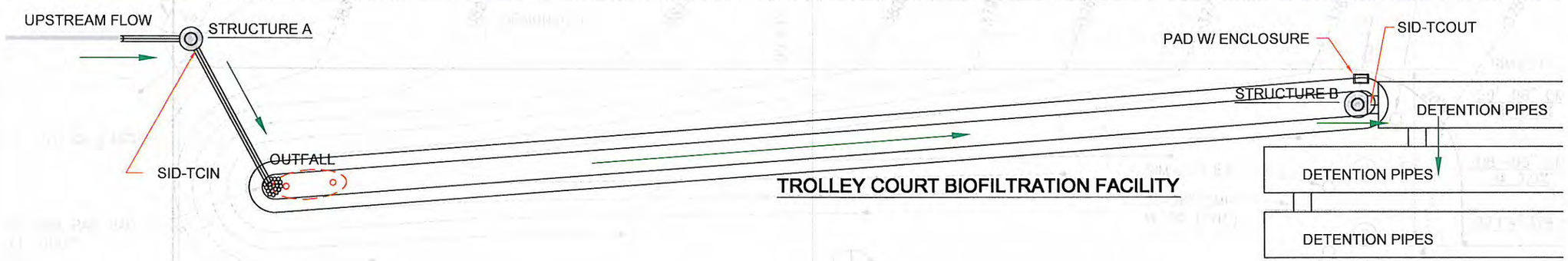
Tacoma

Project Name and Address

FIGURE 7-3C

OUTLET STATIONS FOR 32nd St. BIOFILTRATION FACILITY

Project N/A	Sheet 3 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURE A DETAIL REFER TO FIGURE 7-P.
2. FOR STRUCTURE B DETAIL REFER TO FIGURE 7-Q.
3. FOR INLET SAMPLING & MONITORING LOCATION DETAILS REFER TO FIGURE 7-P.
3. FOR OUTLET SAMPLING & MONITORING LOCATION DETAILS REFER TO FIGURE 7-P.
4. FOR PAD AND ENCLOSURE DETAILS REFER TO FIGURE 7-P.
5. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.
6. SID - SAMPLE IDENTIFICATION NUMBER.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

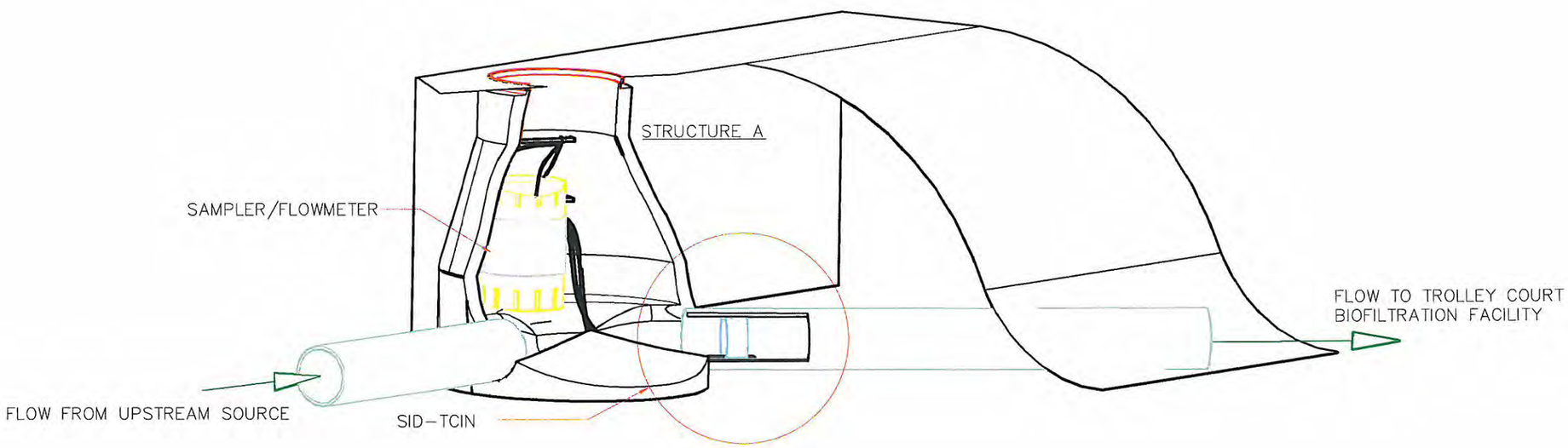
Tacoma

Project Name and Address

FIGURE 7-4A

TROLLEY COURT. BIOFILTRATION FACILITY MONITORING LOCATIONS

Project N/A	Sheet 1 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURE A LOCATION REFER TO FIGURE 7-O.
2. FOR INLET SAMPLING AND MONITORING LOCATION, REFER TO FIGURE 7-O.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

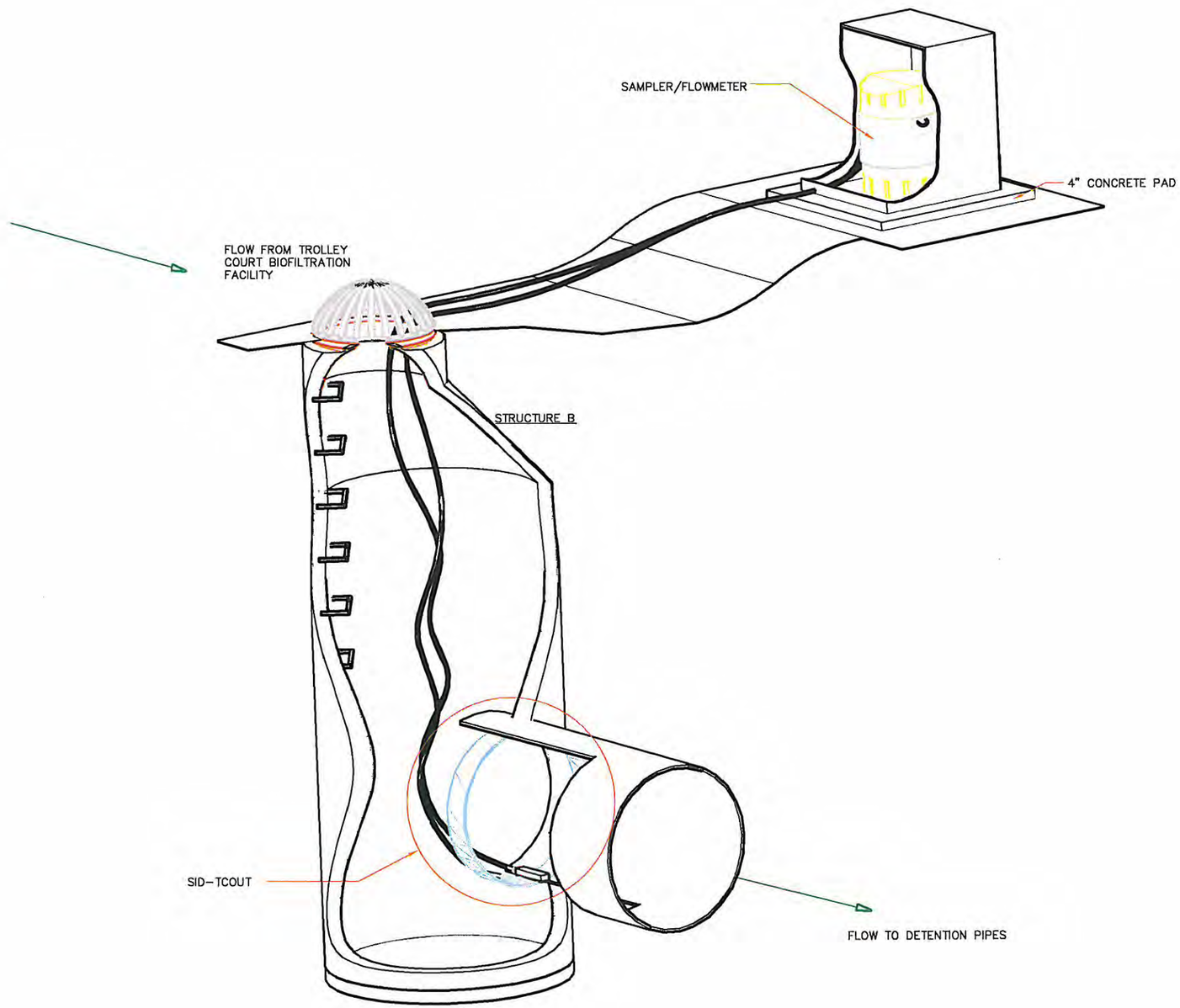
ENVIRONMENTAL COMPLIANCE

Project Name and Address

FIGURE 7-4B

INLET STATION FOR TROLLEY COURT BIOFILTRATION FACILITY

Project N/A	Sheet 2 OF 3
Date JAN 9, 2009	
Scale NTS	



General Notes

1. FOR STRUCTURE B, AND ENCLOSURE LOCATION REFER TO FIGURE 7-O.
2. FOR ALL OUTLET SAMPLING AND MONITORING LOCATIONS, REFER TO FIGURE 7-O.
3. GREEN ARROWS DESIGNATE UPSTREAM TO DOWNSTREAM DIRECTION OF FLOW.

No.	Revision/Issue	Date

Firm Name and Address

CITY OF TACOMA

SCIENCE AND ENGINEERING

ENVIRONMENTAL COMPLIANCE

Project Name and Address

FIGURE 7-4C

OUTLET STATION FOR TROLLEY COURT BIOFILTRATION FACILITY

Project N/A	Sheet 3 OF 3
Date JAN 9, 2009	
Scale NTS	

7.2.3 Pervious Pavements – Landfill

Completed in April 2006, the project was constructed in sections (9,028 SF each) with three sections of pervious pavement (pervious pavers, pervious concrete, and pervious asphalt) and one section of standard, impervious asphalt (see Figure 7-5a). Cross sections of the standard asphalt and pervious pavements used in this project are shown in Appendix B, Figure B-1.

Surface runoff with the standard asphalt section flows to the northwest corner of the site where it proceeds through a 4" surface drain and discharges to a 48" diameter catch basin. Flows from the catch basin proceed into the monitoring manhole and then to the primary stormwater system.

Water that infiltrates through the pervious pavement sections moves through the underlying gravel base and cover soil until it reaches the top HDPE liner. Water then travels along the HDPE liner west until it reaches a perforated pipe which collects these flows. The pipe discharges into the monitoring manhole immediately west of each of the sections (Figure 7-5a and b).

Subsurface flows are isolated from each other by a geosynthetic clay liner (GCL) placed between each pavement section and surrounding the perimeter of the site. The GCL was installed vertically (liner to pavement surface) and connected at the base to the HPDE liner with bentonite. See Appendix B, Figure B-2. for a detail of the GCL installation locations.

Surface runoff with the from the pervious pavement sections flows west until it reaches the west side of the section where it is conveyed in a concrete curb and gutter to a 24" diameter catch basin. Since the concrete curb and gutter is not pervious, it is covered with a metal plate to prevent rainfall from hitting the gutter and being conveyed to the catch basin without having the opportunity to infiltrate through the pervious pavement sections (see Figure 7-5b). The catch basin is equipped with a gate valve that allows water to be collected in the basin during a storm event and then manually discharged after the storm.

A total of two monitoring stations will be established in connection with each pervious pavement section to measure the quantity of infiltrated stormwater flow and surface water runoff. In addition, one monitoring station will be established in connection with the standard asphalt (impervious) section to measure the quantity of surface water runoff. Figure 7-5a shows infiltrated stormwater flow and surface water runoff sampling locations. A picture of the flow monitoring manholes are shown in Figure 7-5b. The equipment is secured and housed in an enclosure located immediately west of each section.

The flow reduction performance of each pervious pavement area will be evaluated based on comparisons of flows measured at the infiltrated stormwater flow and surface water runoff stations, for each pervious pavement area to the impervious area flow. To facilitate interpretation of trends in the data from each of these stations, a rain gauge will continuously monitor precipitation at the study site.

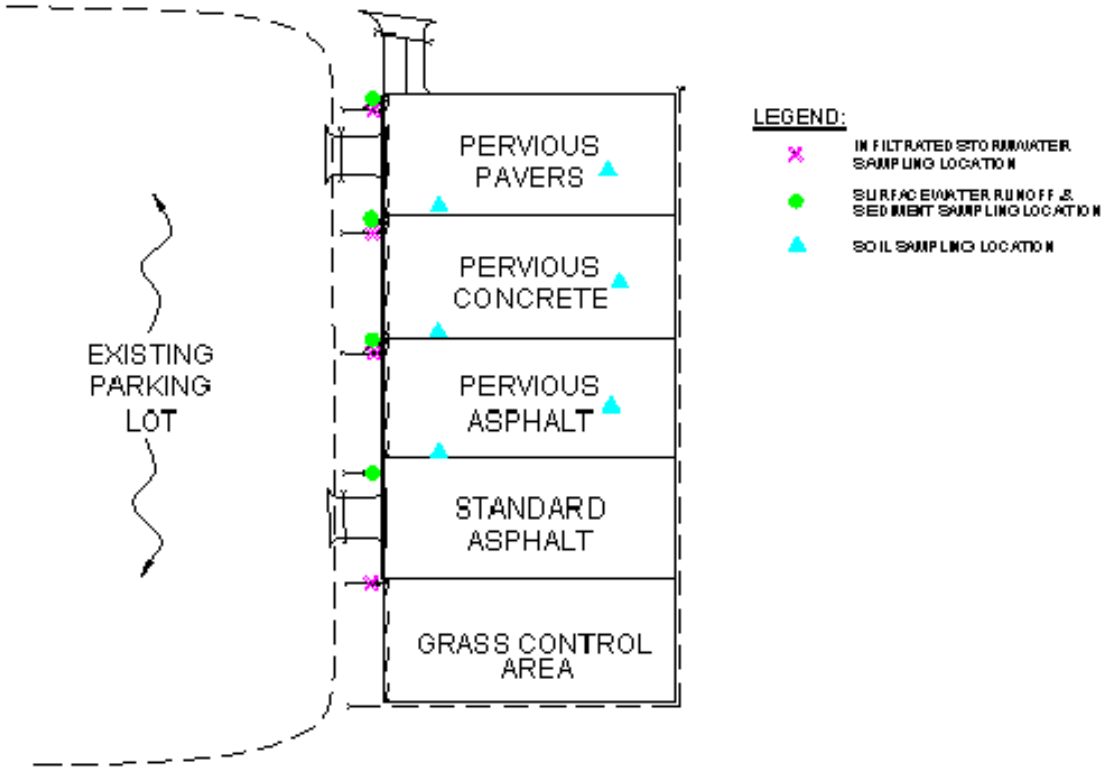


Figure 7-5a Sampling Locations for Each Pavement Section – Tacoma Landfill

Figure 7-5b –Sampling Manholes and Curbing

The specific monitoring stations established in association with each pervious/impervious pavement section will be use to measure:

- Infiltrated stormwater flow as measured at the point of discharge from each pervious pavement section
- Surface water runoff flow as measured at the point of discharge from each pervious/impervious section

The infiltrated stormwater flows will be continuously monitored at the pervious and impervious pavement stations (monitoring manholes). These stations are designated Perv. Pavers, Perv. Concrete, Perv. Asphalt (see Figure 7-5a). The surface water flows will be continuously monitored at the impervious pavement station (monitoring manholes). This station is designated Std. Asphalt. Asphalt (see Figure 7-5a). The surface water flows will be continuously monitored as a depth of water collected in small sumps for each of the pervious pavement stations. Once measured the sumps is emptied by opening a shear gate. Once emptied the shear gate is closed to continue to collect water from the surface water runoff. These stations are designated Perv. Pavers CB, Perv. Concrete CB, Perv. Asphalt CB (see Figure 7-5a). As described above, all stormwater is then discharged into a nearby storm drain. An existing rain gauge (designated Landfill) will be used to continuously monitor precipitation for the project site.

The flow control performance of the pervious sections will be assessed based on statistical analyses performed to quantify the performance of each section with regard to reducing runoff volumes, peak discharge rates, and flow durations in comparison with the standard asphalt section.

7.3 Flow Monitoring Equipment Strategy

The equipment configurations for any particular station will depend on site-specific hydraulic and access considerations. The following subsections provide a more detailed summary of the equipment that will be used in association with each of the facilities (bioinfiltration, biofiltration and pervious pavements) that will be monitored through this study.

7.3.1 Salishan Bioinfiltration Facilities

Continuous flow monitoring will be performed at the following seven stations associated with the bioinfiltration facilities, East 46th & R Street Swale and East 44th Street Pond: RSTIN, RSTOUT, RSTOUTB, 44IN, 44INB, 44OUT and 44OUTB. Finally, continuous precipitation monitoring will occur at stations CTP and MTS. The specific monitoring equipment that will be used in connection with these stations is described in the following subsections.

RSTIN, RSTOUT, 44IN and 44OUT Stations. Automated monitoring equipment will be installed to facilitate the continuous monitoring of discharge. More specifically, an ISCO 6712 Full-size Portable Sampler with an attached ISCO 750 Area/Velocity Flow Module (see detailed description in Appendix D) will be installed. The area/velocity probe will be fitted to the bottom of the concrete pipe to measure the depth of water and velocity in the pipe. The portable sampler will be programmed to record water level/velocity measurements from the flow module at 5-minute intervals.

Data will be downloaded and processed using ISCO supported software. Flows will be estimated using standard hydraulic equations for circular concrete pipe based on the water level and velocity measurements. All the equipment described above will be powered with an ISCO rechargeable battery that is fully charged prior to each sampling event.

For Stations RSTIN, RSTOUTand 44OUT, the portable sampler will be housed in an enclosure. The area/velocity probe cable from the flow module will be discretely routed out of the enclosure and to the concrete pipe so as to avoid incidents of tampering or vandalism (such as above ground or buried PVC conduit). For Station 44IN, the portable sampler will be housed in a manhole structure. The area/velocity probe cable from the flow module will be routed within the manhole and along the pipe to monitoring location.

RSTINB, RSTOUTB and 44OUTB Stations. Automated monitoring equipment will be installed to facilitate the continuous monitoring of discharge. More specifically, an ISCO 2150 750 Area/Velocity Flow Module (see detailed description in Appendix D) will be installed. If the flow conditions are too shallow for the ISCO probe, a Renaissance Instruments Data Gator (pressure transducer) or American Sigma 920 Area/Velocity flow meter will be used. The flow meter probe will be fitted to the bottom of the concrete pipe to measure the depth of water and velocity (or depth of water only) in the pipe. The portable flow module will be programmed to record water level/velocity measurements from the flow module at 5-minute intervals.

Data will be downloaded and processed using manufacturer's supported software. Flows will be estimated using standard hydraulic equations for circular concrete pipe based on the either water level and velocity measurements or water level only. All the equipment described above will be powered with the manufacturer's rechargeable batteries that are fully charged prior to each sampling event.

For Station 44INB, the portable flowmeter will be housed in a manhole structure. The cable from the flow module will be routed within the manhole and along the pipe to monitoring location. For Stations RSTOUTB and 44OUTB, the portable flowmeter will be housed in an enclosure. The cable from the flow module will be discretely routed out of the enclosure and to the concrete pipe so as to avoid incidents of tampering or vandalism (such as above ground or buried PVC conduit).

MTS and CTP Stations. The MTS station will be an ISCO 676 logging system with a tipping bucket rain gauge placed in a secured area owned by Tacoma Water. It will be installed in accordance with the manufacture's specifications. The MTS rain gauge will interface with ISCO's FloLink software . It will be programmed to record the precipitation depth measurements at 5-minute intervals.

The CTP station currently consists of an ISCO 675 tipping bucket rain gauge that is affixed to the roof of the STP Digester at Tacoma's Central Treatment Plant (Figure 3-1) in accordance with the manufacture's specifications. This rain gauge has an AC power source. The CTP rain gauge is interfaced with ISCO's FloLink software . It is programmed to record the precipitation depth measurements at 5-minute intervals.

7.3.2 Biofiltration Facilities

Continuous flow monitoring will be performed at the following eight stations associated with the biofiltration facilities, East 32nd Street Swale and Trolley Court Swale: 32IN1, 32IN2, 32IN1B, 32IN2B, 32OUT, 32OUTB, TCIN and TCOUT. Finally, continuous precipitation monitoring will occur at stations CTP, RG-4 and MTS. The specific monitoring equipment that will be used in connection with these stations is described in the following subsections.

32IN1, 32IN2, 32OUT, TCIN and TCOUT Stations. Automated monitoring equipment will be installed to facilitate the continuous monitoring of discharge. More specifically, an ISCO 6712 Full-size Portable Sampler with an attached ISCO 750 Area/Velocity Flow Module (see detailed description in Appendix D) will be installed. The area/velocity probe will be fitted to the bottom of the concrete pipe to measure the depth of water and velocity in the pipe. The portable sampler will be programmed to record water level/velocity measurements from the flow module at 5-minute intervals.

Data will be downloaded and processed using ISCO supported software. Flows will be estimated using standard hydraulic equations for circular concrete pipe based on the water level and velocity measurements. All the equipment described above will be powered with an ISCO rechargeable battery that is fully charged prior to each sampling event.

For Stations 32IN1, 32IN2, and TCOUT, the portable sampler will be housed in an enclosure. The area/velocity probe cable from the flow module will be discretely routed out of the enclosure and to the concrete pipe so as to avoid incidents of tampering or vandalism (such as above ground or buried PVC conduit). For Stations 32OUT and TCIN, the portable sampler will be housed in a manhole structure. The area/velocity probe cable from the flow module will be routed within the manhole and along the pipe to monitoring location.

32INB1, 32INB2, and 32OUTB Stations. Automated monitoring equipment will be installed to facilitate the continuous monitoring of discharge. More specifically, an ISCO 2150 750 Area/Velocity Flow Module (see detailed description in Appendix D) will be installed. If the flow conditions are too shallow for the ISCO probe, a Renaissance Instruments Data Gator (pressure transducer) or American Sigma 920 Area/Velocity flow meter will be used. The flow meter probe will be fitted to the bottom of the concrete pipe to measure the depth of water and velocity (or depth of water only) in the pipe. The portable flow module will be programmed to record water level/velocity measurements from the flow module at 5-minute intervals.

Data will be downloaded and processed using manufacturer's supported software. Flows will be estimated using standard hydraulic equations for circular concrete pipe based on the either water level and velocity measurements or water level only. All the equipment described above will be powered with the manufacturer's rechargeable batteries that are fully charged prior to each sampling event.

For Stations 32INB1, 32INB2, and 32OUTB, the portable flowmeter will be housed in a manhole structure. The cable from the flow module will be routed within the manhole and along the pipe to monitoring location.

MTS, CTP and RG-4 Stations. For the East 32nd Street Swale, the MTS station will be an ISCO 676 logging system with a tipping bucket rain gauge placed in a secured area owned by Tacoma Water. It will be installed in accordance with the manufacture's specifications. The MTS rain gauge will interfaced with ISCO's FloLink software. It will be programmed to record the precipitation depth measurements at 5-minute intervals.

For the East 32nd Street Swale, the CTP station currently consists of an ISCO 675 tipping bucket rain gauge that is affixed to the roof of the STP Digester at Tacoma's Central Treatment Plant (Figure 3-1) in accordance with the manufacture's specifications. This rain gauge has an AC power source. The CTP rain gauge is interfaced with ISCO's FloLink software. It is programmed to record the precipitation depth measurements at 5-minute intervals.

For the Trolley Court Swale, the RG-4 station currently consists of an ISCO 676 tipping bucket rain gauge and logging system that is affixed to the roof of the Allenmore Hospital (Figure 3-1) in accordance with the manufacture's specifications. The Landfill station, is located at Tacoma's Landfill and is a SCADA system logger, ST-AB8203. Both of these rain gauges have an AC power source and are programmed to record the precipitation depth measurements at 5-minute intervals. The RG-4 rain gauge will be interfaced with ISCO's FloLink software

7.3.3 Pervious Pavements – Landfill

Continuous flow monitoring will be performed at the following seven stations associated with the Landfill project: Perv. Pavers, Perv. Concrete, Perv. Asphalt, Std. Asphalt, Perv. Pavers CB, Perv. Concrete CB, and Perv. Asphalt CB. Continuous precipitation monitoring may also be performed in association with these stations.

Water levels from both the pervious pavement sections (infiltrated flows designated as Perv. Pavers, Perv. Concrete, and Perv. Asphalt) and standard asphalt (surface runoff designated as Std. Asphalt) are measured using a portable ISCO 730 bubbler flow module (see Figure 7-5c). The bubbler flow module measures water depth and this data is converted to flow using Manning's equation (see Figure 7-5c).

Surface runoff from the pervious pavement sections is collected in catch basins associated with each pervious pavement section (designated as Perv. Pavers CB, Perv. Concrete CB, and Perv. Asphalt CB). Volume measurements are taken by field staff after the storm event. After the measurement is taken, water is released from the catch basin and then collected during the next storm event (see Figure 7-5d).

An ISCO 674 rain gauge, which measures rainfall in 0.01 inch increments, is located at the project site. The rain gauge is connected to an ISCO flowmeter, which is responsible for logging the rain data.

The ISCO flow meters and rain gauges are programmed to record at 5 minute intervals. Data will be downloaded and processed using ISCO supported software. All the equipment described above will be powered with ISCO rechargeable batteries.

Figure 7-5c Flow Monitoring setup for Pervious Pavement and Standard Asphalt Sites

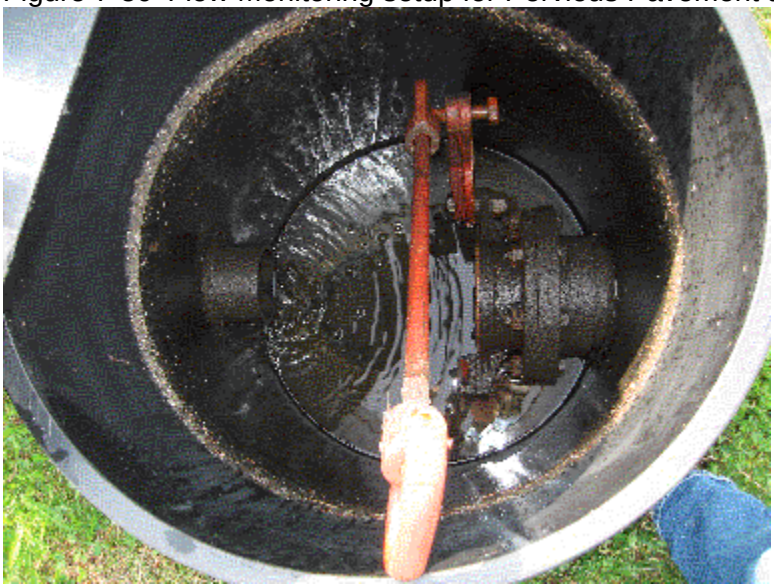


Figure 7-5d Flow Monitoring setup for Surface Water Runoff from Pervious Pavement Sites

7.4 Water Quality Equipment Monitoring Strategy

The configuration of water quality sampling equipment at any particular station will depend on site-specific considerations. The following subsections provide a more detailed summary of the water quality sampling equipment that will be used in association with each of the bioinfiltration and biofiltration facilities that will be monitored through this study.

7.4.1 Salishan Bioinfiltration Facilities - Stations RSTIN, RSTOUT, 44IN and 44OUT

As described above in Section 7.3.1.1, Stations RSTIN, RSTOUTand 44OUT, will be equipped with an ISCO 6712 Full-size Portable Sampler with an attached ISCO 750 Area/Velocity Flow Module (see detailed description in Appendix D) to facilitate flow monitoring at the stations. The same equipment will also be used to facilitate the collection of flow-weighted composite

samples. The intake strainer for the portable sampler will be positioned on the bottom of the concrete pipe to intercept water in the pipe.

For Stations RSTIN, RSTOUTand 44OUT, the portable sampler will be housed in an enclosure. The suction line from the portable sampler will be discretely routed out of the enclosure and to the concrete pipe so as to avoid incidents of tampering or vandalism (such as above ground or buried PVC conduit) (see Section 7.3.1.1). For Station 44IN, the portable sampler will be housed in a manhole structure. The suction line from the portable sampler will be routed within the manhole and along the pipe to monitoring location. The suction line from the portable sampler will also be installed with a continuous slope so that all the water will drain out of the line between successive samples to prevent cross contamination.

7.4.2 Biofiltration Facilities - Stations 32IN1, 32IN2, 32OUT, TCIN and TCOUT

As described above in Section 7.3.1.1, Stations 32IN1, 32IN2, 32OUT, TCIN and TCOUT, will be equipped with an ISCO 6712 Full-size Portable Sampler with an attached ISCO 750 Area/Velocity Flow Module (see detailed description in Appendix D) to facilitate flow monitoring at the stations. The same equipment will also be used to facilitate the collection of flow-weighted composite samples. The intake strainer for the portable sampler will be positioned on the bottom of the concrete pipe to intercept water in the pipe.

For Stations 32IN1, 32IN2, and TCOUT, the portable sampler will be housed in an enclosure. The suction line from the portable sampler will be discretely routed out of the enclosure and to the concrete pipe so as to avoid incidents of tampering or vandalism (such as above ground or buried PVC conduit) (see Section 7.3.1.1). For Stations 32OUT and TCIN, the portable sampler will be housed in a manhole structure. The suction line from the portable sampler will be routed within the manhole and along the pipe to monitoring location. The suction line from the portable sampler will also be installed with a continuous slope so that all the water will drain out of the line between successive samples to prevent cross contamination.

8 SAMPLING PROCEDURES

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. Please refer to S8 Program QAPP, Section 8 Sampling (Field) Procedures for general information related to stormwater sampling which also includes decontamination procedures (S8 Program QAPP, Section 8.1.1). Specific details will be provided in the SOPs. The SOPs will include requirements for training and documentation of activities, collection of field quality control samples, and description of "Clean Handling Techniques" where appropriate.

General procedures for the following activities are described below:

- Flow monitoring,
- Water quality sampling,
- Sediment sampling,
- Soil characterization; and
- Controlled infiltration tests

Specific details of equipment selection and installation are described above in Section 7.

8.1 Sample Identification

All samples will be clearly labeled in the field with indelible ink. Each sample will be uniquely identified by its sample location identifier combined with the sample method (type and technique, i.e. manual grab, automatic flow-weighted composite), the event date and time stamp, and the sample matrix. For composite samples, the date and time stamp will reflect the last aliquot collected.

8.2 Flow Monitoring

As described above in Section 7, continuous monitoring of flows will be performed at influent and effluent monitoring stations associated with bioinfiltration and biofiltration facilities over the 2 year duration of this study (August 2009 – August 2011). In addition, precipitation depths will also be monitored continuously, either using rain gauges at Tacoma's CTP, or at stations established in conjunction with the site. This section begins with a general overview of the sampling procedures that will be used for hydrologic monitoring related to this study. Specific details regarding the monitoring equipment that will be installed in connection with each BMP are presented in Sections 7.3 and 7.4.

To facilitate flow monitoring, sensors for measuring water depth only or water velocity and depth (i.e., ISCO bubbler line or area/velocity probe, respectively) will be installed in stormwater conveyance pipes associated with the monitoring stations. In all cases, the sensors will be installed in accordance with manufacture's specifications and SOPs. To facilitate precipitation monitoring, a rain gauge (ISCO tipping bucket rain gauge) is installed according to manufacturer's specifications in a location where buildings and/or trees in the vicinity will not interfere with its operation.

The sensors for flow and precipitation monitoring will be interfaced with the ISCO or other data loggers capabilities that are programmed to record sensor readings with a 5-minute logging interval. Each data logger will be downloaded manually. A few of the rain gauges are downloaded via Tacoma's SCADA system. Power to most of the data loggers and sensors will be provided by an ISCO rechargeable battery. Some of the rain gauges have AC power. The equipment may be

housed in manhole or locking, vandal resistant enclosures that are hidden from public view to the extent possible.

One week after the equipment is installed at a particular station, field personnel will visit the station to confirm that the equipment was installed correctly and is functioning as designed. After this initial check, field personnel will perform biweekly to monthly site visits to upload data, check and replace batteries as necessary, visually inspect all system components, and perform calibration checks as necessary. Any operational problems that are identified during these site visits will be addressed immediately. Field personnel will document maintenance, calibration, and troubleshooting activities in the field notebook.

Data from each station will be uploaded on a biweekly basis and after major storm events manually. The data will then be exported to ISCO Flolink database for all subsequent data management tasks (see Section 11 of the S8 Program QAPP). At this time, the data will also undergo a quality assurance audit (see Section 12 of the S8 Program QAPP). Any operational problems that are identified through this audit will be addressed immediately.

8.3 Water Quality Sampling

As described above in Section 7, water quality sampling will be performed at influent and effluent monitoring stations associated with bioinfiltration and biofiltration facilities over the 2 year duration of this study (November 2009 – November 2011). The goal of this sampling is to collect flow-weighted composite samples during 8 to12 storm events in each year to obtain up to 35 influent and effluent samples at each BMP by the end of this period. This section describes in detail the sampling procedures that will be used to meet this goal.

To facilitate water quality sampling associated with this study, ISCO 6712 full size automated samplers will be installed in association with the influent and effluent monitoring stations for each BMP. Teflon sampler suction tubing will be routed from each automated sampler to the point of sample collection. The suction tubing will be installed with a continuous positive slope from the point of sample collection to the pump head of the associated automated sampler. This will ensure proper draining of the suction tube during automated sampler purging cycles. A strainer will be installed at the terminus of the sampler suction tubing at the point of sample collection to prevent debris from clogging the tubing. The sampler intakes will be carefully positioned to ensure the homogeneity and representativeness of the samples. Specifically, sampler intakes will be installed to ensure that an adequate depth will be available for sampling and to avoid the capture of litter, debris, bed load, and other gross solids that may be present. The automated samplers will be programmed to perform one rinse cycle prior to actual sample collection in order to reduce the likelihood of cross contamination between successive aliquots.

Antecedent conditions and storm predictions will be monitored via the Internet and review of rain gauge data, and a determination will be made as to whether to target an approaching storm for sampling. The volume used to pace the automated samplers will be determined in advance of the storm event based on rainfall versus runoff relationships that are developed using precipitation and runoff volume data that were collected during previous storm events. Using these relationships, runoff volume for each station will be estimated based on the forecasted rainfall total for the targeted storm event. The estimated runoff volume (cubic feet) will then be divided by the desired number of aliquots (i.e., 100-250 ml aliquots) to estimate the sample pacing (cubic feet) volume necessary to collect the required composite sample volume. The rainfall versus runoff relationships will be continually updated throughout the duration of the study to reflect changing hydrologic conditions.

Once a decision has been made to target a storm event for sampling, field personnel will conduct site visits to deploy clean sample bottles in the automated samplers at each monitoring station, calibrate equipment as necessary, clear any obstructions from the sampler intakes, inspect the rain gauges for blockages, and check the operational status of the flow monitoring equipment. Field personnel will then fill the automatic samplers with ice and initiate the sampler program. Ice is estimated to keep the interior of the samplers cool for 48 hours; consequently, ice will not be added to the samplers more than 24 hours before a targeted storm event. The speed and intensity of incoming storm events will then be tracked using Internet-accessible images from publicly available Doppler radar. Actual rainfall totals during sampled storm events will be monitored from the CTP and City's SCADA rain gauges.

After the storm event, storm event criteria identified in Section 7.1.3 for storm event (Table 7-1) and sample representativeness (Table 7-2) will be assessed prior to sample retrieval by analyzing hydrologic and sampling recorded for each station. If the storm event criteria have not been met, the samples will be discarded and the associated bottles sent to the laboratory for cleaning in preparation for the next storm event. If the criteria have been met, field personnel will remove the chilled sample bottles and place them in coolers. Ice will then be added to the coolers to keep the sample temperatures within the sample bottles below 6 degrees Celsius. The sample bottles will then be transported to the laboratory within the allowable limits for sample holding times (see S8 Program QAPP Table 8-1).

In general, the laboratory will be notified at the onset of each sampling event to ensure that adequate laboratory staff will be available to process the incoming samples. Once in the laboratory, water from the containers will be used to fill pre-cleaned, preserved (where appropriate) sample bottles for the required analyses. All samples will be analyzed for the following parameters:

- Total suspended solids,
- Particle size distribution,
- pH,
- Total phosphorus,
- Ortho-phosphate,
- Hardness,
- Cadmium, total and dissolved
- Copper, total and dissolved
- Lead, total and dissolved,
- Zinc, total and dissolved,
- Mercury, total and dissolved[2],
- Orthophosphate
- Total phosphorus, and
- PAHs and phthalates[2].

[2] These parameters are included as chemicals of concern for Thea Foss Waterway Recontamination Evaluation and are not a required parameter under S8F.

Sample bottles used for water quality sampling will be cleaned by laboratory personnel prior to each sampling event using EPA QA/QC specifications Glassware Cleaning Following EPA Protocols (EPA 1990) (see S8 Program QAPP, Section 8.1.1).

8.4 Sediment Sampling

As described above in Section 7, sediment sampling will be performed at monitoring stations associated with the bioinfiltration and biofiltration facilities annually over the 2 year duration of this study (November 2009 – November 2011). Sample locations will be selected close to the inlet(s) where sedimentation is obvious. The first sample will be collected near the inlet and the second sample will be collected mid-channel in close proximity to the inlet. Both of the samples will be composited into a single sediment sample for the BMP site.

Sediment sampling procedures will generally follow Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (PSEP 1997). In general, the following procedures will be used to sample sediment at any given station.
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1. Any standing water present at the station will be removed using a bucket or pump. Care will be taken during this process to avoid disturbing the sediments in the area to be sampled.

2. The sediment sample will be obtained from the station using a stainless steel trowel or scoop on a pole and emptied into separate, large stainless steel bowl. Nitrile gloves will be worn at all times while collecting the sample. Field observations (including oil sheens and potential contributing activities) and sample characteristics (odor, amount and type of particles being removed, size description, color, etc.) will also be recorded during sample collection.

3. The contents in the bowl will then be homogenized with a stainless steel spoon. Freestanding liquid will be decanted from the bowl prior to homogenization.

4. Any particles greater than approximately 2 centimeter (cm) in size will be removed from the sample, placed in a separate container, and weighed to determine the proportion this material represents relative to the smaller sediment that remains in the bowl. Leaves will not be removed from the samples.

5. A pint jar will then be filled with the homogenized material from the bowl, labeled, placed on ice, and transported to the laboratory within the allowable limits for sample holding times (see S8 Program QAPP Table 8-1).

Once in the laboratory, the sediment samples will be analyzed for the following parameters:

- Grain size,
- Percent total solids,
- Total volatile solids,
- Total organic carbon [2],
- Total phosphorus,
- Total recoverable metals (cadmium, copper, mercury[2] , lead, and zinc),
- Total petroleum hydrocarbons (diesel fraction and oil fraction),
- PAHs and phthalates [2]; and
- PCBs [2].

[2] These parameters are included as chemicals of concern for Thea Foss Waterway Recontamination Evaluation and are not a required parameter under S8F.

All sediment sampling equipment, including the stainless steel trowels, scoops, buckets, and bowls, will be cleaned and decontaminated prior to each sampling event. Sample bottles used for water quality sampling will be cleaned by laboratory personnel prior to each sampling event using EPA QA/QC specifications Glassware Cleaning Following EPA Protocols (EPA 1990) (see S8 Program QAPP, Section 8.1.1).

8.4.1 Sediment Accumulation Monitoring

As described in Section 7, sediment accumulation rates are to be assessed at strategically located stations associated with the bioinfiltration and biofiltration facilities annually over the 2 year duration of this study (November 2009 – November 2011). Sediment accumulation rates will be measured at the sediment monitoring stations established in connection with the rain gardens. At each of these stations, field personnel will survey the cross sectional profile of the swale using a leveling instrument and surveyors rod. These measurements will be summarized graphically for use in quantifying sediment accumulation rates over time.

8.5 Soil Characterization

In the two bio-infiltration facilities, specifications called for installation of gravelly sand and compost. According to the construction manager, verification tests were performed to confirm the import material met the specifications. However, there are no documents that verify this was completed.

To verify the soil mixture in the Salishan swale and pond, three samples from each facility along the length of the facility (i.e., at upgradient, middle, and downgradient locations) will be collected and analyzed. Each sample will be vertically averaged over the depth of the infiltration layer (approximately three feet). The samples will be analyzed for:

- Grain size (including analysis of fines by hydrometer or pipette)
- Total organic carbon
- Cation exchange capacity

In addition, the depth of the infiltration layer will be measured at each sample location by digging or augering a test hole to the gravel underdrain layer. Sampling will be completed in the summer of 2010 when sampling activities won't disrupt stormwater sampling. A technical memo will be prepared summarizing the field methods, observations, and analytical results.

8.6 Controlled Infiltration Tests

8.6.1 Full-Scale Field Testing at East 46th and R Street Bioinfiltration Swale

1. Water from a nearby fire hydrant will be discharged to the stormwater inlet immediately upstream of the swale using a fire hose. A rotameter will be attached to the hose to measure the discharge rate from the hydrant.

2. The discharge rate from the hose will be varied to maintain a water depth of approximately 1.0 feet in the swale. Every 15 to 30 minutes, the discharge rate of water entering the swale and the water depth in the swale will be manually recorded. Optionally, a pressure transducer and data logger will installed and programmed to automatically and continuously record water depths during the test with a 1-minute logging interval.

3. After the discharge rate required for maintaining the target water depth (1.0 feet) in the swale stabilizes and remains constant for 60 minutes, water flow to the swale will be turned off. The time required for water remaining in the swale to infiltrate the soil will then be measured until there is no longer any standing water.

4. The infiltration rate for each swale is then computed using the following formula:

   $IR = \Delta L / \Delta T$

   Where: IR = Infiltration rate (inches/hour)
   ΔL = Change in water depth (in inches) from the time when water inputs are turned off to the time when no standing water is present
   ΔT = Change in time (in hours) from the time when water inputs are turned off to the time when no standing water is present.

5. If the full-scale field test cannot be performed at the East R Street facility due to unanticipated field constraints or logistical problems, the measurements will be performed using infiltrometers, as described in the next section.

8.6.2 Infiltrometer Measurements at East 44th Street Bioinfiltration Pond

1. Three sites within the pond will be selected to set up the double-ring infiltrometers. The sites will be systematically located along the flow path to provide representative coverage of the upper, middle, and lower third of the pond.

2. Vegetation will be cleared in approximately 10 foot by 10 foot area with a lawn mower or weed-whacker to prepare a clear working area. Care will be taken not compact the soil where the double-ring infiltrometers will be placed.

3. The inner ring will be placed with the cutting edge facing down on the ground. Small obstacles such as stones or twigs will be removed. Using a block of wood to spread the load, the infiltration ring will be hammered about 2 inches vertically into the soil. Care will be taken to minimize disturbance of the soil beneath the infiltrometers.

4. The outer ring will be placed around the inner ring and installed as described above for the inner ring.

5. The outer ring will be filled with water, then the inner ring, to a depth of approximately 4 inches. The water levels within the infiltration rings will be kept as low as possible to encourage only vertical infiltration (i.e., to minimize mounding and lateral loss). The rings will not be allowed to go dry.

6. Water from a nearby fire hydrant will be transferred to a tote tank located on the pond access road. Water will be transferred to a set of Mariotte tubes (constant head device) at each infiltrometer with a garden hose or bucket. Flow rate will be controlled by a valve or by adjusting the head, depending on the infiltration rate.

7. After the discharge rate required for maintaining the target water depth (4.0 inches) in the rings stabilizes and remains constant for 60 minutes, water flow will be turned off. The time required for water remaining in each inner ring to infiltrate the soil will then be measured until there is no longer any standing water.

8. The infiltration rate for each infiltrometer set will then computed using the following formula:

   $IR = \Delta L / \Delta T$

   Where: IR = Infiltration rate (inches/hour)

   ΔL = Change in water depth (in inches) from the time when water inputs are turned off to the time when no standing water is present

   ΔT = Change in time (in hours) from the time when water inputs are turned off to the time when no standing water is present.

9 MEASUREMENT PROCEDURES

Please refer to S8 Program QAPP, Section 9 Measurement Procedures for Water and Sediment Quality Analysis.

10 QUALITY CONTROL

Please refer to S8 Program QAPP, Section 10 Measurement Procedures.

11 DATA MANAGEMENT PROCEDURES

Please refer to S8 Program QAPP, Section 11 Data Management & Documentation Procedures.

12 AUDITS AND REPORTS

Please refer to S8 Program QAPP, Section 12 Audits and Reports.

13 DATA VERIFICATION AND VALIDATION

Please refer to S8 Program QAPP, Section 13 Data Verification and Validation.

14 DATA QUALITY (USABILITY) ASSESSMENT

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.

Please refer to S8 Program QAPP, Section 14 Data Quality (Usability) Assessment.

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 numbers of valid field and laboratory measurements 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 influent 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.

- **Statistical Power**. The statistical variability of the monitoring data (specifically, the coefficient of variation) will be evaluated using the statistical power table (Table 6-1) 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, the following summary statistics will be calculated for influent and effluent stormwater data sets:

- 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 (50th percentile)
- 10th and 90th percentile concentrations

Summary statistics will be calculated for each monitoring year and for the combined two-year (or longer) duration of the monitoring program.

The following rainfall parameters will be tabulated for each sampled storm event:

- Rain depth (inches)
- Peak storm intensity (inches/hour)
- Antecedent dry period (hours)

The following hydrologic parameters will be tabulated for each influent and effluent events:

- Average flow (cfs)
- Peak flow (cfs)
- Total discharge volume (acre-feet)

14.2.2 Treatment Efficiency Calculations

Treatment efficiency calculations are dependent on the hydraulic residence time of the BMP, as described below.

Biofiltration BMPs. The biofiltration BMPs are short-term facilities with hydraulic residence times on the order of 10 to 20 minutes. Treatment efficiency calculations will therefore be performed in accordance with Appendix A of Ecology's TAPE guidance, and primary emphasis will be placed on event mean comparisons. The following performance metrics will be calculated for each biofiltration site:

- Individual storm reduction in pollutant concentration
- Individual storm reduction in pollutant loading
- Average annual reduction in pollutant concentration
- Average annual reduction in pollutant loading

Bioinfiltration BMPs. Bioinfiltration BMPs are intermediate-term facilities with estimated lag times of 4 to 7 hours between influent and effluent peaks, based on subsurface infiltration rates and travel times. For smaller storms (i.e., less than about 0.5 inches), it is expected that the water exiting the BMPs will be residual pore water generated during a previous storm or storms. As a result, the influent and effluent data will not be analyzed as event-based data pairs, but instead the data will be pooled over many storms (i.e., over an entire year, or over the duration of the entire monitoring

program) for general characterization and comparison purposes. By continuously monitoring the influent/effluent flows at these facilities, the following performance metrics will be calculated for each bioinfiltration site:

- Average annual reduction in pollutant concentration
- Average annual reduction in pollutant loading

Pervious Pavement BMPs. The pervious pavement plots are classified as short-term BMPs for hydrologic control. To evaluate hydrologic control efficiencies, the following performance metrics will be calculated for each of the pervious pavement plots:

- Individual storm reduction in peak flow
- Individual storm reduction in average flow
- Average annual reduction in flow volume

14.2.3 Graphical Data Presentation

Box-and-Whisker Plots. Box-and-whisker plots will be prepared to provide a qualitative comparison of differences between influent and effluent composition. Paired box-and-whisker plots will be prepared for key chemical parameters, including the following:

- Total suspended solids (TSS)
- Copper and zinc (total and dissolved)
- Phosphorus (total and ortho-)
- Particle size (median and 90th percentile)

To evaluate the effectiveness of the hydrologic control BMP at the pervious pavement site, box-and-whisker plots will be prepared for each test site for the following hydrologic parameters:

- Average flow (cfs)
- Peak flow (cfs)
- Total runoff volume (acre-feet)

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)

Time-Series Graphs. Time-series graphs will be prepared for key chemical and hydrologic parameters. The influent and effluent concentrations will be displayed on the same graph. These graphs will be inspected to determine whether any changes in the effectiveness of the BMP are discernible over time, e.g. whether there is any improvement or deterioration in the performance of the BMP as the BMP surfaces mature (e.g., compaction of pavement surfaces, growth of vegetative cover, bio/geo/chemical changes in subsurface soil properties, etc.). Pollutant reductions (in percent) for key constituents will also be graphed over time (see Section 14.2.2).

14.2.4 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 percent non-detects). 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).

14.2.5 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 outlier concentrations. 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. This type of information would be discussed with Ecology before any decisions are made to exclude any outlier data points.

14.2.6 Statistical Distribution Testing

To verify the appropriateness of using parametric statistical tests, such as pair comparison tests of influent versus effluent concentrations (see Section 14.2.7), conformance of stormwater data with standard statistical distributions (e.g., normal or lognormal distributions) should be demonstrated. Statistical distribution testing will generally follow *Statistical Guidance for Ecology Site Managers* (Ecology 1992, 1993) using the *MTCAStat* program.

For constituents containing mostly detected concentrations (<15% nondetects), numerical distribution tests may be used (Shapiro and Wilk 1965; Gilbert 1987). It is expected that the majority of the monitoring parameters for BMP effectiveness will meet this criterion. For data with a higher percentage of nondetects, 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 2008). These results indicate BMP influent and effluent stormwater concentrations may be similarly lognormal in character, and that parametric statistical tests may be appropriate. However, the assumption of lognormality will be confirmed with the BMP monitoring data.

14.2.7 Pair Comparison Tests (Short-term Biofiltration Facilities and Pervious Pavements)

For treatment facilities with short detention times, including biofiltration and pervious pavement BMPs, treatment efficiencies will be determined using pair comparison tests of influent versus effluent concentrations for individual storm events. Such tests will demonstrate whether significant reductions in chemical concentrations, flow rates or volumes are observed in the effluent stream after treatment.

If the influent and effluent data conform to normal distributions (see Section 14.2.6), then a paired T-test will be performed. If the influent and effluent data conform to lognormal distributions, then a paired T-test will be performed using the logarithms of the data.

If data distributions do not conform to standard normal or lognormal distributions, nonparametric statistical methods will be employed to determine whether influent and effluent concentrations are significantly different. Ecology recommends two types of nonparametric pair comparison tests – the Sign Test and the Mann-Whitney Signed Rank Test. The Mann-Whitney Signed Rank Test has more power than the Sign Test but it requires the data distributions to be symmetrical. As a result, it may be more appropriate to conduct this test using the logarithms of the data to attenuate highly skewed values, which are sometimes observed in stormwater.

While the concentration reduction is the primary effectiveness metric, a mass loading reduction may also be calculated since there will be continual flow monitoring of the BMP devices. In particular, there may be some infiltration beneath the biofiltration BMPs, and thus some reduction in both stormwater volume and concentration. For this calculation, the mean influent and effluent flow-weighted concentrations will be multiplied by the total annual influent and effluent discharge volumes to calculate an annualized mass loading reduction.

14.2.8 Population Comparison Tests (Intermediate-term Bioinfiltration Facilities)

For bioinfiltration facilities with intermediate detention times, event-based pair comparisons are not appropriate. Instead, influent and effluent data will be pooled across many storms to provide general population characteristics for statistical comparisons. Reductions in concentration will be calculated for each complete water year and also for the entire BMP monitoring program. Confidence intervals on the concentration reductions may be calculated using the Monte Carlo method presented in Ecology's Draft TAPE for Long Detention Times, or alternatively, a nonparametric "bootstrapping" method may be used which makes no assumptions about the statistical distributions of the data.

While the concentration reduction is the primary effectiveness metric, a mass loading reduction may also be calculated since there will be continual flow monitoring of the BMP devices. Although the underdrains will likely capture much of the infiltration, there may be lateral losses from the facility or losses to transpiration or other processes, and thus some reduction in both stormwater volume and concentration. For this calculation, the mean influent and effluent flow-weighted concentrations will be multiplied by the total annual influent and effluent discharge volumes to calculate an annualized mass loading reduction.

15 DATA ANALYSIS AND PRESENTATION

This section discusses the content of the Annual Stormwater Monitoring Report, which covers data collected during the previous water year. Each Annual Stormwater Monitoring Report, which is an attachment to the Annual Report under the Phase I Permit, is required to include the following four elements (Permit Section H.1 .a):

1. A summary including the BMP type location, land use, drainage area size, and hydrology for each site,
2. The status of implementing the monitoring program,
3. A comprehensive data and QA/QC report for each part of the monitoring program, with an explanation and discussion of the results of each monitoring study; and
4. Performance data.

These requirements are discussed below in three sections that will likely provide the outline for the report; a site summary, a comprehensive data summary, and a QA/QC summary.

15.1 Site Summary and Status

The site summary and status will include a summary of the study and the current status.

Site Summary The "summary including the BMP type location, land use, drainage area size, and hydrology for each site" is a brief description of the more detailed information presented in this QAPP. Additionally, the following information, if applicable, will be included in this section of the annual Stormwater Monitoring Report:

- Describe any land use changes in the drainage basin that would potentially affect hydrology or pollutant loading.
- Indicate hydrologic information if a monitoring site is subject to base flow from groundwater or is tidally influenced. Describe backwater conditions or other site-specific conditions if they influence sampling.
- Describe any preliminary conclusions regarding BMP effectiveness. Ecology recognizes that it may be too early to draw conclusions depending upon study design.

Status:

- A description of any changes made to the sampling program. Significant changes must be documented in a revised QAPP.
- A narrative description of status as of the end of the reporting period and statement as to when the program will be completed, if appropriate.
- A physical description of the BMP for the reporting period, such as damage, maintenance actions or repairs.
- Based on the monitoring activities up through the reporting period, the status of meeting the statistical goal, including an estimate of the remaining number of samples needed to meet these statistical performance measures.

15.2 Comprehensive Data Summary

The comprehensive data report will include at a minimum:

Stormwater sampling results

- A table or descriptive summary indicating whether the sampled storm events met the requirements listed in Tables 7-1 and 7-2.
- For each storm event at each site, a summary or graph of the following:
  - Time versus precipitation,
  - Time versus flow rate, and
  - Time versus initiation of aliquot collection.
- Tables showing qualified analytical results from each sampling event.
- Tables showing hydrological information for each measured event:
  - Total precipitation (inches),
  - Influent, effluent, and bypass peak flow rate (gpm), and
  - Total influent, effluent, and bypass volume (gallons).
- Tables showing sampling information for each measured event:
  - Number of influent and effluent aliquots,
  - Influent and effluent EMCs for each parameter monitored.

Sediment sample results

- Tables showing qualified sediment quality data.

Performance results

- Tables showing performance data for each event that has usable paired data.

15.3 Quality Assurance/Quality Control Summary

The QA/QC summary will include at a minimum:

1. A data validation memo for each sampling event 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.

2. A summary Quality Assurance Report, which includes:
   - A narrative summarizing the data validation memos that apply to the entire reporting period.
   - An overall assessment of the usability and representativeness of the data.
   - A summary description of any planned changes or deviations from the approved QAPP to address problems encountered during QA/QC.

References

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Ecology. 2008. Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol - Ecology (TAPE). Publication No. 02-10-037. Washington State Department of Ecology, Olympia, Washington.

Tacoma 2008. August 2001-2007 Stormwater Monitoring Report , Thea Foss and Wheeler-Osgood Waterways dated February 2008. Prepared by City of Tacoma.

PSEP. 1997. Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound. Prepared for U.S. Environmental Protection Agency and U.S. Army Corps of Engineers by the Puget Sound Estuary Program (PSEP), Olympia, Washington.

List of Revisions

The current list of revisions for this QAPP follows.

Revision Number	Effective Date	Revised by	Revision Summary
S8F-001	8/11/2008	Dana de Leon, Lauren McIntire, Chris Burke and Todd Thornburg	Initial draft.
S8F-002	1/30/2009	Dana de Leon, Lauren McIntire, Chris Burke and Todd Thornburg	Redline
S8F-003	11/30/2009	Dana de Leon, Lauren McIntire, Chris Burke and Todd Thornburg	Final

Appendix A
Design Criteria for BMPs

Design Criteria for Salishan Rain Garden

TABLE A-1.	Salishan Bioinfiltration Swale Info Requested /4/2008 for DOE Evaluation
TABLE A-2.	Flow Splitter Orifice Calculations
DOCUMENT A-1.	Design Criteria from DOE BMP T7.30 Bio-infiltration Swale
FIGURE A-1.	Salishan Drawings

Design Criteria for Alternatives

TABLE A-3.	Trolley Court Biofiltration Swale Info Requested 2/4/2008 for DOE Evaluation
TABLE A-4.	Design Criteria from DOE BMP T9.10 Basic Biofiltration Swale
FIGURE A-2.	Trolley Court Drawings
TABLE A-5.	E. 32nd Biofiltration Swale Info Requested 2/4/2008 for DOE Evaluation
TABLE A-6.	Design Criteria from DOE BMP T9.10 Basic Biofiltration Swale
TABLE A-7.	Flow Splitter Orifice Calculations
FIGURE A-2.	E. 32nd Drawings

<u>Note: D</u>esign drawings that have been provided on the CD are designated as Exhibits A – L. Design reports that have been provided on the CD are designated as Reports 1 – 3.

TABLE A-1. Salishan Bioinfiltration Info Requested 2/4/2008 for DOE Evaluation

1	**Drainage area details:**		
1a	**Percentage of area in each Land Use category**		
	100% Residential		
1b	**Impervious area total:**		
	East 44th Pond	8.183	acre
	East R Swale 1	0.611	acre
1c	**Type and sizes of impervious areas:**		
	Type: ***residential streets & parking; NOTE:*** *roof impervious bypasses treatment & is tight-lined to the storm water conveyance system.*		
	Sizes: ***See 1b above for impervious areas generating runoff that are infiltrated by the swales***		
1d	**PGIS :** ***NOTE:*** *all impervious considered was PGIS*		
	East 44th Pond	8.183	acre
	East R Swale 1	0.611	acre
1e	**PGPS:**		
	East 44th Pond	5.715	acre
	East R Swale 1	1.432	acre
1f	**Non-PGIS:**		
	0 acres or 0 SF total; NOTE: *all pervious surfaces were assumed to be PGPS*		
1g	**Type of pervious areas:**		
	Till Grass		

TABLE A-1 Cont.

2 Design Documentation:

2a Engineering calculations for sizing the facility:

Appendix D of Report 1 on the CD

2b Comparison to all design criteria and sizing required by the permit/'05 manual:

See Document A-1 of this appendix.

2c Drawings showing location, dimensions, influent and effluent conveyances:

See Figure A-1. Salishan Drawings of this appendix.

2d Verification of the facility as on-line or *off-line*

If off-line, provide design basis and details of bypass or **splitter:**

See Appendix C of Report 1 on the CD for 44th Street Pond flow splitter calcs.

3 Site Soils and Groundwater (soils testing will be done by City of Tacoma in November 2009)

3a High groundwater elevations (especially critical for wetpool designs):

n/a

3b Site soils and pertinent design details

3b1 Liner(s):

No liner. Layers consist of existing subsoil, bio-infiltration soil mix, and shredded bark mulch.

3b2 Estimated infiltration losses from pond/wetland:

Unknown

3b3 Documentation of soil analyses (size gradation, CEC, etc) and compost quality if involved in treatment or design water loss:

Existing soils analyses: ***see Appendix A of Report 1 on the CD.***

3c Description of methods & procedures used to determine the long-term bioinfiltration swale infiltration rates:

Unknown

TABLE A-1 Cont.

4 Media Description and Specifications (soils testing & plant I.D. will be done by the City of Tacoma; 4a-d will be revised)

4a Vegetation species (swales, strips, bioretention, wetlands) and densities:

native groundcover & shrub plants

4b Artificial media types, sizes/gradation, depths (or thickness):

Unknown

Sand type, gradation, depth (or thickness)

4c ***65-70% gravelly sand***

Description of any Amendments

4d ***30-35% composted by volume; compost will be 7/16-inch material per WAC 173-350-220 (10) rating.***

5 Proposed Monitoring Locations

5a Percent of drainage area and influent flow tributary to monitoring site; NOTE: not shared drainage area

	Drainage Area (%)	Influent Flow Tributary to Monitor (%)
East 44th Pond	100%	100.0%
East R Swale 1	100%	100.0%

6 O&M Status

6a The condition of the facility as compared to the parameters in the Maintenance Table (Table 4.5 of the '05 manual).

The East R St. Swale 1 will be maintained by either the Tacoma Housing Authority (THA) or a homeowners association. The East 44th St. pond will be maintained by the City of Tacoma. Amended soils will be tested & maintained, plants will be pruned & replaced when necessary, litter & sediment will be removed, and the hydraulic structures will be repaired when necessary. Appendix G Report 1 on the CD is a draft maintenance checklist.

This system was recently installed; therefore it is too early to comment on the condition.

TABLE A-2. Flow Splitter Orifice Calculations: Calculation 1 on CD

CITY OF TACOMA'S ASSESSMENT

THEORETICAL

Equation	Orifice Equation		Q =	CA(2gh)^.5
Given	WQ=	0.7016	cfs	NOTE: from WWHM2 using 15-min time steps
	WQ (110%)		cfs	
	=	0.77176		
	C=	0.62	per EIT Book	
	g=	32.2		

Find Dimensions for flow splitter such that:

* A flow splitter must be designed to deliver the WQ design flow rate specified in this volume to the WQ treatment facility.
* The maximum head must be minimized for flow in excess of the WQ design flow. Specifically, flow to the WQ facility at the 100-year water surface must not increase the design WQ flow by more than 10%.

Solve

Diameter, D (in)	Area, A (ft^2)	Head, h (ft)	Orifice Q at 100-yr Flow (cfs)	% of WQ Design Flow
0.5	0.0014			
1	0.0055			
1.5	0.0123			
2	0.0218	50.54968951	0.77176	110.00%
2.5	0.0341	20.70515282	0.77176	110.00%
3	0.0491	9.985123853	0.77176	110.00%
3.5	0.0668	5.389721163	0.77176	110.00%
4	0.0873	3.159355594	0.77176	110.00%
4.5	0.1104	1.972370144	0.77176	110.00%
5	0.1364	***1.294072051***	0.77176	110.00%
5.5	0.1650	0.883868623	0.77176	110.00%
6	0.1964	0.624070241	0.77176	110.00%

TABLE A-2. Cont.

ACTUAL				
Equation	Orifice Equation		WQactual =	CA(2gh)^.5
Given	WQ=	0.7016	cfs	NOTE: from WWHM2 using 15-min time steps
	WQ (110%) =	0.77176	cfs	
	C=	0.62	per EIT Book	
	g=	32.2		
	h=	1.5	ft	
	A=	0.1364	ft^2	
Find	WQactual			
	%ofWQ			
Solve	**WQactual=**	***0.8309***	***cfs***	
	%of WQ=	***15.56***	***%***	Should be no more than 110% of 6-month, 24-hr storm per DOE
	% beyond WQ(110%)=	5.91	%	Approximately 6% more flow going to system than max allowable

TABLE A-2. Cont.

PARAMETRIX'S ASSESSMENT; NOTE: All inputs are the same as in their Appendix C of the report except the 110%-of-WQ value is fixed											
THEORETICAL											
Equation	Orifice Equation		Q =	CA(2gh)^.5							
Given	WQ=	0.6402	cfs	NOTE: from WWHM2 using 15-min time steps							
	WQ (110%) =	0.70422	cfs								
	C=	0.68	Source unknown; back-calculated								
	g=	32.2									
Find	Dimensions for flow splitter such that:										
	*	A flow splitter must be designed to deliver the WQ design flow rate specified in this volume to the WQ treatment facility.									
	*	The maximum head must be minimized for flow in excess of the WQ design flow. Specifically, flow to the WQ facility at the 100-year water surface must not increase the design WQ flow by more than 10%.									
Solve											
	Diameter, D (in)	**Area, A (ft^2)**	**Head, h (ft)**	**Orifice Q at 100-yr Flow (cfs)**	**% of WQ Design Flow**						
	0.5	0.0014									
	1	0.0055									
	1.5	0.0123									
	2	0.0218	34.98937821	0.70422	110.00%						
	2.5	0.0341	14.33164932	0.70422	110.00%						
	3	0.0491	6.911482116	0.70422	110.00%						
	3.5	0.0668	3.730645907	0.70422	110.00%						
	4	0.0873	2.186836138	0.70422	110.00%						
	4.5	0.1104	1.365231035	0.70422	110.00%						
	5	0.1364	***0.895728082***	0.70422	110.00%						
	5.5	0.1650	0.611794333	0.70422	110.00%						
	6	0.1964	0.431967632	0.70422	110.00%						

TABLE A-2. Cont.

ACTUAL											
Equation	Orifice Equation		WQactual =	CA(2gh)^.5							
Given	WQ=	0.6402	cfs	NOTE: from WWHM2 using 15-min time steps							
	WQ (110%) =	0.70422	cfs								
	C=	0.68	per EIT Book								
	g=	32.2									
	h=	1.5	ft								
	A=	0.1364	ft^2								
Find	WQactual										
	%ofWQ										
Solve	**WQactual=**	***0.9113***	***cfs***								
	%of WQ=	***29.75***	***%***	Should be no more than 110% of 6-month, 24-hr storm per DOE							
	% beyond WQ(110%)=	20.71	%	Approximately 20% more flow going to system than max allowable							

TABLE A-2. Cont.

CONCLUSION	
	Appendix C of Report 1 on the CD shows that Parametrix found that an orifice diameter of 4-inches should be used. For a diameter of 4-inches, the weir height (head) is approx. 1.97-ft, or 2-ft. However, on sheet C5.3 (Exhibit B) it shows that the orifice diameter proposed to be used changed to 5-inches with a weir height of 2-ft. It was field verified that the installed orifice's diameter is 5-inches with a weir height of 1.5-ft.
	In "Parametrix's Assessment" above it can be seen that the WQ = 0.6102 cfs, which is not the WQ shown in the WWHM2 calculations calculations found in Appendix D of Report 1 on the CD. On 12/31/08 Greg Hannan wrote "Please note that the flow splitter calculations were completed before the final tweaking of the basins and modeling & explains why there is a minor difference between the flow rates.
	This should not have any impact whatsoever to the function of the system." For Parametrix's orifice diameter of 5-inches the calculated weir height (i.e. head) is found to be 0.8-ft whereas the actual installed weir height is 1.5-ft, thus the water quality pond receives more than the 6-month, 24-hr WQ determined by Parametrix. Using the actual installed weir height and Parametrix's other values, the WQactual = 0.9113cfs, or 29.75% of the WQ. Recall that the max allowable WQ rate per DOE is WQ(110%) = 0.70422 cfs, making the WQactual approximately 20.7% beyond that.
	"The City of Tacoma's Assessment" above shows the results using a slightly different C value and the correct WQ = 0.7016 cfs.
	The resultant weir height for an orifice diameter of 5-inches is 1.29-ft. Using the actual installed values determined in the field the WQactual = .0.8309 cfs, or 15.56% of the WQ. Recall that the max allowable WQ rate per DOE is WQ(110%) = 0.77176 cfs, making the WQactual approximately 5.91% beyond that.
	Assuming "The City of Tacoma's Assessment" is correct, the weir height is approximately 0.21-ft or 2.5-inches too tall. If this concrete weir were modified to the correct weir height of approximately 1.29-ft, the flow control structure would bypass flows greater than the 6-month, 24-hr storm event.

DOCUMENT A-1. Design Criteria from DOE BMP T7.30 Bio-infiltration Swale
(DOE 2005 Manual Volume V page 7-5)

- **Sizing**
  Use the same design sizing procedures outlined in Chapter 3 of Volume III for infiltration facilities designed as treatment facilities.

  - **<u>2005 DOE Manual Excerpt:</u> Volume III Section 3.3.9**

    (B) For 91% infiltration (water quality treatment volume)

    On-line treatment facilities placed ***upstream or downstream*** of a detention facility must be sized to infiltrate 91% of the runoff file volume directed to it.
    Off-line treatment facilities placed ***upstream*** of a detention facility must have a flow splitter designed to send all flows at or below the 15-minute water quality flow rate, as predicted by WWHM (or other approved continuous runoff model), to the treatment facility. Within the WWHM, the flow splitter icon is placed ahead of the pond icon which represents the infiltration basin. The treatment facility must be sized to infiltrate all the runoff sent to it (no overflows from the treatment facility are allowed).

    See Chapter 4 for flow splitter design details.

    NOTE: The above referenced "Chapter 4" appears to not exist under Volume III. It has been assumed that the reference meant to refer to Volume V Section 4.5.1 and thus the assessment of the flow splitter design was done using Vol. V Sec. 4.5.1. See "….." to see this assessment.

  - **<u>Salishan HOPE VI Redevelopment Stormwater Site Plan – Area 2A (100% Design)</u>, hereafter referred to as "Report 1"**

    In Appendix D "Bioinfiltration (Soil Filtration) Facility Sizing Calculations are the WWHM2 calculations for East 44th Pond and East R Swale 1. At the end of the output data is the following information per swale:

    East 44th Pond
    <u>Water Quality BMP Flow and Volume:</u>
    On-line facility volume: *1.0419 acre-feet*
    On-line facility target flow: *1.114 cfs*
    Adjusted for 15 min: *1.1973 cfs*
    Off-line facility target flow: *0.6402 cfs*
    Adjusted for 15 min: *0.688 cfs*

East R Swale

Water Quality BMP Flow and Volume:

On-line facility volume:	*0.1121 acre-feet*
On-line facility target flow:	*0.0916 cfs*
Adjusted for 15 min:	*0.0949 cfs*
Off-line facility target flow:	*0.0514 cfs*
Adjusted for 15 min:	*0.0533 cfs*

- **Drawdown Time**
  For the water quality design volume: 48 hours max. See Site Suitability Criterion (SSC 4) in Section 3.3.7, Chapter 3, Volume III**.**

  - **Manual Excerpt: SSC-4, Volume III Section 3.3.7**

    Drawdown time:
    For infiltration facilities designed strictly for flow control purposes, there isn't a maximum drawdown time. If sizing a treatment facility, document that the 91st percentile, 24-hour runoff volume (indicated by WWHM or MGS Flood) can infiltrate through the infiltration basin surface within 48 hours. This can be calculated using a horizontal projection of the infiltration basin mid-depth dimensions and the estimated long-term infiltration rate.

    This drawdown restriction is intended to meet the following objectives:
    • aerate vegetation and soil to keep the vegetation healthy
    • enhance the biodegradation of pollutants and organics in the soil.

  - **Report 1:**
    2"/hr (per a Parametrix employee affiliated with the project)

- **Swale Bottom:**
  Flat with a longitudinal slope less than 1%
  - **Report 1:**

    Swale 1 = 0%
    Swale 2 = 0%

- **Max Ponded Level:**
  6 inches

  - **Report 1:**
    1' (overflow height)

- **Treatment Soil:** City of Tacoma will test actual soils and report in the annual report. To be at least 18 inches thick with a CEC of at least 5 meq/100 gm dry soil, organic content of at least 1%, and sufficient target pollutant loading capacity. The design soil

thickness may be reduced to as low as 6 inches if appropriate performance data demonstrates that the vegetated root zone and the natural soil can be expected to provide adequate removal and loading capacities for the target pollutants. The design professional **should** calculate the pollutant loading capacity of the treatment soil to estimate if there is sufficient treatment soil volume for an acceptable design period. (See Criteria for Assessing the Trace Element Removal Capacity of Biofiltration Systems, Stan Miller, Spokane County, June 2000).

NOTE: Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.

- **Report 1:**
  - "Each water quality treatment facility will be constructed by excavating and backfilling with a minimum of 18 inches of compost-amended soils to improve water retaining capacity, filtration, and sorption as well as allowing for pollutant uptake by vegetative root zones." (pg 4-5)
  - "The engineered soil mix for the bioretention facilities will nominally be 30 to 35 percent composted material by volume and approximately 65 to 70 percent gravelly sand. These materials will be well-mixed and placed in the facilities to a depth of 2 to 4.5 feet. Compost will be 7/16-inch material meeting the stability rating of very stable, stable, or moderately unstable as defined in WAC 173-350-220 (10)." (pg 4-5)
  - Per site construction manager, contractor submittals and some testing to verify conformance to specifications was completed.

- **Treatment Zone Depth:**
  6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation. City of Tacoma will test actual soils and report in the annual report.
  - **Report 1:**
    Refer to the response to the above "Treatment Soil" subject

- **Treatment Soil Infiltration Rate:** Facilities will be tested by Tacoma per QAPP
  Should not exceed 1-inch per hour for a treatment zone depth of 6 inches relying on the root zone to enhance pollutant removal. The Site Suitability Criteria in Section 3.3.7 of Chapter 3, Volume III **must** also be applied, if a design soil depth of 18 inches is used then a maximum infiltration rate of 2.4 inches per hour is applicable.
  - **Report 1:**
    Refer to the response to the above "Treatment Soil" subject

    "**Facility infiltration rates:** Based on the expected infiltration rate of the amended soils, an infiltration rate of 2.4 inches per hour was used for swales in Area 2A." (pg 4-7)

- **Grass:**
  Use native or adapted grass should be used.

  - **<u>Report 1:</u>**
    "Swales and ponds will be planted with native groundcover and shrub plants." (Pg 4-5)

  - Per site construction manager, plantings were completed by Berger Partnership. Tacoma will confirm plantings per QAPP

- **Pretreatment:**
  Pretreatment of debris, gross TSS, and oil & grease to prevent the clogging of the treatment soil and/or growth of the vegetation, **where necessary**.

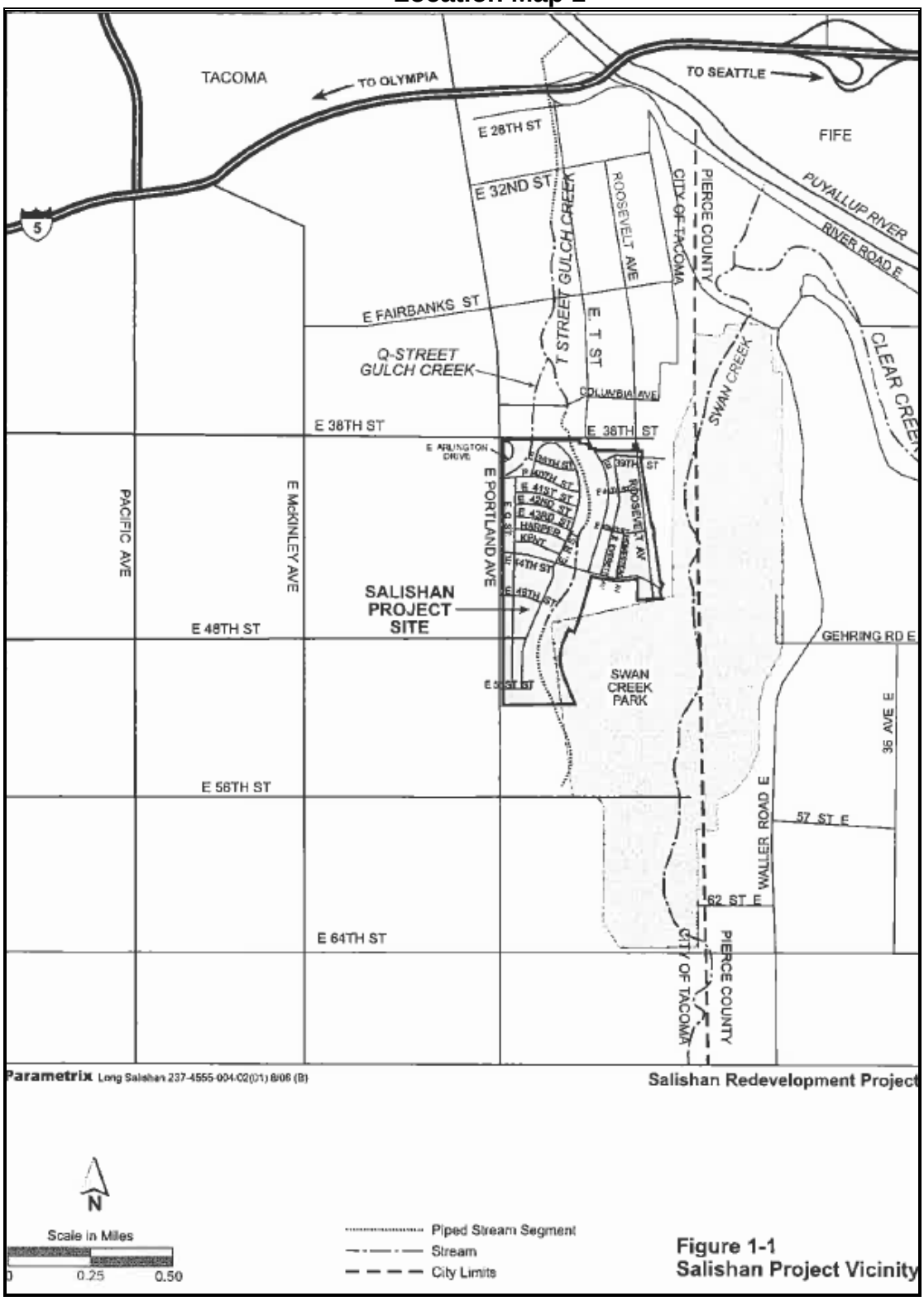
  - **<u>Salishan Site Visit:</u>**
    No pretreatment exists nor is it necessary.

- **Pollutant Identification:**
  Identify pollutants particularly in industrial and commercial area runoff, that could cause a violation of Ecology's ground water quality Standards (Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.

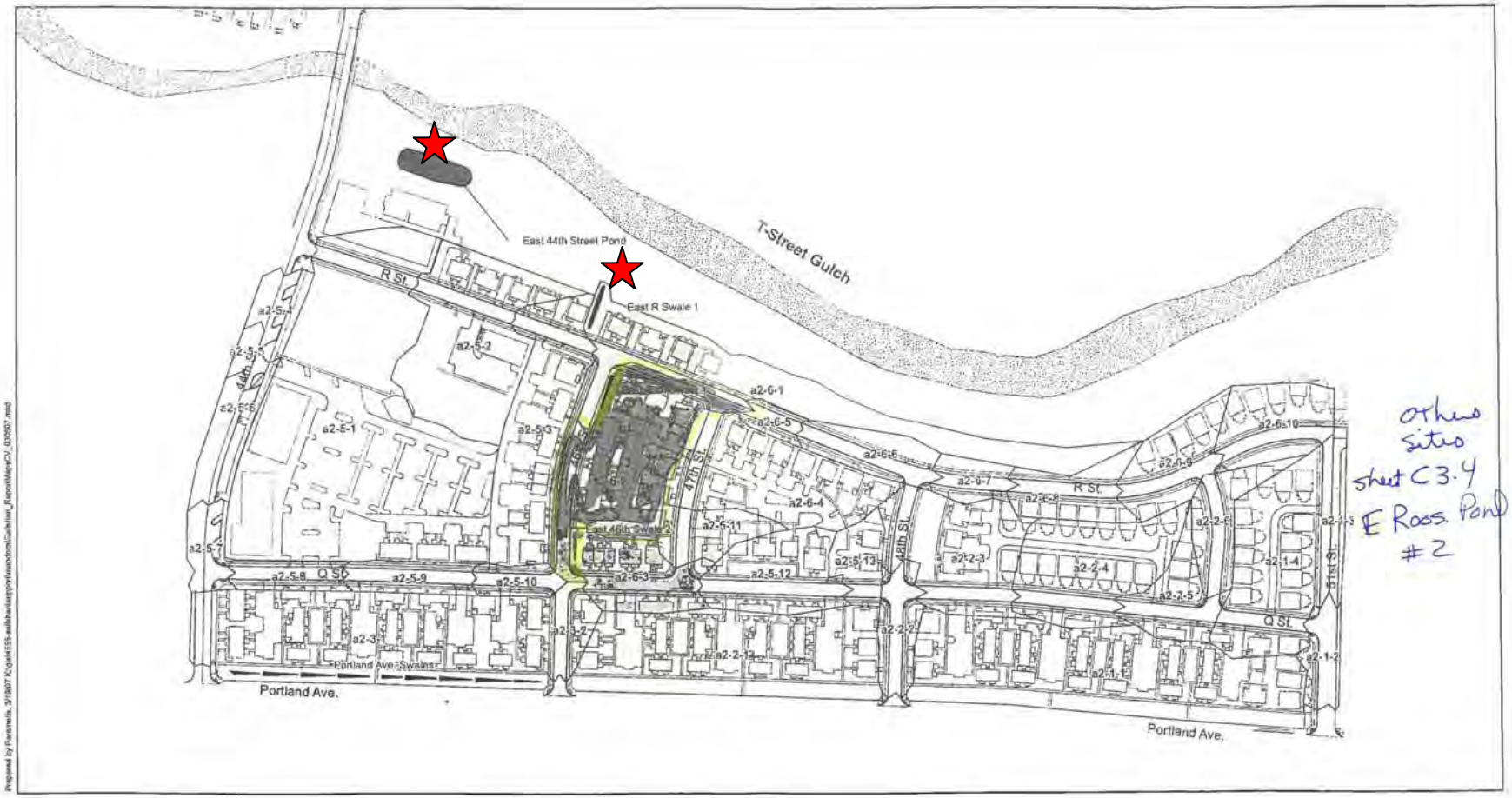
  - **<u>Salishan Site Visit:</u>**
    Pollutants of this type are not of concern in this residential development.

FIGURE A-1. Salishan Drawings

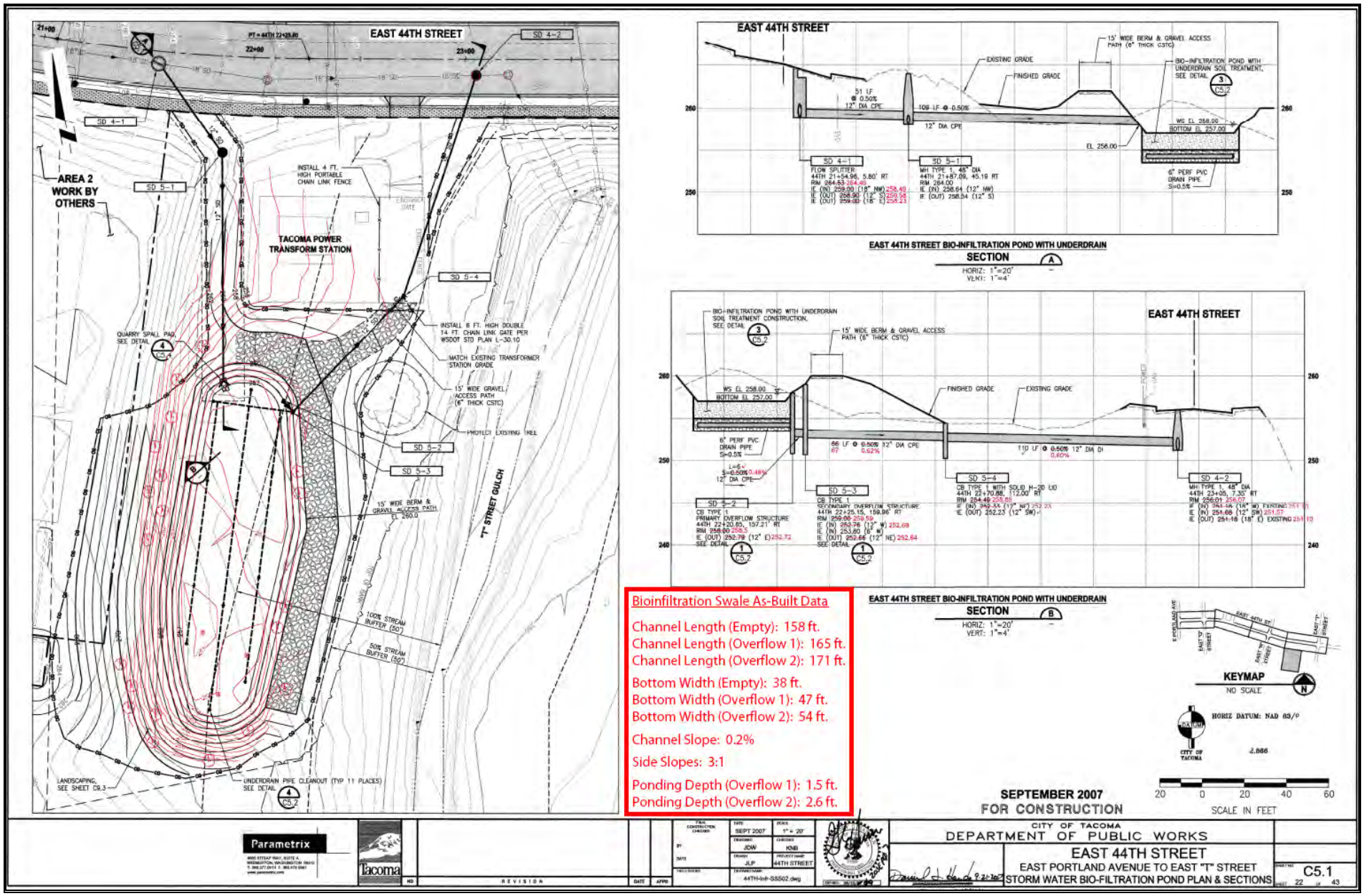
Location Map 1



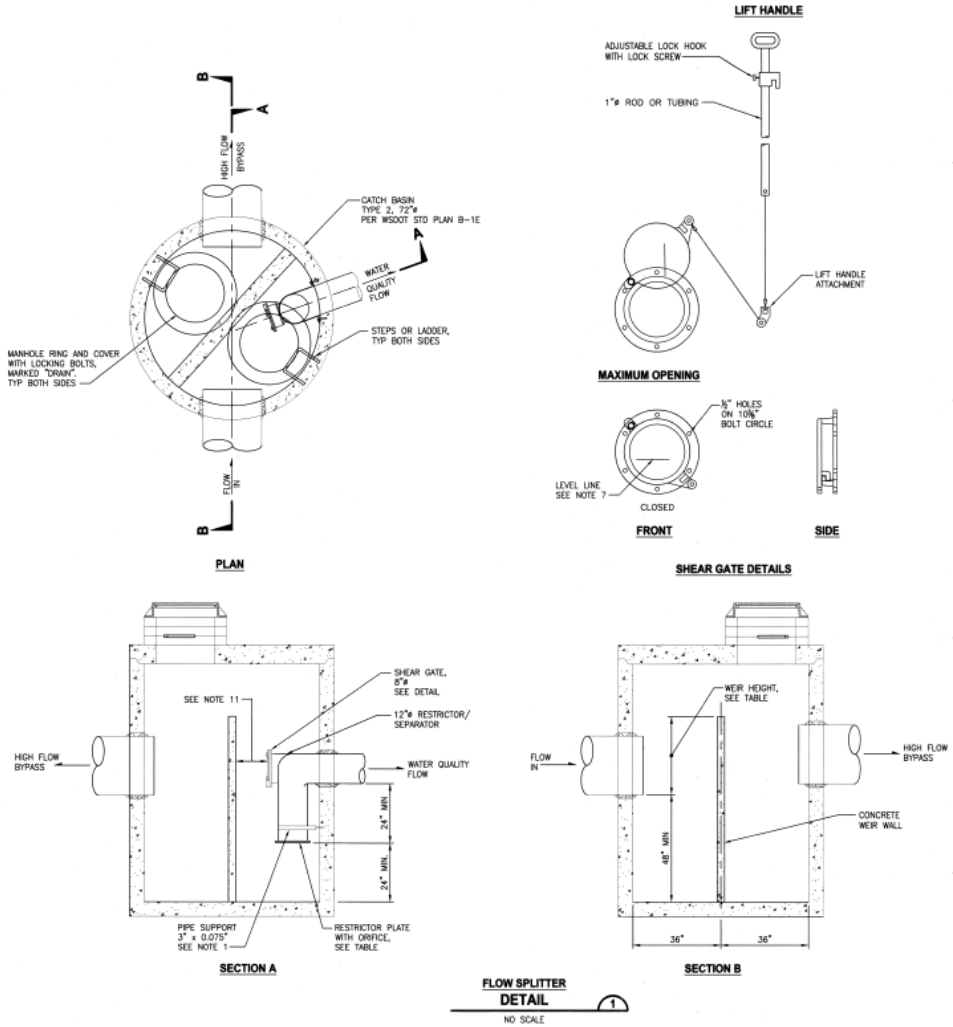
Location Map 2



44th St. Pond: Exhibit A on CD



44th St. Pond Flow Splitter Details: Exhibit B on CD



FLOW SPLITTER DETAIL 1

NO SCALE

FLOW SPLITTER NOTES:

1. THE PIPE SUPPORT AND THE RESTRICTOR/SEPARATOR SHALL BE CONSTRUCTED OF THE SAME MATERIAL AND BE ANCHORED AT A MAXIMUM SPACING OF 36". ATTACH THE PIPE SUPPORT TO THE MANHOLE WITH 5/8" STAINLESS STEEL EXPANSION BOLTS OR EMBED THE SUPPORT INTO THE MANHOLE WALL 2".
2. THE FLOW RESTRICTOR/SEPARATOR SHALL BE FABRICATED FROM ONE OF THE FOLLOWING MATERIALS:
   0.060" CORRUGATED ALUMINUM ALLOY DRAIN PIPE
   0.064" CORRUGATED GALVANIZED STEEL DRAIN PIPE WITH TREATMENT 1
   0.064" CORRUGATED ALUMINIZED STEEL DRAIN PIPE
   0.060" ALUMINUM ALLOY FLAT SHEET, IN ACCORDANCE WITH ASTM B 209M, 5052 H32 OR EPS
   HIGH DENSITY POLYETHYLENE STORM SEWER PIPE.
3. THE FRAME AND LADDER OR STEPS ARE TO BE OFFSET SO THAT: THE SHEAR GATE IS VISIBLE FROM THE TOP; THE CLIMB-DOWN SPACE IS CLEAR OF THE RISER AND GATE; THE FRAME IS CLEAR OF THE CURB.
4. ORIFICE IS TO BE CUT ROUND AND SMOOTH.
5. THE SHEAR GATE SHALL BE MADE OF ALUMINUM ALLOY IN ACCORDANCE WITH ASTM B 26M AND ASTM B 275, DESIGNATION ZG32A; OR CAST IRON IN ACCORDANCE WITH ASTM A 48, CLASS 30B. THE LIFT HANDLE SHALL BE MADE OF A SIMILAR METAL TO THE GATE (TO PREVENT GALVANIC CORROSION), IT MAY BE OF SOLID ROD OR HOLLOW TUBING, WITH ADJUSTABLE HOOK AS REQUIRED. A NEOPRENE RUBBER GASKET IS REQUIRED BETWEEN THE RISER MOUNTING FLANGE AND THE GATE FLANGE. INSTALL THE GATE SO THAT THE LEVEL-LINE MARK IS LEVEL WHEN THE GATE IS CLOSED. THE MATING SURFACES OF THE LID AND THE BODY SHALL BE MACHINED FOR PROPER FIT. ALL SHEAR GATE BOLTS SHALL BE STAINLESS STEEL.
6. THE SHEAR GATE MAXIMUM OPENING SHALL BE CONTROLLED BY LIMITED HINGE MOVEMENT, A STOP TAB, OR SOME OTHER DEVICE.
7. ALTERNATE SHEAR GATE DESIGNS ARE ACCEPTABLE, IF MATERIAL SPECIFICATIONS ARE MET AND FLANGE BOLT PATTERN MATCHES.
8. SEE PLANS FOR SIZE AND LOCATION OF ALL PIPES AND ORIFICES.
9. CONCRETE WEIR WALL SHALL HAVE #4 BAR AT 12" SPACING EACH WAY.
10. CONCRETE WEIR WALL SHALL BE KEYED AND GROUTED IN PLACE.
11. PROVIDE MAXIMUM CLEARANCE BETWEEN THE WEIR WALL AND THE SHEAR GATE (18 INCHES MINIMUM). THIS MAY BE ACHIEVED BY SKEWING THE OUTLET PIPE AWAY FROM CENTER AS NEEDED.

FLOW SPLITTER TABLE

FLOW SPLITTER #	SWALE/POND	WEIR HEIGHT (FT)	ORIFICE ø IN
SD 4-1	44TH ST POND	~~2.0~~ 1.6	5.0

SEPTEMBER 2007
FOR CONSTRUCTION

Parametrix
4660 KITSAP WAY, SUITE A
BREMERTON, WASHINGTON 98312
T. 360.377.8014 F. 360.479.5961
www.parametrix.com

Tacoma

NO	REVISION	DATE	APPD

CONSTRUCTION CHECKED	DATE SEPT 2007	SCALE NO SCALE
BY	DESIGNED JOW	CHECKED KNB
DATE	DRAWN JLP	PROJECT NAME 44TH STREET
FIELD BOOKS	DRAWING NAME 44TH-Infr-DET01.dwg	

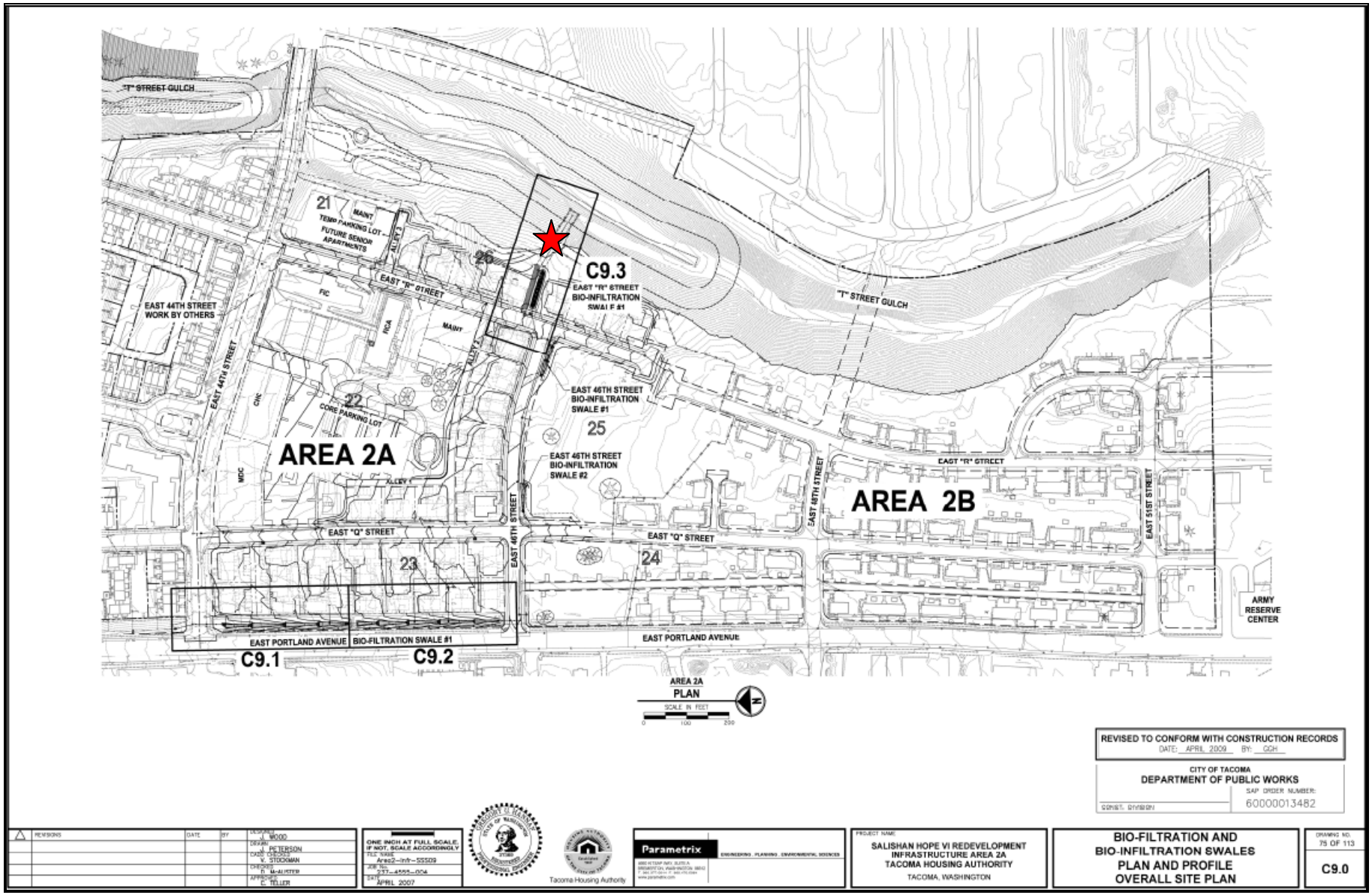
Daniel C. Edwards 9.21.2007

CITY OF TACOMA
DEPARTMENT OF PUBLIC WORKS

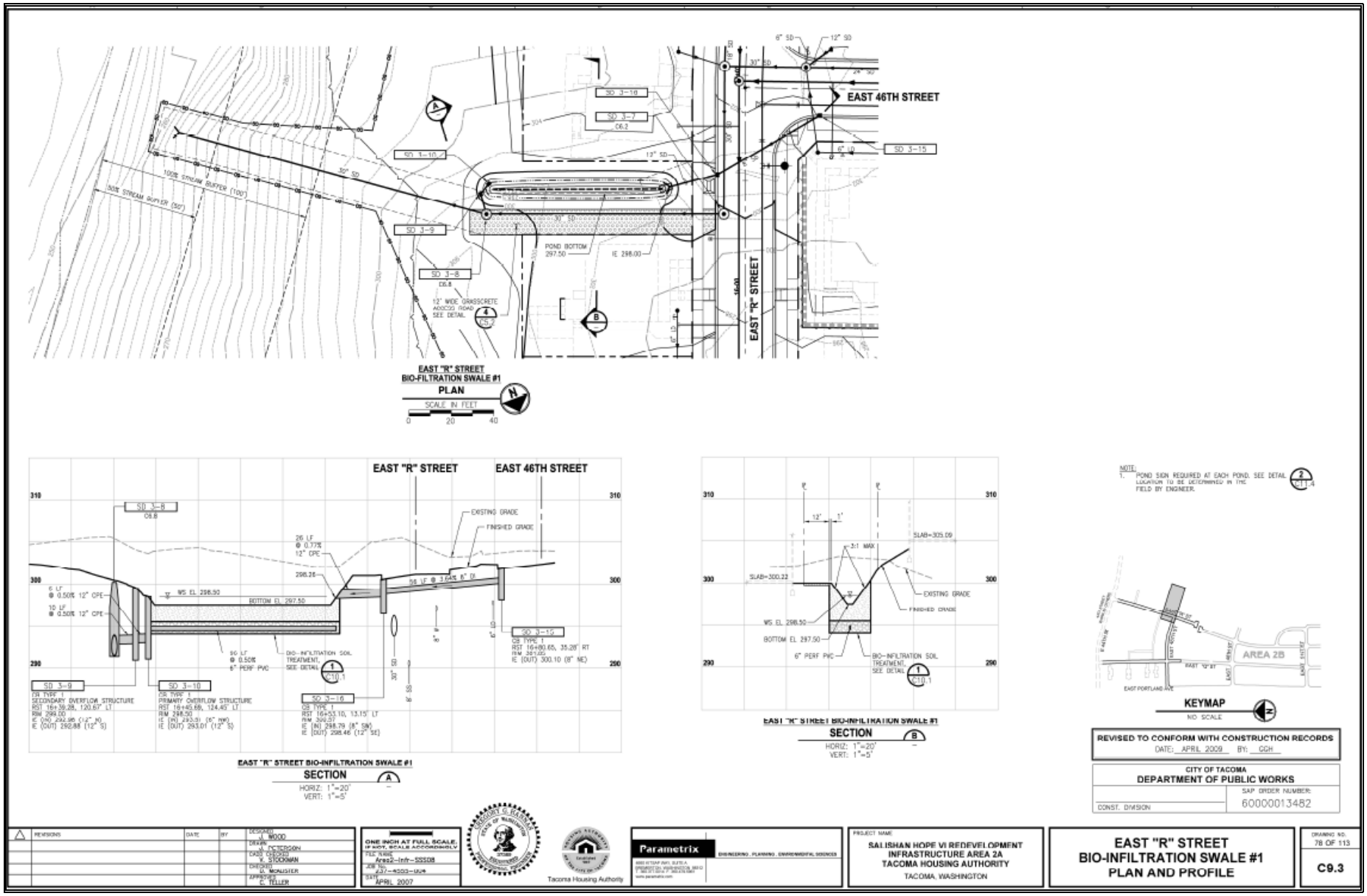
EAST 44TH STREET
EAST PORTLAND AVENUE TO EAST "T" STREET
FLOW SPLITTER DETAIL

SHEET NO. C5.3
SHEET 24 OF 43

R St. Swale Plan: Exhibit C on CD



R St. Swale: Exhibit D on CD



R-Street Bio-infiltration Details: Exhibit E on CD

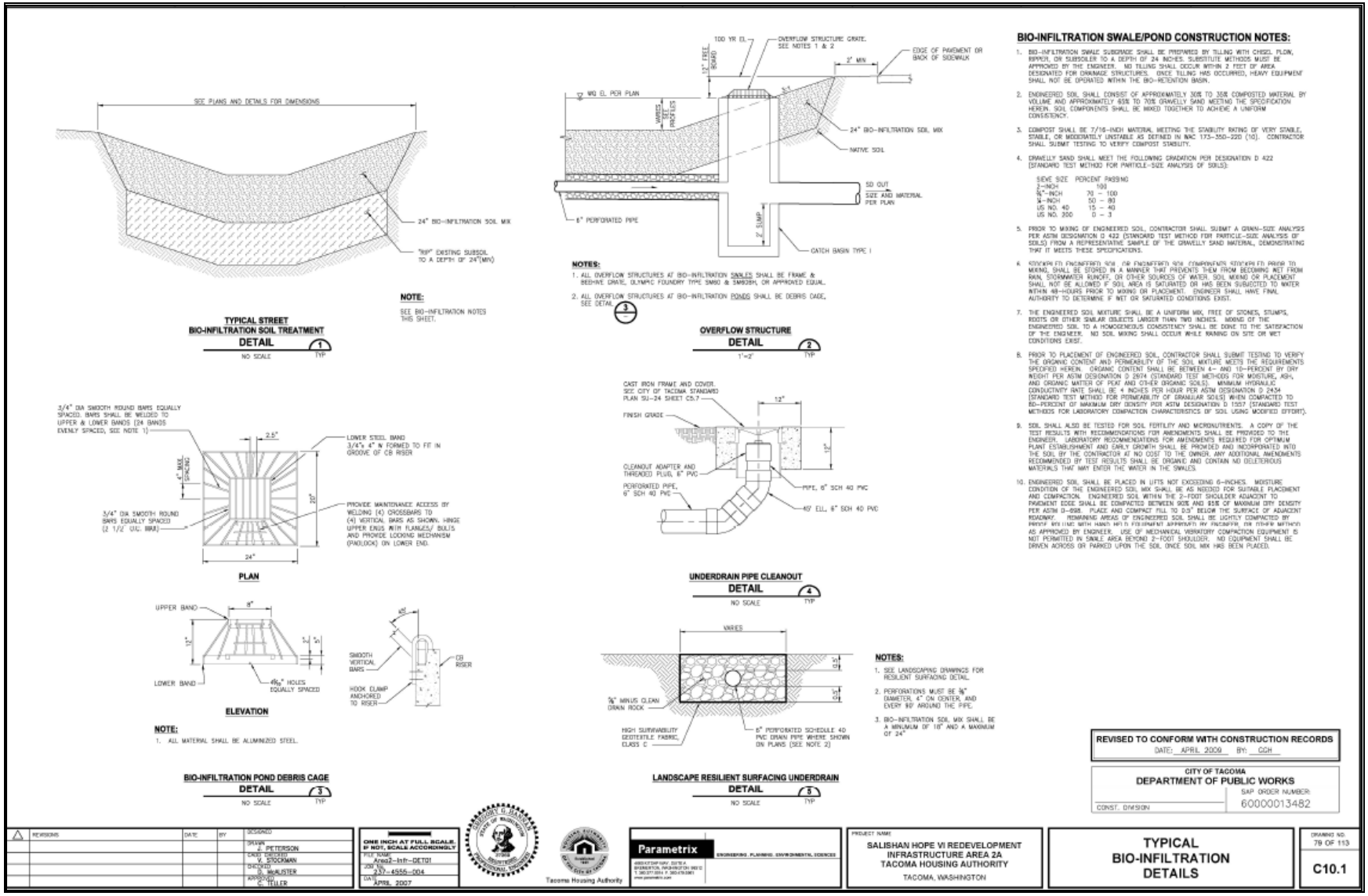


TABLE A-3. Trolley Court Info Requested 2/4/2008 for DOE Evaluation

1	**Drainage area details:**						
1a	**Percentage of area in each Land Use category:**						
		Residential (100%)	2.27	acre	or	***98,881.2***	SF
1b	**Impervious area total:**						
		Roads	0.53	acre	or	23,086.8	SF
		Lots (11)	0.56	acre	or	24,393.6	SF
		Total	***1.09***	***acre***	***or***	***47,480.4***	***SF***
1c	**Type and sizes of impervious areas:**						
		Type	***Public road, access road, private road, and 11 lots @ 2200 SF each.***				
		Sizes	***See 1b above for impervious areas***				
1d	**PGIS :**	***Assuming driveways are 300SF***					
		(11 x 300SF) + 23,086.8 = 26386.8SF or 0.6 acres					
1e	**PGPS:**						
		Landscaping for 11 Lots	0.83	acre	or	36,154.8	
1f	**Non-PGIS:**	***Assuming driveways are 300SF***					
		24,393.6 - (11 x 300SF) = 21093.6SF or 0.48 acres					
1g	**Type of pervious areas:**						
		Grass storm tract & landscaping for 11 lots					

TABLE A-3. Cont.

2 Design Documentation:

2a Engineering calculations for sizing the facility: ***Appendix C of Report 2***

2b Comparison to all design criteria & sizing required by DOE 2005 manual:

See Table A-4 of this appendix and Exhibits F, G, & H on the CD.

2c Drawings showing location, dimensions, influent and effluent conveyances:

See Figure A-2 of this appendix. Additional info: 4ft-wide, 186ft-long, & a longitudinal with a slope of 2%.

2d Verification of the facility as on-line or off-line

The system is on-line per the drawings and a site visit.

3 Site Soils and Groundwater (if applicable)

3a High groundwater elevations (especially critical for wetpool designs): *n/a*

3b Site soils and pertinent design details

3b1 Liner(s):
No liner.

3b2 Estimated infiltration losses from pond/wetland
N/A

3b3 Documentation of soil analyses (size gradation, CEC, etc.) & compost quality if treatment or design water loss:

Existing soils analyses: ***Type C***

3c Description of methods & procedures used to determine the long-term bioswale infiltration rates:
Unknown

4 Media Description and Specifications (if applicable)

4a Vegetation species (swales, strips, bioretention, wetlands) and densities:
In calcs assumed "grass-legume mixture (it seems, as was in the example calcs in the manual). On November 13th City Environmental Specialists/Biologists performed a preliminary bioswale vegetation identification; see Exhibit L for the technical memorandum. Some grasses can only be identified when growing, thus, the sites will be revisited in the spring (2010).

4b Artificial media types, sizes/gradation, depths (or thickness)
Unknown

4c Sand type, gradation, depth (or thickness)
Unknown

4d Description of any Amendments
A mix of compost and native soil

TABLE A-3. Cont.

5 Proposed Monitoring Locations

5a Percent of drainage area and influent flow tributary to monitoring site

	Drainage Area (%)	Influent Flow Tributary to Monitor (%)
Swale Series	100.0%	100.0%

6 O&M Status

6a The condition of the facility as compared to the parameters in the Maintenance Table (Table 4.5 of the '05 manual). ***"Storm Drainage Maintenance Manual" of the SSP, pg 23-24; Also listed on pg 65 of the City's "Storm Water Detention***

& Treatment Facilities: Operation & Maintenance Manual"

Is comparable to that of DOE pg 9-19 http://www.ecy.wa.gov/pubs/0510033.pdf:
Maintenance
Criteria

• Inspect biofilters at least once every 6 months, preferably during storm events, and also after storm events of > 0.5 inch rainfall/ 24 hours. Maintain adequate grass growth and eliminate bare spots.

• Mow grasses, if needed for good growth {typically maintain at 4 – 9 inches and not below design flow level (King County, 1998)}.

• Remove sediment as needed at head of the swale if grass growth is inhibited in greater than 10 percent of the swale, or if the sediment is blocking the distribution and entry of the water (King County, 1998).

• Remove leaves, litter, and oily materials, and re-seed or resod, and regrade, as needed. Clean curb cuts and level spreaders as needed. Prevent scouring and soil erosion in the biofilter. If flow channeling occurs, regrade and reseed the biofilter, as necessary.

Maintain access to biofilter inlet, outlet, and to mowing (Figure 9.8)

• If a swale is equipped with underdrains, vehicular traffic on the swale bottom (other than grass mowing equipment) should be avoided to prevent damage to the drainpipes.

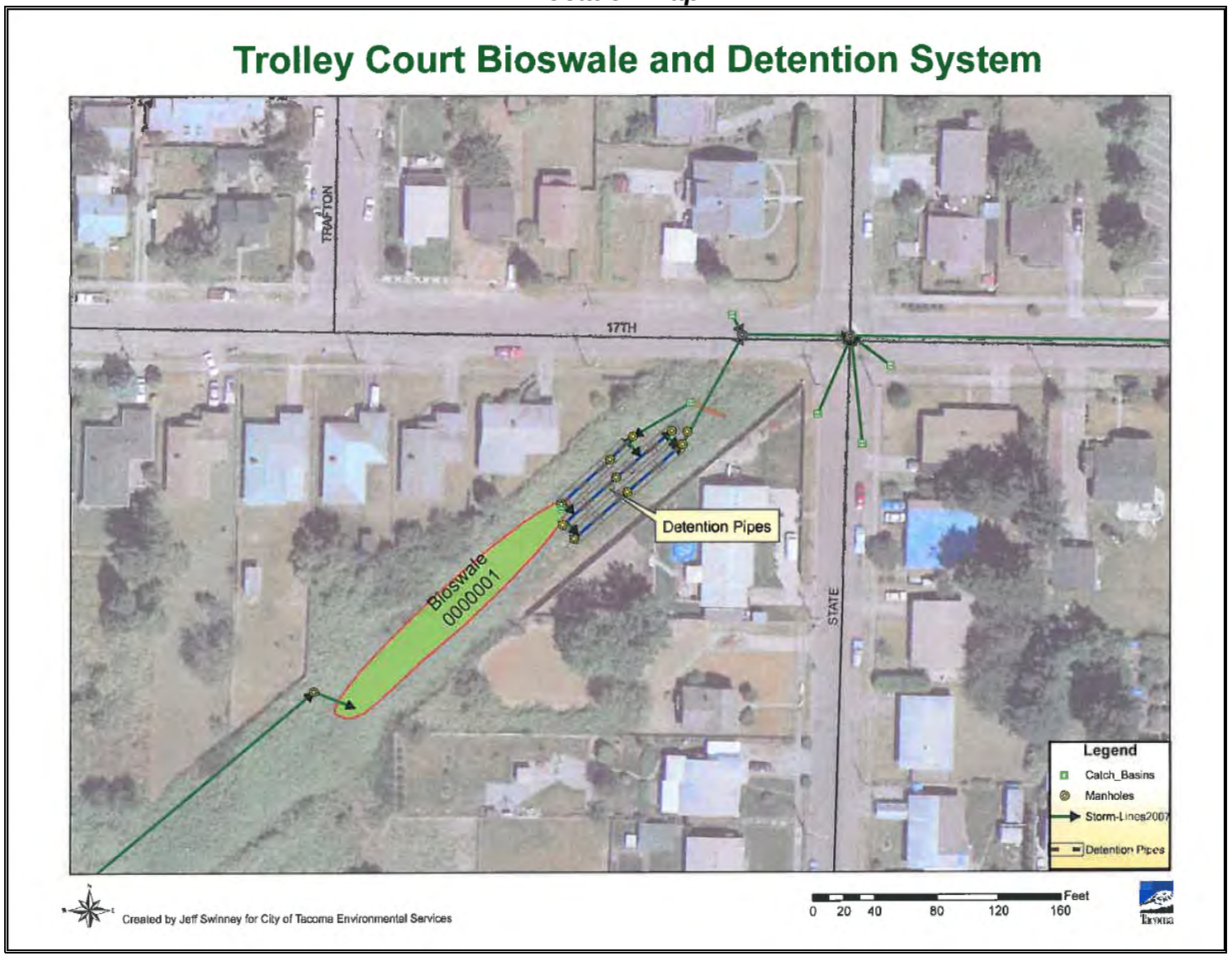
TABLE A-4. Design Criteria from DOE BMP T9.10 Basic Biofiltration Swale

Design Parameter	BMP T 9.10-Biofiltration Swale	Trolley Court Final Design Value
Longitudinal Slope	.015 - .025 ft/ft	0.02 ft/ft
Max. Velocity	1 ft/s @ K multiplied by the WQ design flow rate; for stability, 3 ft/s max	0.306 ft/s where K=1.8 & the WQ design velocity was 0.17 ft/s
Max. Water Depth	2"- if mowed frequently; 4" if mowed infrequently	0.25ft or 3"
Manning Coefficient	(0.2 - 0.3); (0.24 if mowed infrequently)	0.2
Bed Width (bottom)	2-10ft	3.99ft
Freeboard Height	0.5ft	0.5ft
Min. Hydraulic Residence Time at Water Quality Design Flow Rate	9 min (18 min for continuous inflow *See Vol. I, Appdx B	1320s or 22min
Min. Length	100ft	186ft
Max. Sideslope	3H : 1V ; 4H : 1V preferred	3H : 1V

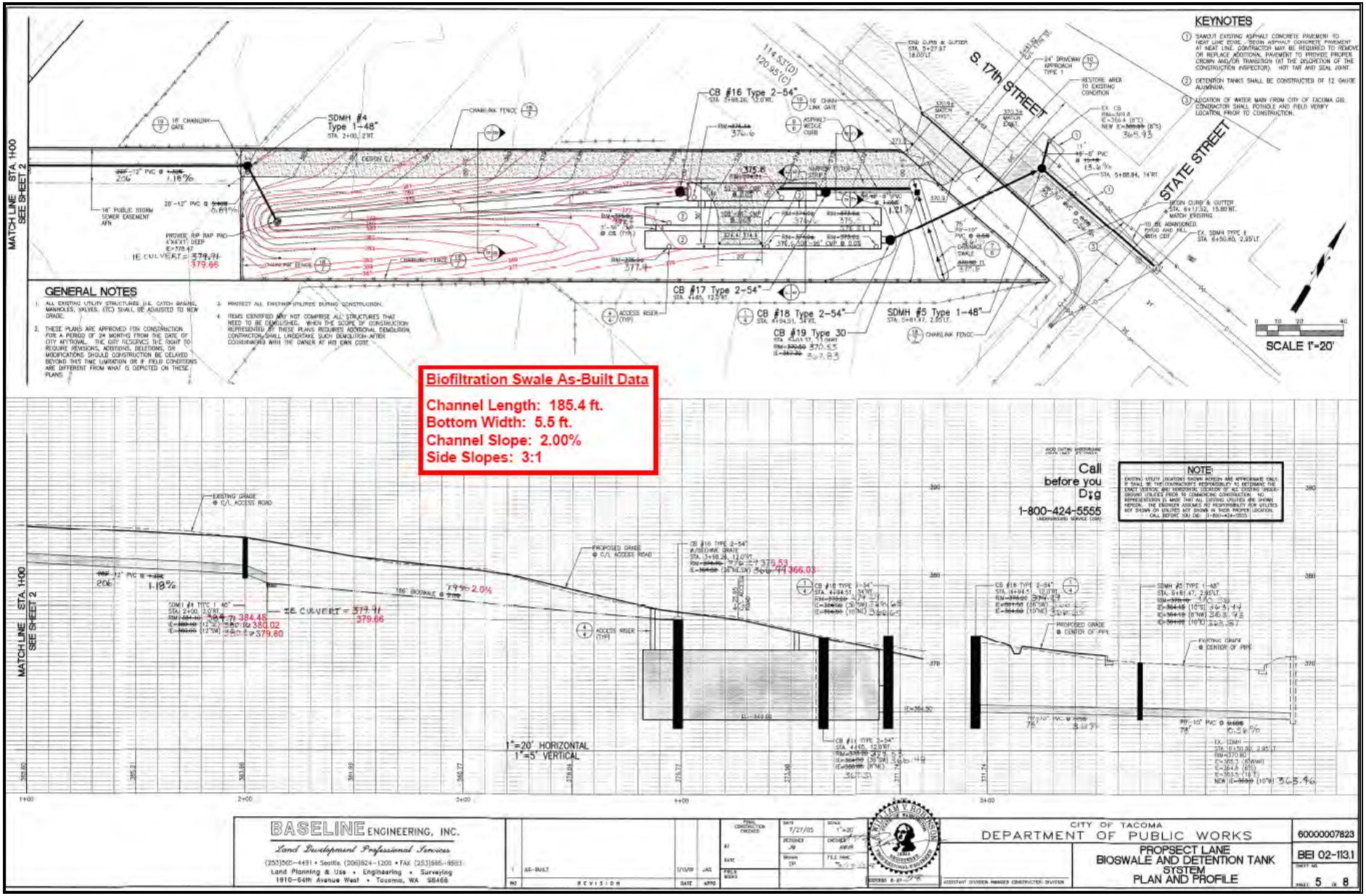
NOTE: The Max. Velocity was determined using WWHM per Appendix C pages 48 & 49 of the SSP.

FIGURE A-2. Trolley Court Drawings

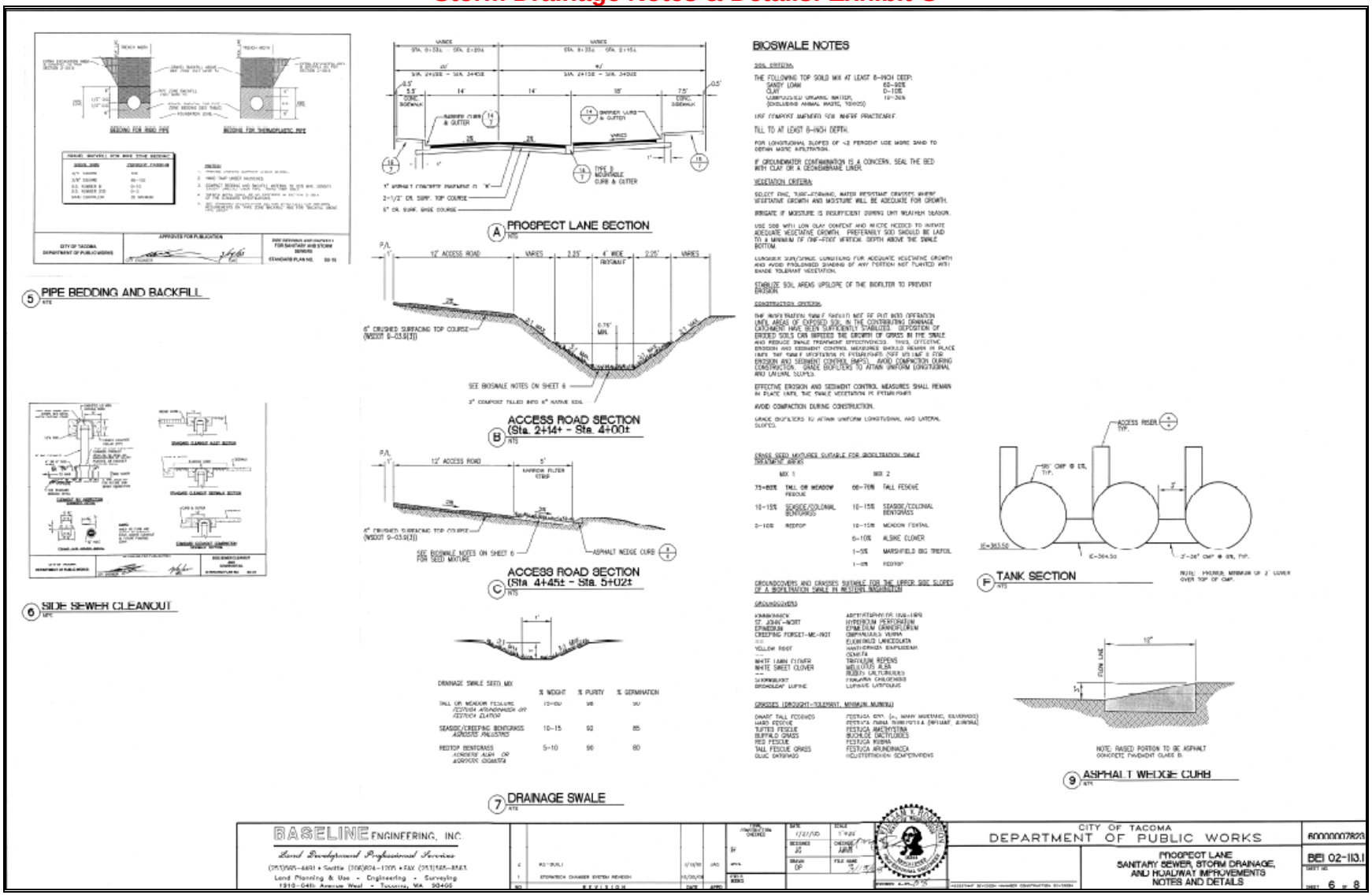
Location Map



Biofiltration Swale & Detention Tank Profile: Exhibit F



Storm Drainage Notes & Details: Exhibit G



Public Flow Restrictor-Oil Pollution Control Device: Exhibit H

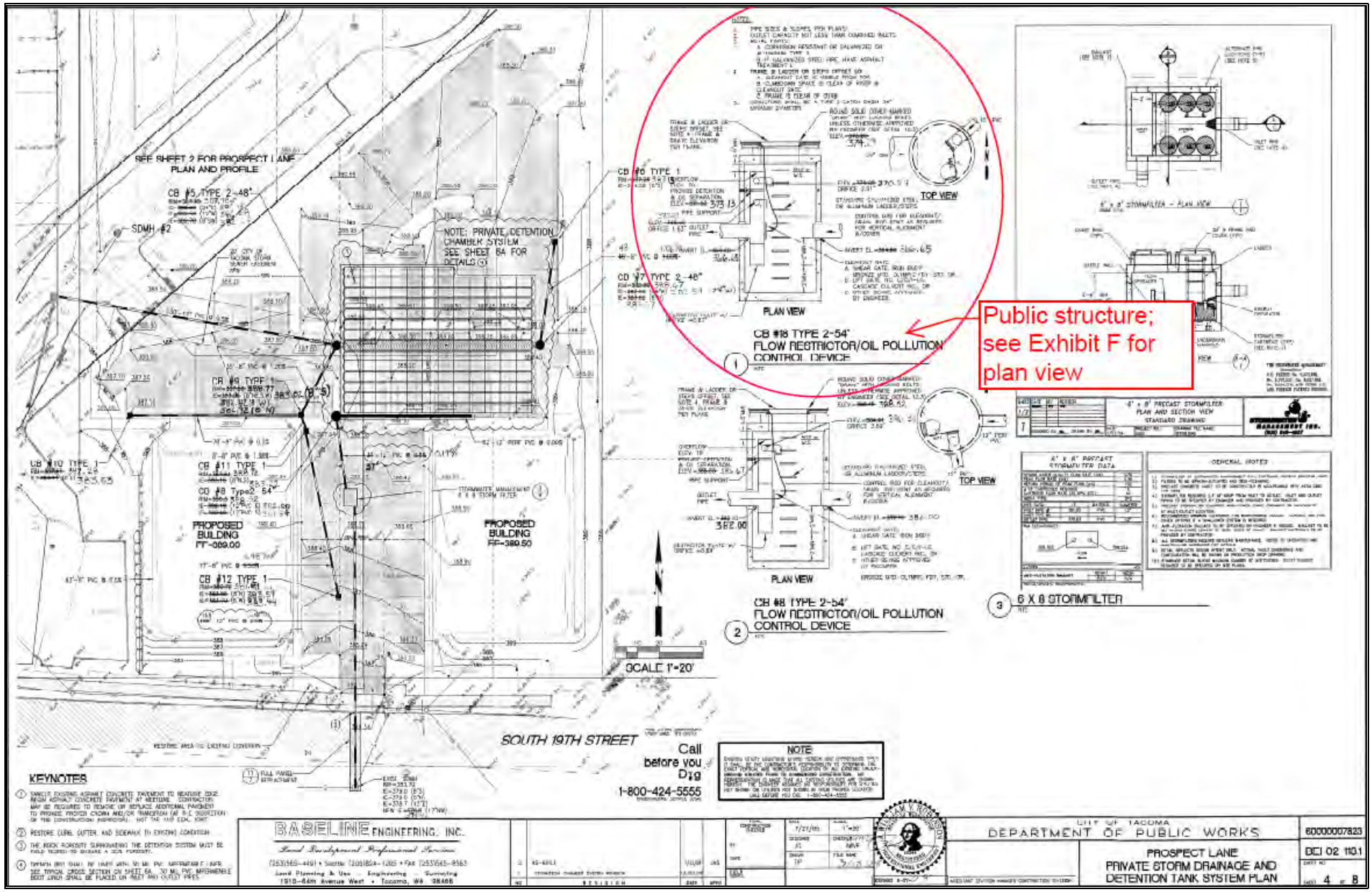


TABLE A-4. E. 32nd Biofiltration Swale Info Requested 2/4/2008 for DOE Evaluation

1	**Drainage area details:**							
1a	**Percentage of area in each Land Use category:**							
		Residential		3.9	acre		***60.00***	***%***
		Commercial		2.6	acre		***40.00***	***%*** ***Not provided; Estimated from visual inspection***
			Total	***6.5***	***acre***			
1b	**Impervious area total:**							
		Residential		N/A	acre	or	N/A	SF
		Commercial		N/A	acre	or	N/A	SF
			Total	***5.23***	***acre***	***or***	***227819***	***SF***
1c	**Type and sizes of impervious areas:**							
		Type		***Residential & commercial pavement & roofs***				
		Sizes		***See 1b above for impervious areas***				
1d	**PGIS :**	***80%***						***Not provided; Estimated from visual inspection***
1e	**Pervious area total:**							
		Residential		N/A	acre	or	N/A	SF
		Commercial		N/A	acre	or	N/A	SF
			Total	***1.31***	***acre***	***or***	***57063.6***	***SF***
1f	**PGPS:**	***N/A***						
1g	**Type of pervious areas:**							
		Open spaces, lawns, parks (>75% grass)						
2	**Design Documentation:**							
2a	**Engineering calculations for sizing the facility:**							
		Appendices of Report 3 on CD.						
2b	**Comparison to all design criteria & sizing required by DOE 2005 manual:**							
		See Table A-5 of this appendix.						
2c	**Drawings showing location, dimensions, influent and effluent conveyances:**							
		See Figure A-3 of this appendix.						
2d	**Verification of the facility as on-line or off-line**							
		If off-line, provide design basis and details of bypass or splitter:						
		The bioswales were designed for the 6-month 24-hr event where all excess flow is routed to a bypass manhole. The system is off-line. Additional information not provided.						

TABLE A-4. Cont.

3 Site Soils and Groundwater (if applicable)

3a High groundwater elevations (especially critical for wetpool designs):

N/A

3b Site soils and pertinent design details

3b1 Liner(s):

No liner.

3b2 Estimated infiltration losses from pond/wetland (?)

N/A

3b3 Documentation of soil analyses (size gradation, CEC, etc) and compost quality if involved in treatment or design water loss:

Existing soils analyses: ***deemed suitable for proposed improvements with geotech's recommendations.***

Soil contains coarse gravel, fine to medium sand with silt, and more. See Report 3 on the CD.

Engineered soils analyses: ***Not provided.***

3c Description of methods & procedures used to determine the long-term bioswale infiltration rates:

Unknown

4 Media Description and Specifications (if applicable)

4a Vegetation species (swales, strips, bioretention, wetlands) and densities:

On November 13th City Environmental Specialists/Biologists performed a preliminary bioswale vegetation identification; see Exhibit L for the technical memorandum. Some grasses can only be identified when growing, thus, the sites will be revisited in the spring (2010).

4b Artificial media types, sizes/gradation, depths (or thickness)

Not provided

4c Sand type, gradation, depth (or thickness)

Not provided

4d Description of any Amendments

Not provided

TABLE A-4. Cont.

5	**Proposed Monitoring Locations**
5a	Percent of drainage area and influent flow tributary to monitoring site ***Unknown since it is off-line. Swales receive 6.5 acres of 7.07 acre area (92% to bioswales pre-bypass)***
6	**O&M Status**
6a	The condition of the facility as compared to the parameters in the Maintenance Table (Table 4.5 of the '05 manual). ***"Operation & Maintenance Manual" Section 6.0 of Report 3 on the CD*** Is comparable to that of DOE pg 9-19 http://www.ecy.wa.gov/pubs/0510033.pdf: Maintenance Criteria • Inspect biofilters at least once every 6 months, preferably during storm events, and also after storm events of > 0.5 inch rainfall/ 24 hours. Maintain adequate grass growth and eliminate bare spots. • Mow grasses, if needed for good growth {typically maintain at 4 – 9 inches and not below design flow level (King County, 1998)}. • Remove sediment as needed at head of the swale if grass growth is inhibited in greater than 10 percent of the swale, or if the sediment is blocking the distribution and entry of the water (King County, 1998). • Remove leaves, litter, and oily materials, and re-seed or resod, and regrade, as needed. Clean curb cuts and level spreaders as needed. Prevent scouring and soil erosion in the biofilter. If flow channeling occurs, regrade and reseed the biofilter, as necessary. Maintain access to biofilter inlet, outlet, and to mowing (Figure 9.8) • If a swale is equipped with underdrains, vehicular traffic on the swale bottom (other than grass mowing equipment) should be avoided to prevent damage to the drainpipes.

TABLE A-5. Design Criteria from DOE BMP T9.10 Basic Biofiltration Swale

BIOFILTRATION SWALE CALCULATOR

Water Quality Equations:

b = Kb * Q * n / (1.49 * y^1.67 * s^0.5) - Z * y
T = b + 2 * y * z
A = b * y + Z * y^2
V = K * Q / A
L = V * t * 60
Vd = Ld / 60 / t
Ad = Q / Vd
bd = (Ad - Z * y * y) / y

Water Quality Variables:

y	=	Depth of Flow (in)	y	3.96	Max. 4; or Max. 2 if Mowed Frequently
y	=	Depth of Flow (ft)	y	0.33	
n	=	Manning's Roughness Coefficient for WQ	n	0.30	0.2-0.3, 0.24 if Mowed Infrequently
Z	=	Side Slope of Trapezoid	Z	3	
Kb	=	Adjustment Factor for Calculating b	Kb	1.0	2.5 for WWHM; 1.0 for SBUH
Q	=	Water Quality Design Flow Rate (cfs)	Q	0.82	SBUH*
s	=	Longitudinal Slope (dimensionless)	s	0.01	Maximum 0.025
b	=	Bottom Width of Trapezoid (ft)	b	10.19	2 to 16
T	=	Top Width of Trapezoid (ft)	T	12.17	
A	=	Cross Sectional Area (sf)	A	3.69	
K	=	Ratio of SBUH Peak / WQ Flow - See Figure 9.6	K	N/A	1 for SBUH; 2.5*(?) for WWHM
V	=	Design Flow Velocity (fps)	V	.22	Vmax = 1.0 (or 0.5 for Filter Strip)
t	=	Hydraulic Residence Time (min)	t	9	9 ; Use 18 for Continuous Inflow
L	=	Swale Length (ft)	L	117	Minimum 100

Sizing Criteria

Design Parameter	BMP T 9.10-Biofiltration Swale	E 32nd St. Final Design Value (w/o κ & 2.5)	E 32nd St. Final Design Value (w/κ & 2.5)
Longitudinal Slope	.015 - .025 ft/ft	.01 ft/ft	.01 ft/ft
Max. Velocity	1 ft/s @ K multiplied by the WQ design flow rate; for stability, 3 ft/s max	.22 ft/s; stability N/A since "offline"	.78 ft/s; stability N/A since "offline"
Max. Water Depth	2"- if mowed frequently; 4" if mowed infrequently	3.96"	3.96"
Manning Coefficient	(0.2 - 0.3); (0.24 if mowed infrequently)	.3	.3
Bed Width (bottom)	2-10ft	10.19ft	10.19ft
Freeboard Height	0.5ft	0.0ft	0.0ft
Min. Hydraulic Residence Time at Water Quality Design Flow Rate	9 min (18 min for continuous inflow *See Vol. I, Appendix B	9min	3min
Min. Length	100ft	117ft	117ft
Max. Sideslope	3H : 1V ; 4H : 1V preferred	3H : 1V	3H : 1V

The designer(s) used the 6-month 24-hr flow event from the SBUH model where $Q_{6\ month}$ is 1.64 cfs, the peak flow. Since there are two identical bioswales this value was divided into two yielding a flow of .82cfs/Swale as shown above.

The alteration to Manning's equation for determining the base width of a trapezoid (the bioswale) in the 2005 DOE manual applies a factor of 2.5 to account for the differential between Water Quality design flow rate and the SBUH design flow. The designer(s) used FlowMaster where the 2.5 factor was not accounted for.

The old DOE and City of Tacoma SWMMs' step for calculating the maximum velocity for Biofiltration Swales reads:

$$V = \frac{Q}{A}$$

Whereas it should have read as follows:

$$V = \frac{\kappa Q}{A}$$

Due to the above error the designer(s) did not account for "κ". If it had been accounted for it would have had a value of "3.5". Without using the "κ" both the hydraulic residence time and the maximum velocity were not "correct" as they are both dependent variables.

TABLE A-6. Flow Splitter Orifice Calcs: Calculation 2 on CD

SDMH #57: CITY OF TACOMA'S ASSESSMENT

THEORETICAL

Equation	Orifice Equation		Q =	CA(2gh)^.5
Given	WQ=	1.64	cfs	NOTE: from SBUH, 6-month 24-hr event
	WQper=	0.82	cfs	
	WQ (110%) =	1.804	cfs	NOTE: didn't design for 110%, just 100%
	C=	0.62	per EIT Book	
	g=	32.2		

Find Dimensions for flow splitter such that:

* A flow splitter must be designed to deliver the WQ design flow rate specified in this volume to the WQ treatment facility.
* The maximum head must be minimized for flow in excess of the WQ design flow. Specifically, flow to the WQ facility at the 100-year water surface must not increase the design WQ flow by more than 10%.

Solve

Diameter, D (in)	Area, A (ft^2)	Head, h (ft)	WQ (cfs)	% of WQ Design Flow
0.5	0.0014			
1	0.0055			
1.5	0.0123			
2	0.0218	57.06655635	0.82	100.00%
2.5	0.0341	23.37446148	0.82	100.00%
3	0.0491	11.27240619	0.82	100.00%
3.5	0.0668	6.084564109	0.82	100.00%
4	0.0873	3.566659772	0.82	100.00%
4.5	0.1104	2.226648137	0.82	100.00%
5	0.1364	1.460903843	0.82	100.00%
5.5	0.1650	***0.997816981***	0.82	100.00%
6	0.1964	0.704525387	0.82	100.00%

TABLE A-6. Cont.

ACTUAL PER COT ENGINEERING TECHS				
Equation	Orifice Equation		WQactual =	CA(2gh)^.5
Given	WQ=	1.64	cfs	NOTE: from WWHM2 using 15-min time steps
	WQper=	0.82	cfs	
	C=	0.62	per EIT Book	
	g=	32.2		
	h=	0.57	ft	
	A=	0.1650	ft^2	
Find	WQactual & % of WQ			
Solve	**WQactual=**	***0.6198***	***cfs***	
	%of WQ=	***75.58***	***%***	Should be no more than 110% of 6-month, 24-hr storm per DOE
CONCLUSION				

Appendix C of Report 3 on the CD shows that Barghausen found that an orifice diameter of 5.5-inches yields a head in the control structure of approximately 1-foot. These calculations were re-run by the City as shown above under "City of Tacoma's (COT's) Assessment" & the calculations found equivalent results. Using Exhibit K on the CD titled “Water Quality Details,” the City utilized the specified orifice diameter to find the corresponding head in the control structure. It was field verified that the installed orifice's diameter is 5.5-inches with a head in control structure value of 0.51-ft.

As shown above in the COT's Assessment of SDMH #57, it was found that the bypass flow is less than the design proposal, thus the WQactual is only 75.58% of the WQ. Therefore, the western bioswale receives less flow than it is supposed to.

TABLE A-6. Cont.

SDMH# 45: CITY OF TACOMA'S ASSESSMENT

THEORETICAL

Equation	Orifice Equation		Q =	CA(2gh)^.5
Given	WQ=	1.64	cfs	NOTE: from SBUH, 6-month 24-hr event
	WQper=	0.82	cfs	
	WQ (110%) =	1.804	cfs	NOTE: didn't design for 110%, just 100%
	C=	0.62	per EIT Book	
	g=	32.2		

Find Dimensions for flow splitter such that:

* A flow splitter must be designed to deliver the WQ design flow rate specified in this volume to the WQ treatment facility.
* The maximum head must be minimized for flow in excess of the WQ design flow. Specifically, flow to the WQ facility at the 100-year water surface must not increase the design WQ flow by more than 10%.

Solve

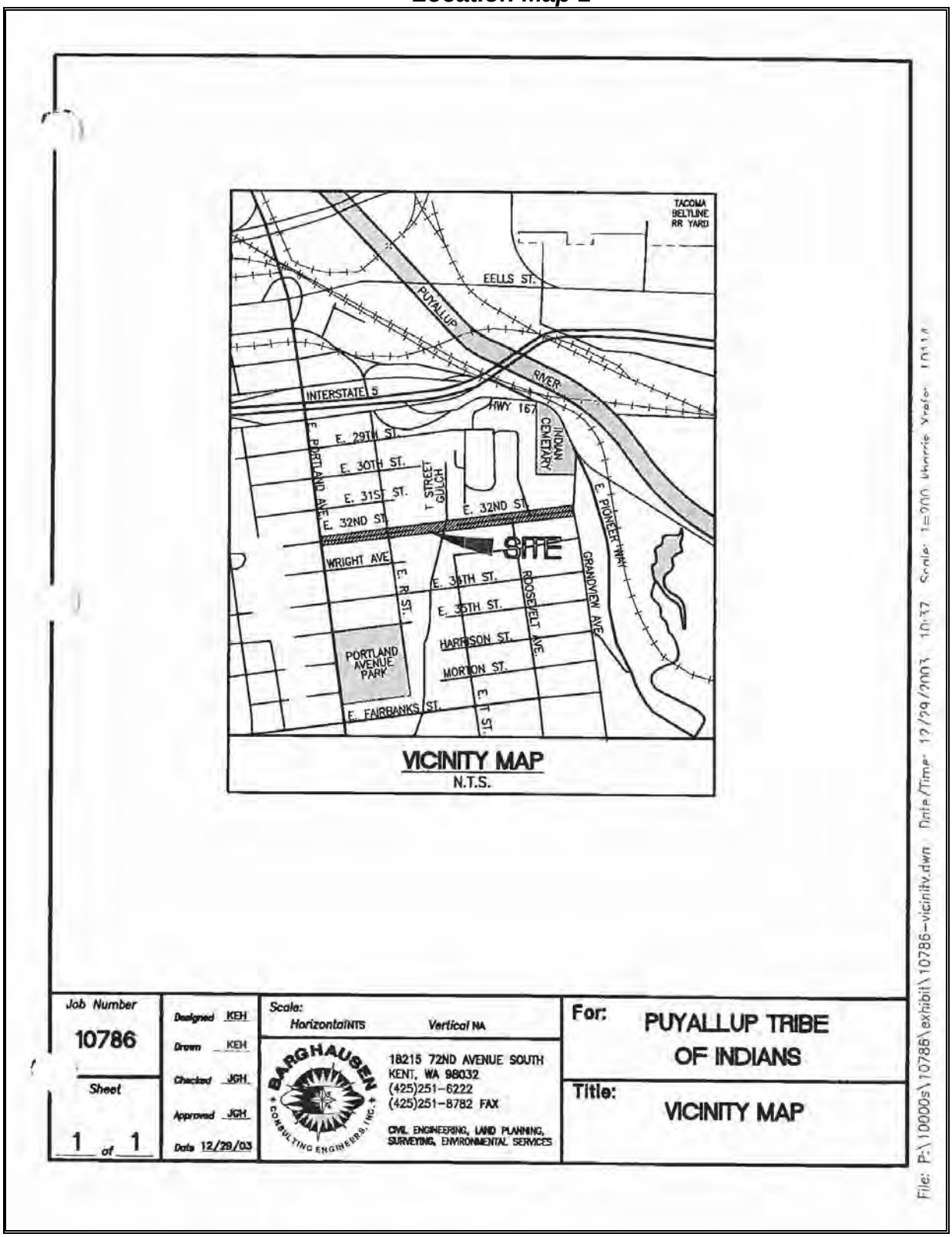
Diameter, D (in)	Area, A (ft^2)	Head, h (ft)	WQ (cfs)	% of WQ Design Flow
0.5	0.0014			
1	0.0055			
1.5	0.0123			
2	0.0218	57.06655635	0.82	100.00%
2.5	0.0341	23.37446148	0.82	100.00%
3	0.0491	11.27240619	0.82	100.00%
3.5	0.0668	6.084564109	0.82	100.00%
4	0.0873	3.566659772	0.82	100.00%
4.5	0.1104	2.226648137	0.82	100.00%
5	0.1364	1.460903843	0.82	100.00%
5.5	0.1650	***0.997816981***	0.82	100.00%
6	0.1964	0.704525387	0.82	100.00%

TABLE A-6. Cont.

ACTUAL PER COT ENGINEERING TECHS				
Equation	Orifice Equation		WQactual =	CA(2gh)^.5
Given	WQ=	1.64	cfs	NOTE: from WWHM2 using 15-min time steps
	WQper=	0.82	cfs	
	C=	0.62	per EIT Book	
	g=	32.2		
	h=	2	ft	
	A=	0.1650	ft^2	
Find	WQactual			
	%ofWQ			
Solve	**WQactual=**	***1.5358***	***cfs***	
	%of WQ=	***187.29***	***%***	Should be no more than 110% of 6-month, 24-hr storm per DOE
CONCLUSION				
	Appendix C of Report 3 on the CD shows that Barghausen found that an orifice diameter of 5.5-inches yields a head in the control structure of approximately 1-foot. These calculations were re-run by the City as shown above under "City of Tacoma's (COT's) Assessment" & the calculations found equivalent results. Using Exhibit K on the CD titled “Water Quality Details,” the City utilized the specified orifice diameter to find the corresponding head in the control structure. It was field verified that the installed orifice's diameter is 5.5-inches with a head in control structure value of 2-ft.			
	As shown above in the COT's Assessment of SDMH #45, it was found that the bypass flow is one foot greater than the design proposal, thus the WQactual is greater than 110% of the WQ. Therefore, the eastern bioswale receives more flow than it is supposed to.			

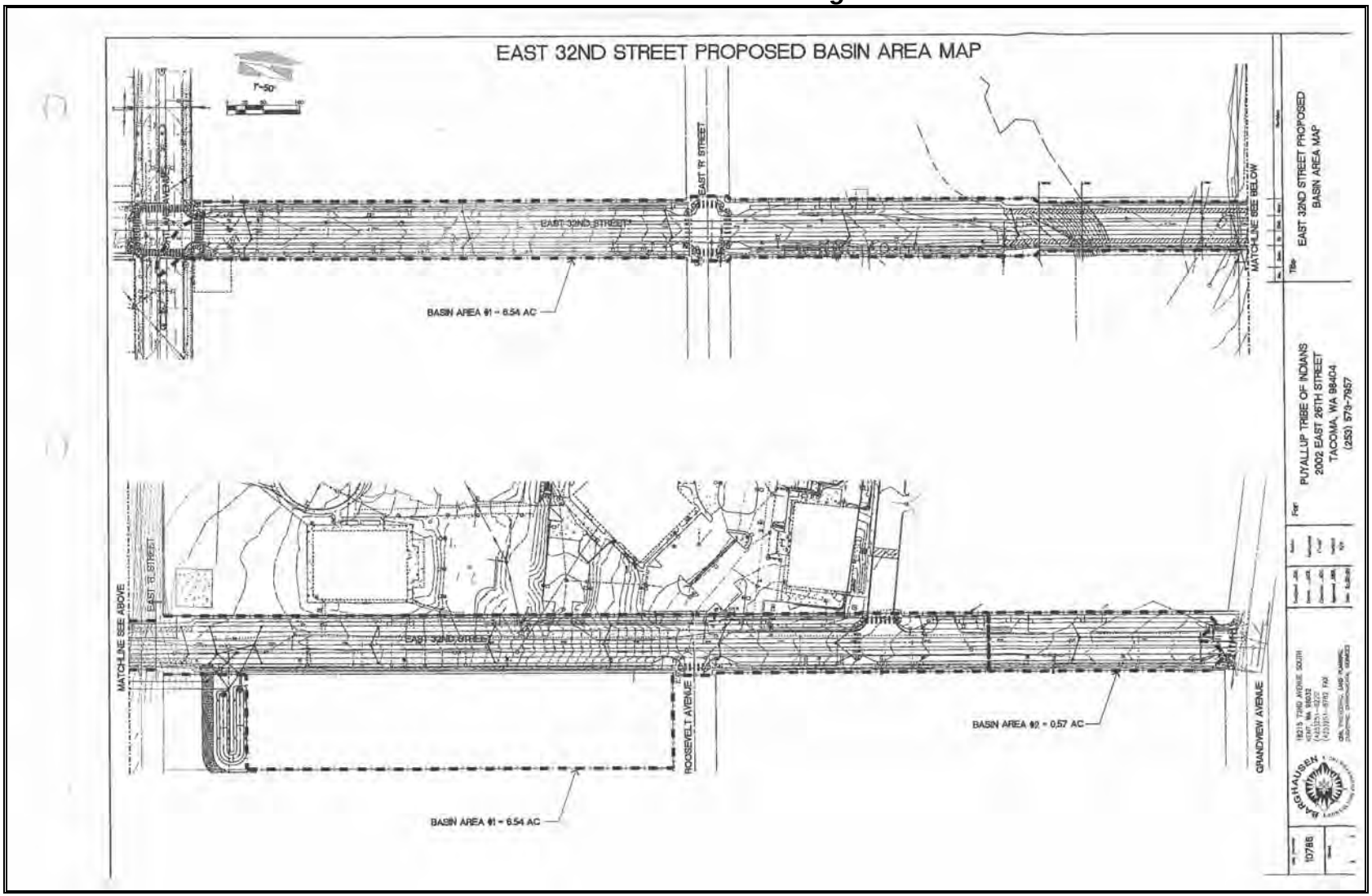
FIGURE A-3. **E. 32nd Drawings**

Location Map 1

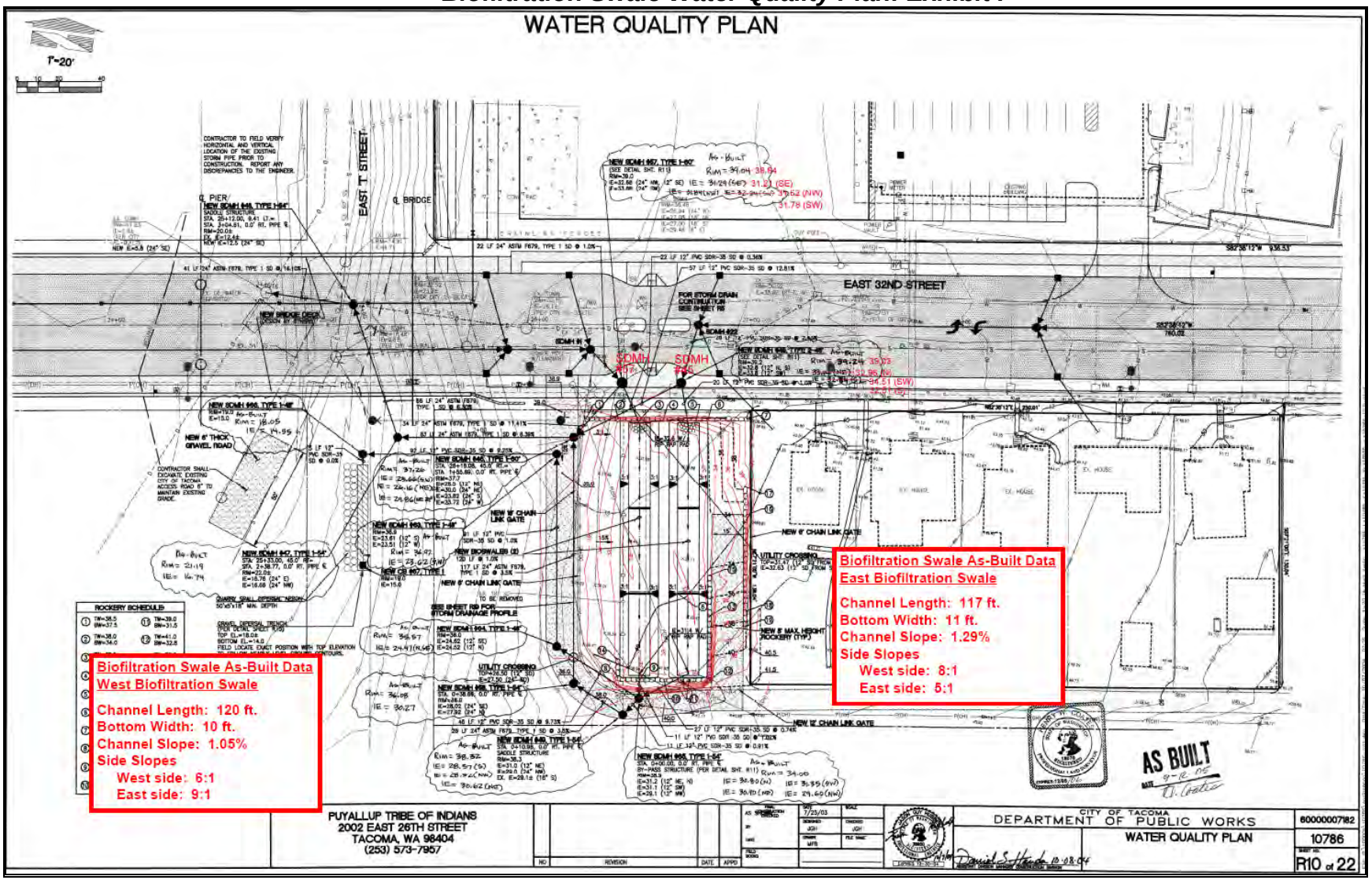


Location Map 2

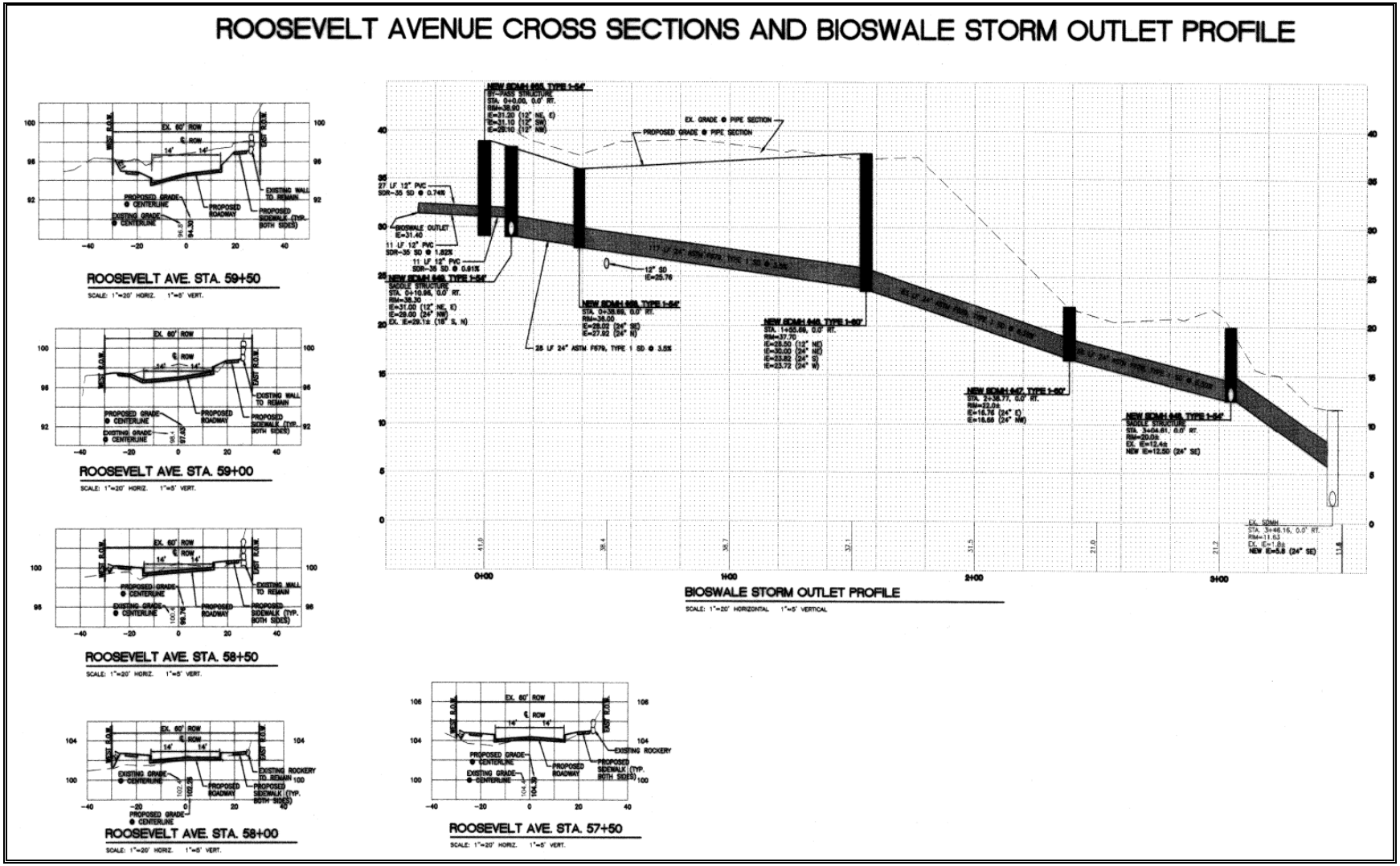
Biofiltration Swales Contributing Basin Area



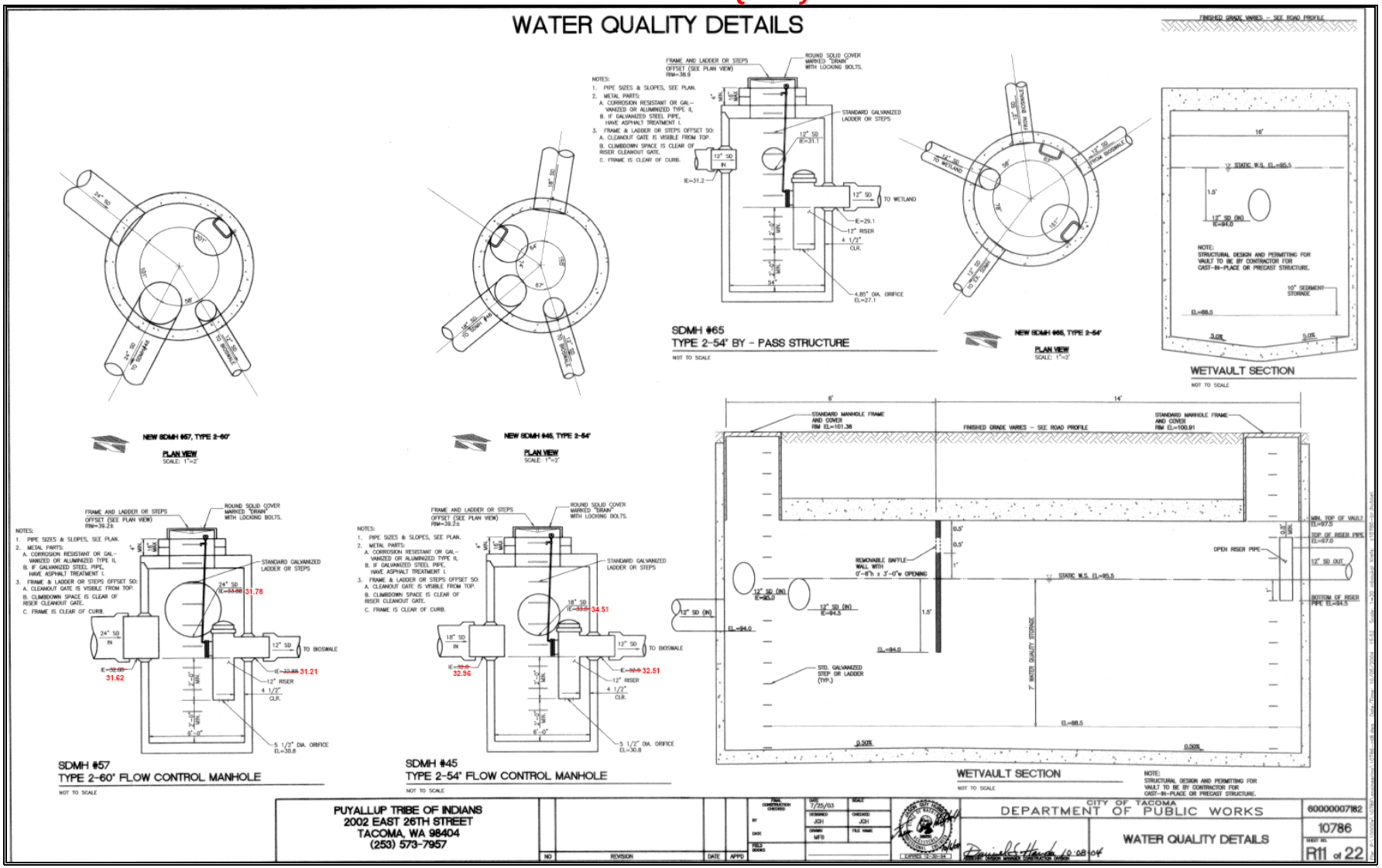
Biofiltration Swale Water Quality Plan: Exhibit I



Biofiltration Swale Outlet Profile: Exhibit J



Biofiltration Swale Water Quality Details: Exhibit K



Preliminary Biofiltration Swale Vegetation Identification: Exhibit L

Department of
Public Works

Technical Memorandum

November 18, 2009

To: Dana B. de Leon, P.E.
From: Karla Kluge, Senior Environmental Specialist

Subject: Bioswale vegetation preliminary identification

Request Description: Detailed description of the vegetation cover in the bioswales located at the 32nd Street Bridge and Trolley court, including specie types growing in the swale bottom and side slopes, as well as an estimate of the percentage of swale covered in vegetation.

I visited the sites with Shannon Stragier, Senior Environmental Specialist, on November 13, 2009.

32nd Street Bridge, Easement 3598 (50003800100, 50003800110, 50003800130)

Sides of Swale:
White clover (*Trifolium repens*)
Red clover (*Trifolium wormskjoldii*)
Cottonwood saplings (*Populus balsamifera*)
Velvet grass (*Holcus sp.)*
Vetch*
Quackgrass (*Agropyron repens*)
Common western dandelion*
Queen Anne's lace (*Daucus carota*)
English plantain (*Plantago lanceolate*)
Curly dock (*Rumex crispus*)
Bitter dock (*Rumex obtusifolius*)
Fireweed (*Epilobium angustifolium*)
Buckwheat (possibly *Polygonum bistortoides*)
Unknown Grass*

Bottom of Swale:
Soft Rush (*Juncus effuses*)
Willow smartweed (*Polygonium lapathifolicem*)
Vetch*
Reed Canary Grass (*Phalaris arundinacea*)
Common western dandelion*
Quackgrass (*Agropyron repens*)
Buttercup (*Ranunculus repens*)
Red clover (*Trifolium wormskjoldii*)
White clover (*Trifolium repens*)
Horsetail*

Ryegrass*
Unknown Grass*

The percentage of vegetation cover in the swale is 90-95%.

In addition to the vegetation noted above, I believe that there is also Tansy Ragwort located in both the bottom and on the sides of the bioswale.

<u>Trolley Court, 1712 State Street (4715014340 and 4715014350)</u>

Sides of Swale: Vetch*
Broadleaf plantain (*Plantago major*)
English plantain (*Plantago lanceolata*)
Himalayan blackberry (*Rubus procerus*)
Red clover (*Trifolium wormskjoldii*)
Velvet grass (*Holcus sp.)*
Thistle (*Cirsium arvense*)
Scotchbroom (*Cytisus scoparius*)
Mint- Bugleweed-(*Lycopus uniflorus*)
Tufted hairgrass (*Deschampsia cespitosa*)
Fireweed (*Epilobium angustifolium*)
Dandelion*
Unknown grass (poa sp.)

Bottom of Swale: Quackgrass (*Agropyron repens*)
Red clover (*Trifolium wormskjoldii*)
Buttercup (*Ranunculus repens*)
Dandelion*
Velvet grass (*Holcus sp.)*
Soft Rush (*Juncus effuses*)
Timothy (*Phleum pretense*)
Reed Canary grass (*Phalaris arundinacea)*
Sweet Vernal grass (*Anthoxanthum odoratum*)
Colonial bentgrass (*Agrostis tenius*)

Percentage of vegetation cover in the swale is 98-100%.

*Due to the lack of inflorescence on many plants and the season, some of the plant identifications described above should be considered preliminary until I am able to return to the site and verify them, especially the grasses. Grasses should be identified in the growing/flowering season, and I can not identify the unknown grass species at this time to determine if the grass represents the seed mix used in construction.

I recommend that a follow-up site visit occur in the spring after flowering starts to evaluate and confirm these preliminary plant identifications. Mowing of the bioswale should temporarily cease to allow the grass to flower prior to my next site visit. Please contact me in the spring to conduct a follow-up site visit.

Appendix B
Tacoma Landfill Pervious Pavements Details

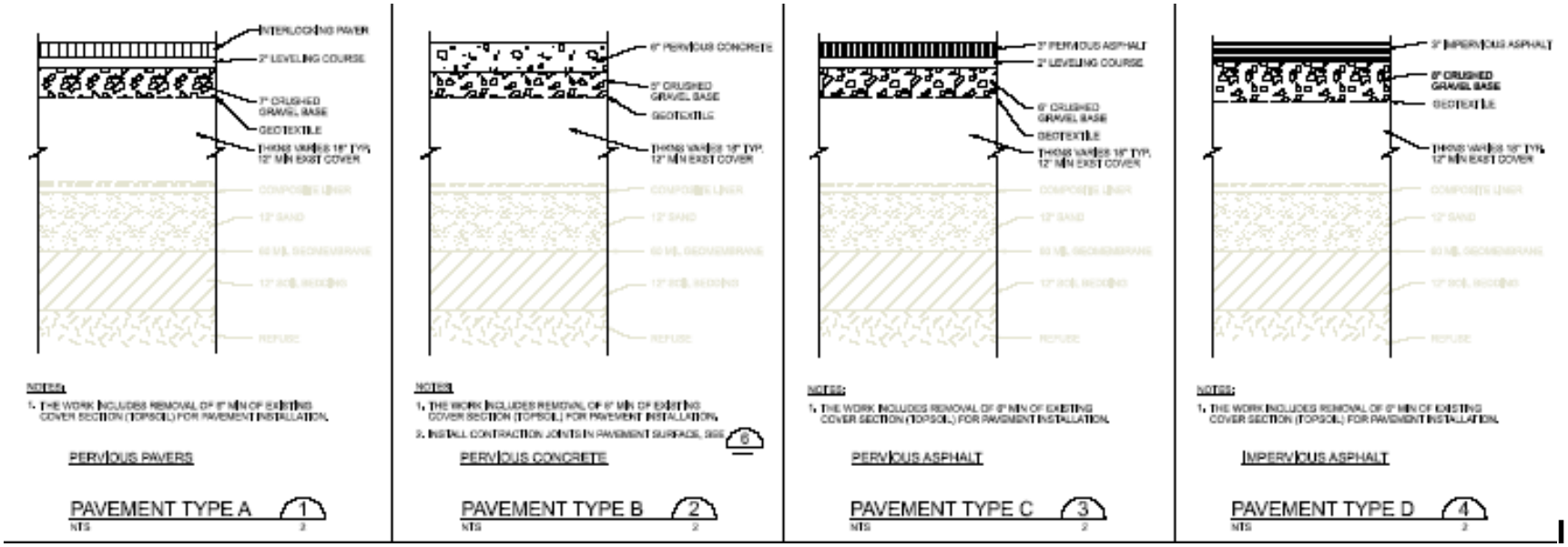
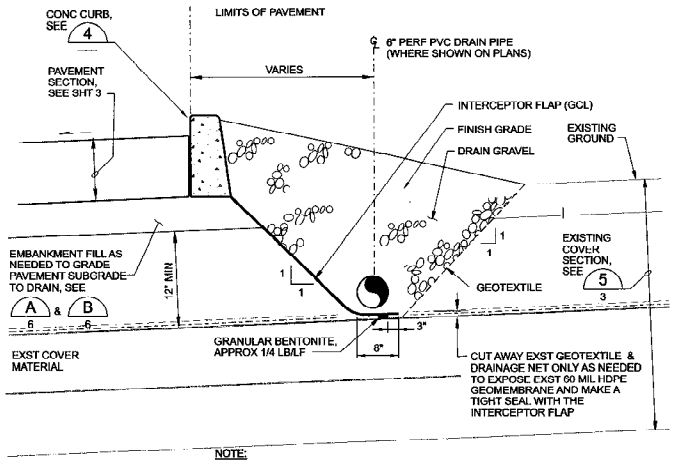


Figure B-1. Typical Cross Section for Standard Asphalt and Pervious Pavements

Hydraulic Separation between the Standard Asphalt & Pervious Pavement Cells

As shown on Details 1, 3, and 6 on Sheet 4 of the Plans (see Figure B-2), the parking lot is isolated from adjacent flows using an interceptor flap. This flap consists of a geosynthetic clay liner (GCL) which is connected to the existing HDPE landfill liner using granular bentonite. When subsurface flows from surrounding areas reach the parking lot area, they are stopped by the GCL and are collected in a 6" perforated PVC pipe. These flows are conveyed around the parking lot and discharged downstream.

Subsurface flows between the pavement test sections are also isolated using a GCL flap as shown in Detail 7 on Sheet 4 of the Plans (see Figure B-2). Surface flows are prevented from moving between pavement sections via a concrete curb.

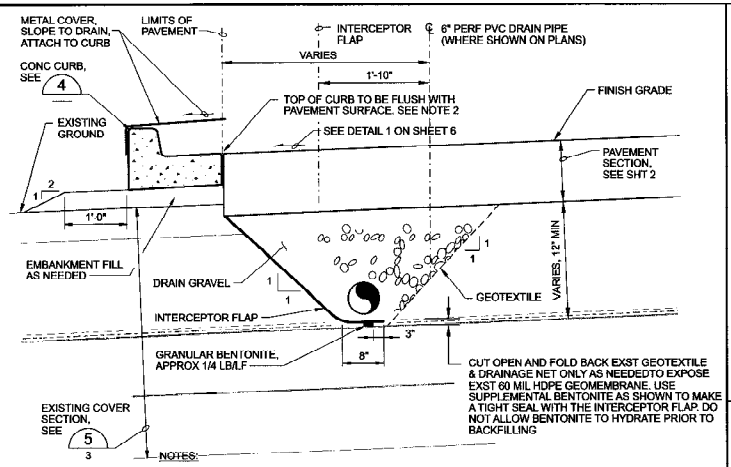


NOTE:

DO NOT CUT OR OTHERWISE DAMAGE EXISTING GEOMEMBRANE. CONTRACTOR SHALL REPAIR ANY DAMAGE AT HIS OWN EXPENSE.

EAST INTERCEPTOR FLAP & DRAIN PIPE (1)

NTS 2, 6

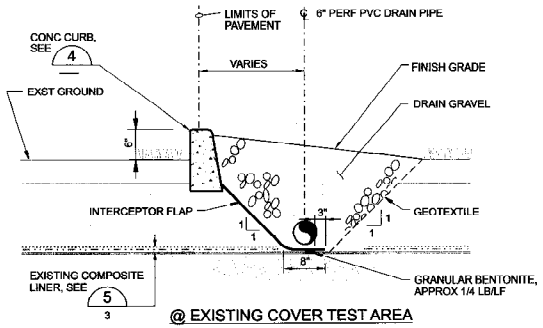


NOTES:

1. DO NOT CUT OR OTHERWISE DAMAGE EXISTING GEOMEMBRANE.
2. PROVIDE RAISED BERM AND CLOSED CHANNEL AT ACCESS ROAD CROSSINGS AS NEEDED TO DIVERT SW RUN-OFF TO THE DRAINAGE CHANNELS, SEE

WEST INTERCEPTOR FLAP & DRAIN PIPE (3)

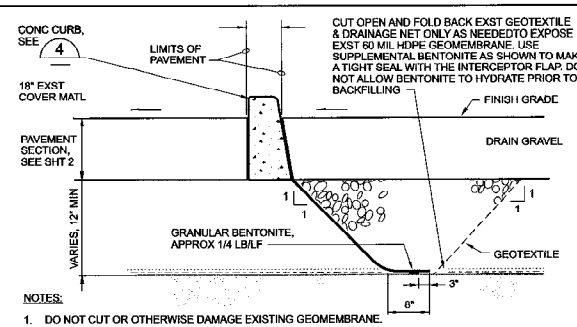
NTS 2, 4, 6



@ EXISTING COVER TEST AREA

SOUTH INTERCEPTOR FLAP (6)

NTS 2, 5



NOTES:

1. DO NOT CUT OR OTHERWISE DAMAGE EXISTING GEOMEMBRANE.
2. PLACE CURB AND INTERCEPTOR FLAP BETWEEN PAVEMENTS TO ISOLATE SURFACE WATER RUN-OFF.
3. PLACE ASPHALT BERMS OVER CURBS IN ALL DRIVING LANES, SEE D 5

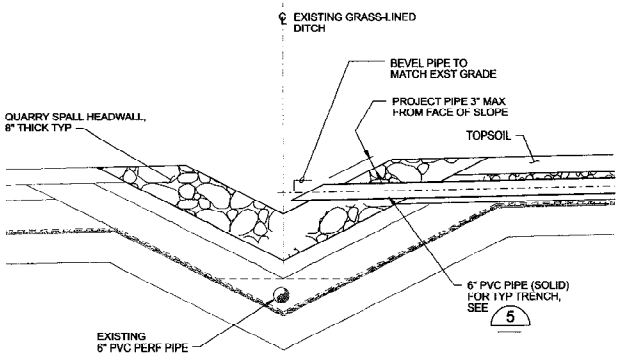
BETWEEN PAVEMENT AREAS

INTERMEDIATE INTERCEPTOR FLAP (7)

NTS 2, 6

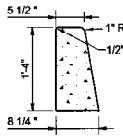
NOTE:

1. EXTEND QUARRY SPALLS 5'-0" EACH SIDE OF CULVERT CENTERLINE.



DISCHARGE TO EXISTING GRASS-LINED DITCH (2)

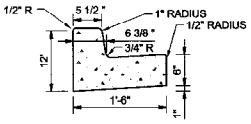
NTS 2



CEMENT CONCRETE TRAFFIC CURB

NOTES:

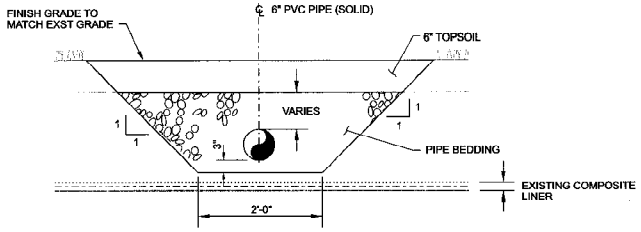
1. CURBS ARE WSDOT STANDARD PLAN F-1.
2. CONTRACTOR IS RESPONSIBLE FOR SETTING AND SECURING CONCRETE CURBS TO ONE ANOTHER AND TO THE PAVEMENT AREAS SO THAT THE COMBINED AREAS FUNCTION AS A UNIFORMLY SLOPING INTEGRAL SLAB HAVING THE DIMENSIONS, ELEVATIONS AND SURFACE GRADES AS SHOWN IN 1/6



CEMENT CONCRETE TRAFFIC CURB AND GUTTER

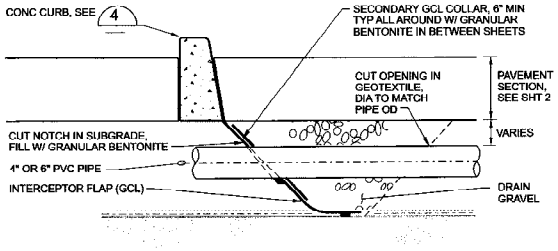
PRECAST CONCRETE CURBS (4)

NTS



TYPICAL PIPE TRENCH (5)

NTS 6



PIPE PENETRATION @ INTERCEPTOR FLAP (8)

NTS 5

NO	REVISION	DATE	APPD
1	FOR BID	7-30-05	CLE

CH2MHILL

Tacoma

FINAL CONSTRUCTION CHECKED BY DATE FIELD BOOKS

DATE MAY 2005 | SCALE NTS | DESIGNED CLE | CHECKED BD | DRAWN | PROJECT NAME 326982 | DRAWING NAME 326982 details dwg 4.dgn

28-II IN-2005 12:42:50

7-21-05

EXPIRES 3/31/06

ENGINEERING DIVISION MANAGER

CITY OF TACOMA
DEPARTMENT OF PUBLIC WORKS

Tacoma Landfill Employee Parking Lot Expansion & Pervious Pavement Demonstration Project
INTERCEPTOR DETAILS

ENV-00205

SHEET NO. 4

SHEET 4 OF 10

Appendix C
National Stormwater BMP Database Requirements

Table C-1. National Stormwater BMP Database requirements for all BMPs.

Data Element	Description
General Test Site Information	
BMP Test Site Name	Name that site is known by locally.
City	City closest to test site.
State	State where test was performed.
Zip Code	Zip code of the test site.
Country	Country where the test site is located.
Altitude	Altitude to nearest 100 ft or 30 m.
Sponsoring and Monitoring Agencies for Test Site	
Address	Includes monitoring and sponsoring agency name and contact information.
Watershed Information	
Subject Watershed Name	Name that watershed is referred to locally.
Total Watershed Area	Topographically defined area drained by system.
Percent (%) Impervious Area	Total percent of impervious surface in watershed.
Regional Climate Station (US)	Regional climate station in US that is most relevant to test site.
Land Use Information	Description of land uses (only required for non-structural BMPs).
Monitoring Stations	
Station	User-defined name for subject monitoring station.
Identify Upstream BMP	BMP upstream of the monitoring point (if any).
Identify Relationship to Upstream BMP	Identify the relationship of the monitoring station to the upstream BMP (i.e. inflow, outflow or not applicable).
Identify Downstream BMP	BMP downstream of the monitoring point (if any).
Identify Relationship to Downstream BMP	Identify the relationship of the monitoring station to the downstream BMP (i.e. inflow, outflow or not applicable).
Monitoring Instrumentation	
Monitoring Station Name	Select monitoring station where the instrument is located.
Precipitation Data	
Monitoring Station Name	Identify monitoring station where precipitation event was monitored.
Storm Runoff and Base Flow Data	
Monitoring Station Name	Select monitoring station where flow event was monitored.
Type of Flow	Base flow or stormwater runoff.
Flow Start Date	Month, day and 4-digit year (e.g. 01/01/1998).
Total Bypass Volume (if any)	Total runoff volume minus runoff volume influent to BMP.
Total Storm Flow Volume into or from BMP	Total runoff volume minus the bypass volume.
Dry Weather Base Flow Rate	Flow rate during dry-weather conditions.

Table C-1. National Stormwater BMP Database requirements for all BMPs. (continued).

Water Quality Sampling Event	
Monitoring Station Name	Select monitoring station where samples were collected.
Related Flow-Event	Select flow data corresponding to water quality data.
Date Water Quality Sample Collected	Month, day and 4-digit year the water quality sample was collected.
What Medium Does the Instrument Monitor	e.g. Groundwater, surface runoff.
Water Quality Parameters	STORET water quality parameters analyzed.
Value	Value of measured constituent.
Unit	Units of measured constituent.
Qualifier	Select STORET qualifier code.

Table C-2. National Stormwater BMP Database requirements for structural BMPs.

Data Element	Description
Structural BMP Information	
Structural BMP Name	Common name by which BMP is referred to locally.
Structural BMP Type	Select the type of BMP being monitored at the site (drop-down list).
Date Facility Was Put Into Service	Month, day and 4-digit year facility became operational.
Number of Separate Inflows	Number of inflows into the facility.
Describe the Type and Design of Each BMP Outlet	Description of the outlet configuration (i.e. Perforated riser).
Is the BMP Designed to Bypass When Full?	Select "Overflow" or "bypass" characteristics of BMP.
BMP Drawing	Plan view and profile of BMP (in bitmap format for database).

Table C-3. National Stormwater BMP Database requirements for individual structural BMPs.

Data Element	Description
Wetland Channel and Swale Design Data	
Length of Channel/Swale	Length of channel or swale from stormwater inflow to outflow point.
Longitudinal Slope of Channel/Swale	Measured slope between grade control structures in swale.
Bottom Width of Channel /Swale	Average width between side slopes.
Side Slope of Channel Swale	Average slope of swale sides.
2-Year Flow Design Depth in Channel/Swale	Average depth of water in channel/swale during 2-yr flow.
2-Year Peak Design Flow Velocity	Design velocity for 2-yr flow.
Type of Plant Species in Wetland Zone or Swale	List and description of plant species, percent of cover and densities.
Media Filter Design Data	
Permanent Pool Volume, Upstream of Filter Media (if any)	Volume of the permanent pool, if pool is part of filter basin.
Permanent Pool Surface Area	Area of water surface of permanent pool.
Permanent Pool Length	Distance between inflow and outflow (average for multiple inflows).
Surcharge Detention Volume	The design water quality detention volume, including the volume above the filter.
Surcharge Detention Volume Surface Area	The surface area of the design water quality capture volume.
Surcharge Detention Volume's Design Drain Time	The drain time (in hours) of the water quality capture volume.
Surcharge Detention Volume Design Depth	Depth of water quality capture volume.
Media Filter Surface Area	Surface area of the media filter.
Angle of Sloping or Vertical Filter	Inclination of filter in degrees above the horizontal plane.
Number of Media Filter Layers	Number of layers of different filter material in BMP.
Describe Depth and Type of Each Filter Media Layer	Description of the type and depth of media used in the filter.

Appendix D
Sampling Equipment Specifications

Isco Product Data

Isco 2150 Area Velocity Flow Module

The 2150 Flow Module uses continuous wave Doppler technology to measure mean velocity. The sensor transmits a continuous ultrasonic wave, then measures the frequency shift of returned echoes reflected by air bubbles or particles in the flow.

The 2150's "smart" area velocity probe is built on digital electronics, so the analog level is digitized in the sensor itself to overcome electromagnetic interference. The probe is also factory-calibrated for 10-foot (3 meter) span at different temperatures. This built-in calibration eliminates drift in the level signal, providing long-term level stability that reduces recalibration frequency and completely eliminates span recalibration.

In field use, the 2150 is typically powered either by two alkaline, or Isco Rechargeable Lead-acid batteries, within a 2191 Battery Module. Highly efficient power management extends battery life up to 15 months at 15-minute data storage intervals. Other power options (including solar) are available.

Applications

- Portable and permanent-site AV flow monitoring for inflow and infiltration, capacity assessment, sewer overflow, and other sewer studies.
- Measuring shallow flows in small pipes. Our low-profile area velocity sensor minimizes flow stream obstruction and senses velocity in flows down to 1 inch (25 mm) in depth.

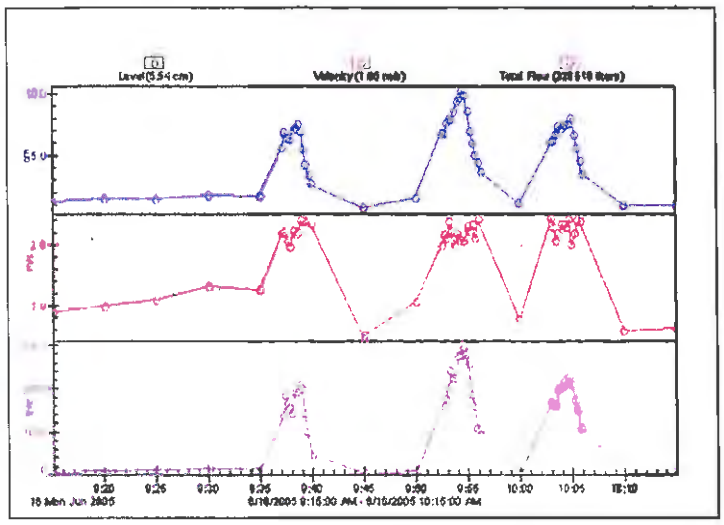
Standard Features

- Rugged, submersible enclosure meets NEMA 4X, 6P (IP68) environmental specs.
- Chemically resistant epoxy-encapsulated sensor withstands abuse, resists oil and grease fouling, and eliminates the need for frequent cleaning.
- Replaceable high-capacity internal desiccant cartridge and hydrophobic filter protect sensor reference from water entry and internal moisture.
- Pressure transducer vent system automatically compensates for atmospheric pressure changes to maintain accuracy.
- The quick-connect sensor can be easily removed and interchanged in the field without requiring recalibration.
- Up to four 2100 Series flow modules can be networked by stacking and/or extension cables.

Above left: Additional modules can be added for redundant or multi-stream measuring (Isco 2110 Ultrasonic Module shown). Right: Optional mounting rings provide quick, secure sensor installation in round pipes from 6 to 80 inches (150 to 2000 mm).

Software Features

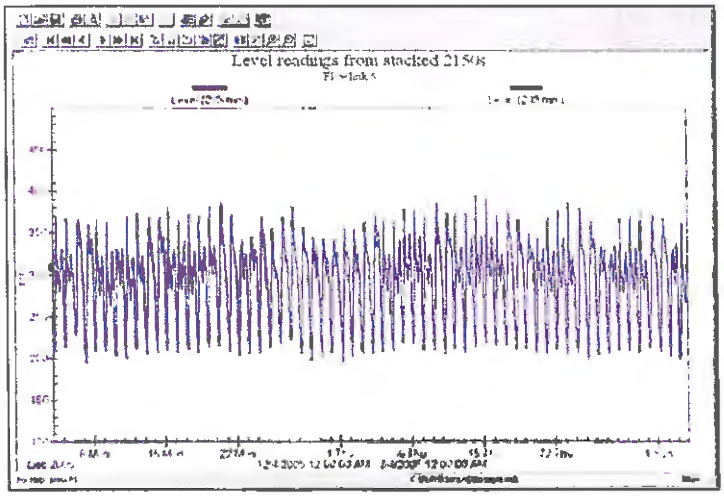
- Secure data storage. All data are continuously stored in flash memory to protect against loss in case of power failure
- Easy to upgrade. New operating software can be downloaded into non-volatile flash memory, without affecting stored program and data.
- Records and stores input voltage and temperature data.
- Variable rate data storage lets you change the data storage interval when programmed conditions occur. This feature assures maximum information about an exceptional event – such as an overflow – while conserving power and data capacity during normal conditions.
- 38,400 bps communication provides speedy setup and data retrieval.



Variable rate data storage

The 2150 flow module has the ability to automatically switch data storage rates based on varying conditions.

In the example at left, the 5-minute data storage rate automatically changed to 30 seconds when the flow rose above a programmed level.



Level stability

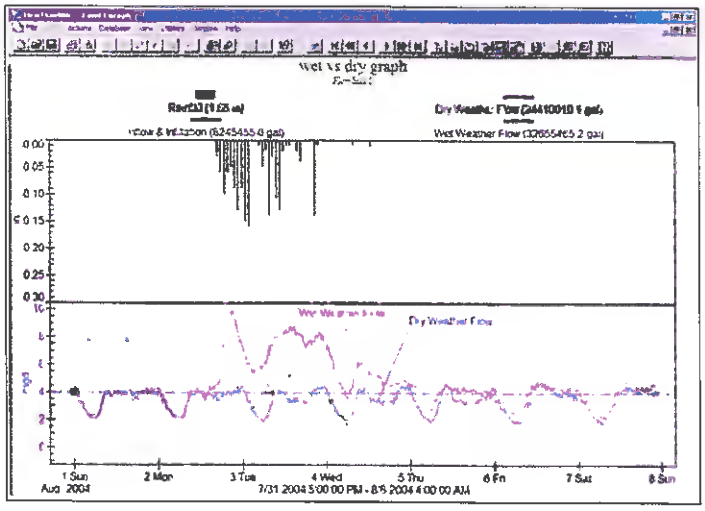
Frequent multipoint level recalibration is a requirement with other area velocity flow meters. Isco's exclusive "smart" sensor design in the area velocity probe yields exceptionally low drift in the level signal.

The 2150's factory-calibrated 3-meter span totally eliminates the need for cumbersome span recalibration in the field.

In the example at left, two area velocity probes were installed at the same site. The level readings from both sensors track closely without any drift, over an 8-week period.

Flowlink® Data Analysis

Isco Flowlink® Software is a powerful tool for analyzing flow and water quality data. It provides site setup, data retrieval, and comprehensive data analysis, as well as advanced reporting and graphing. See separate datasheets for details on Flowlink and Flowlink Pro software.



The Flowlink screen shown above gives a comparison of dry and wet weather flows, plus rainfall typical of an inflow & infiltration study

Information Delivery

Isco 2100 Series Flow Modules offer a wide variety of communication and retrieval options, to minimize the need for expensive on-site visits and confined space entry. These include:

Isco 2103 Land-line Modem Module
Reliable two-way dial-up communication between down-hole 2100 Flow Modules and your desktop computer, equipped with Isco Flowlink Software. A dial-out feature enables the system to transmit a text message alarm to your digital cell phone or pager.

Isco 2103c Cellular Modem Module
All the features of the 2103 Modem with the convenience of cell phone access. And the 2103c can automatically send data via the Internet to a designated server running Flowlink Pro software, using economical 1xRTT packet-switched data transmission.

Isco 2108 Analog Output Module
Provides current outputs for use with Isco 2100 Series Area Velocity and Ultrasonic Flow Modules. It allows easy interface with SCADA/DCS or other secondary instrument systems.

Modbus
2100 Series Flow Modules provide digital RS 232 Modbus output that can be used to interface with external communication modules, SCADA systems, or other devices.

On-site Data Retrieval

Isco Flowlink Software
Download and process data on-site. Enjoy unmatched data management capability, advanced data editing and analysis, powerful reporting and presentation choices, and a variety of downloading and data handling options.

Isco 2101 Field Wizard
A durable, weatherproof module for on-site data retrieval. Don't risk damage to your fragile notebook PC. The 2101 Field Wizard provides on-site display of current readings, information about stored data, diagnostics, and more.

Interrogate all 2100 Series Flow Modules in the stack at one time, and store more than 14 days' data from up to 20 modules!

Isco 2102 Communication Module
Connect with your Isco 2100 Series Flow Modules from the safety and convenience of your vehicle.

Digital spread-spectrum radio signals enable "drive-up" data retrieval, system configuration, and level calibration, with minimum power consumption. "Plug and Play" setup – no interfacing needed.

Specifications

2150 Flow Module	
Size (HxWxD):	2.9 x 11.3 x 7.5 in (74 x 287 x 191 mm)
Weight:	2.0 lb (0.9 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self-certified):	NEMA 4X, 6P (IP68)
Temperature Range:	-40° to 140° F (-40° to 60° C) operating and storage
Power Required:	12 VDC nominal (7.0 to 16.6 VDC), 100 mA typical, 1 mA standby
Power Source:	Typically, an Isco 2191 Battery Module, containing 2 alkaline or 2 rechargeable lead-acid batteries. (Other power options are available; ask for details.)
Typical Battery Life:	Using 15-minute data storage interval Energizer® Model 529 alkaline - 15 months Isco rechargeable lead-acid - 2.5 months
Program Memory:	Non-volatile programmable flash; can be updated using PC without opening enclosure; retains user program after updating.
Built-in Conversions	
Flow Rate Conversions:	Up to 2 independent level-to-area conversions and/or level-to-flow rate conversions.
Level-to-Area Conversions:	Channel Shapes - round, U-shaped, rectangular, trapezoidal, elliptical, with silt correction; Data Points - Up to 50 level-area points.
Level-to-Flow Conversions:	Most common weirs and flumes; Manning Formula; Data Points (up to 50 level-flow points); 2-term polynomial equation
Total Flow Calculations:	Up to 2 independent, net, positive or negative, based on either flow rate conversion
Data Handling and Communications	
Data Storage:	Non-volatile flash; retains stored data during program updates. Capacity 395,000 bytes (up to 79,000 readings, equal to over 270 days of level and velocity readings at 15-minute intervals, plus total flow and input voltage readings at 24-hour intervals)
Data Types:	Level, velocity, flow rate 1, flow rate 2, total flow 1, total flow 2, input voltage, temperature
Storage Mode:	Rollover; 5 bytes per reading.
Storage Interval:	15 or 30 seconds; 1, 2, 5, 15, or 30 minutes; or 1, 2, 4, 12, or 24 hours Storage rate variable based on level, velocity, flow rate, total flow, or input voltage
Data Retrieval:	Serial connection to PC or optional 2101 Field Wizard module; optional modules for spread spectrum radio; land-line or cellular modem; 1xRTT, Modbus and 4-20 mA analog available.
Software:	Isco Flowlink for setup, data retrieval, editing, analysis, and reporting
Multi-module networking:	Up to four 2100 Series Flow Modules, stacked and/or remotely connected. Max distance between modules 3300 ft (1000 m).
Serial Communication Speed:	38,400 bps

2150 Area Velocity Sensor	
Size (HxWxD):	0.75 x 1.3 x 6.0 in (19 x 33 x 152 mm)
Cable (Length x Diameter):	25 ft x 0.37 in (7.6 m x 9 mm) standard. Custom lengths available on request.
Weight (including cable):	2.2 lbs (1 kg)
Materials of construction:	Sensor - Epoxy, chlorinated polyvinyl chloride (CPVC), stainless steel Cable - Polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC)
Operating Temperature:	32° to 140° F (0° to 60° C)
Level Measurement:	Method - Submerged pressure transducer mounted in the flow stream Transducer Type - Differential linear integrated circuit pressure transducer Range (standard) 0.033 to 10 ft (0.010 to 3.05 m); (optional) up to 30 ft (9.15 m). Maximum Allowable Level 34 ft (10.5 m) Accuracy ±0.01 ft from 0.033 to 10 ft, (±0.003 m from 0.01 to 3.05 m,) Long-Term Stability ±0.023 ft/yr (±0.007 m/yr) Compensated Range 32° to 122°F (0° to 50°C)
Velocity Measurement:	Method - Doppler ultrasonic, frequency 500 kHz Typical Minimum Depth 0.08 ft (25 mm) Range -5 to +20 ft/s (-1.5 to +6.1 m/s) Accuracy (in water with uniform velocity profile, speed of sound = 4850 ft/s, for indicated velocity range) ±0.1 ft/s from -5 to 5 ft/s (±0.03 m/s from -1.5 to +1.5 m/s) ±2% of reading from 5 to 20 ft/s (1.5 to 6.1 m/s)
Temperature Measurement:	Accuracy ±3.6° F (±2° C)

2191 Battery Module	
Size (HxWxD):	6.0 x 9.6 x 7.6 in (152 x 244 x 193 mm)
Weight (without batteries):	3.2 lb (1.4 kg)
Materials of construction:	High-impact polystyrene, stainless steel
Enclosure (self certified):	NEMA 4X, 6P, (IP68)
Batteries:	Two 6-volt Energizer Model 529* alkaline (25 Ahrs capacity) or Isco Rechargeable Lead-acid (5 Ahrs capacity) recommended. *Note – Energizer 529 ER does not give specified life.

2150 Ordering Information

Contact your Teledyne Isco representative for complete ordering details and information on other 2100 Series Modules.

Description	Part No.
2150 with AV sensor, 2191 Battery Module, and Handle	68-2050-002
2150 Module with AV sensor (only)	68-2050-001
Isco Flowlink® 5 Software	68-2540-200
Energizer® Model 529 Alkaline Lantern Battery (2 required)	340-2006-02
Isco Rechargeable Lead-acid Battery (2 required)	60-2004-041
Charger for Lead-acid Batteries (holds 2 batteries)	60-2004-040

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Isco Product Data

Isco 6712 Full-size Portable Sampler

Isco's 6700 Series Portable Samplers have set the industry standard, providing the most comprehensive and durable performance available. With the introduction of our new 6712, Isco takes another step toward the ultimate by including SDI-12 interface capabilities.

This full-size portable lets you take full advantage of the advanced 6712 Controller, with its powerful pump, versatile programming, and optional plug-in modules for integrated flow measurement. Setup is fast and simple, with online help just a key stroke away.

The environmentally-sealed 6712 controller delivers maximum accuracy and easily handles all of your sampling applications, including:

- Flow-paced sampling with or without wastewater effluent
- stormwater monitoring
- CSO monitoring
- permit compliance
- pretreatment compliance

In the Standard Programming Mode, the controller walks you through the sampling sequence step-by-step, allowing you to choose all parameters specific to your application. Selecting the Extended Programming Mode lets you enter more complex programs.

Optional land-line and GSM and CDMA cellular telephone modems allow programming changes and data collection to be performed remotely, from a touch-tone phone. They also provide dial-out alarm.

Versatile and Convenient

With eleven bottle choices, Isco's 6712 Sampler lets you quickly adapt for simple or intricate sampling routines. Up to 30 pounds (13.5 kg) of ice fits in the insulated base, preserving samples for extended periods, even in extreme conditions. The 6712 with the "Jumbo Base" option holds bottles up to 5.5 gallon (21 liter).

Tough and Reliable

The 6712 Portable Sampler features a vacuum-formed ABS plastic shell to withstand exposure and abuse. Its tapered design and trim 20-inch (50.8 cm) diameter result in easy manhole installation and removal. Large, comfortable handles make transporting safe and convenient—even when wearing gloves.

Isco's 6712 Portable Sampler carries a NEMA 4X, 6 (IP67) enclosure rating.

Superior capability, rugged construction, and unmatched reliability make the 6712 the ideal choice for portable sampling in just about any application.

Bottle options are available for practically any sequential or composite application.

Specifications

Isco 6712 Full-size Portable Sampler	
Size (Height x Diameter):	27 x 20 inches (50.7 x 68.6 cm)
Weight:	Dry, less battery - 32 lbs (15 kg)
Bottle configurations:	24 - 1 Liter PP or 350 ml Glass 24 - 1 Liter ProPak Disposable Sample Bags 12 - 1 Liter PE or 950 ml Glass 8 - 2 Liter PE or 1.8 Liter Glass 4 - 3.8 Liter PE or Glass 1 - 9.5 Liter PE or Glass 1 - 5.5 gallon (21 Liter)PE or 5 gallon (19 Liter) Glass, (with optional Jumbo Base)
Power Requirements:	12 V DC (Supplied by battery or AC power converter.)

Pump	
Intake suction tubing: Length Material Inside dimension	 3 to 99 feet (1 to 30 m) Vinyl or Teflon 3/8 inch (1 cm)
Pump tubing life:	Typically 1,000,000 pump counts
Maximum lift:	28 feet (8.5 m)
Typical Repeatability	±5 ml or ±5% of the average volume in a set
Typical line velocity at Head height: of 3 ft. (0.9 m) 10 ft. (3.1 m) 15 ft. (4.6 m)	 3.0 ft./s (0.91 m/s) 2.9 ft./s (0.87 m/s) 2.7 ft./s (0.83 m/s)
Liquid presence detector:	Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.

Controller	
Weight:	13 lbs. (5.9 kg)
Size (HxWxD)	10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)
Operational temperature:	32° to 120°F (0° to 49°C)
Enclosure rating:	NEMA 4X, 6 (IP67)
Program memory:	Non-volatile ROM
Flow meter signal input:	5 to 15 volt DC pulse or 25 millisecond isolated contact closure.
Number of composite samples:	Programmable from 1 to 999 samples
Clock Accuracy:	1 minute per month, typical, for real time clock

Software	
Sample frequency:	1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses
Sampling modes:	Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)
Programmable sample volumes:	10 to 9,990 ml in 1 ml increments
Sample retries:	If no sample is detected, up to 3 attempts; user selectable
Rinse cycles:	Automatic rinsing of suction line up to 3 rinses for each sample collection
Program storage:	5 sampling programs
Sampling Stop/Resume:	Up to 24 real time/date sample stop/resume commands
Controller diagnostics:	Tests for RAM, ROM, pump, display, and distributor

Ordering Information

Note: Power source, bottle configuration, suction line, and strainer must be ordered separately. Many options and accessories are available for 6712 Samplers; see separate literature for 700 Series Modules and other components to expand your monitoring capabilities. Contact Isco, or your Isco representative for pricing and additional information.

Description	Part Number
6712 Portable Sampler, Full-size Includes controller with 512kB RAM, top cover, center section, base, distributor arm, instruction manual, pocket guide.	68-6710-070
6712 Portable Sampler, with Jumbo Base As described above	68-6710-082

The 6712 Controller is also an SDI-12 data logger, and has many optional capabilities. Please contact Isco or your Isco distributor for more information.

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Internet: www.isco.com

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Support Products

Rain Gauges

The Isco 674 Rain Gauge connects directly to Isco 6700 Series Samplers, 4200 Flow Meters, and 4100 Flow Loggers to log rainfall along with sampler and flow data.

Our 676 Logging System records rainfall at sites where no sampler or flow meter is deployed.

- Tipping bucket mechanism with jeweled pivot for maximum accuracy

581 Rapid Transfer Device (RTD)

A handy plug-in alternative to using notebook computers in the field.

Retrieve data from these Isco instruments:

- 6700/6712 Samplers and Avalanche
- 4100 Flow Loggers
- 4200 Flow Meters

Isco Power Products

Rugged, reliable batteries and chargers for environmental monitoring applications.

- Built to withstand the harshest environments

Open Channel Flow Measurement Handbook

An essential and extensive resource for professionals who deal with open channel flow.

More than 500 pages of comprehensive information, including standard discharge tables for a wide variety of primary devices.

- 6th Edition
- Recently updated and expanded.

Street Level Tools

Minimize or eliminate manhole entry.

Versatile accessories that allow a single worker to quickly and safely insert and remove a variety of sensors in manholes as deep as 5 meters.