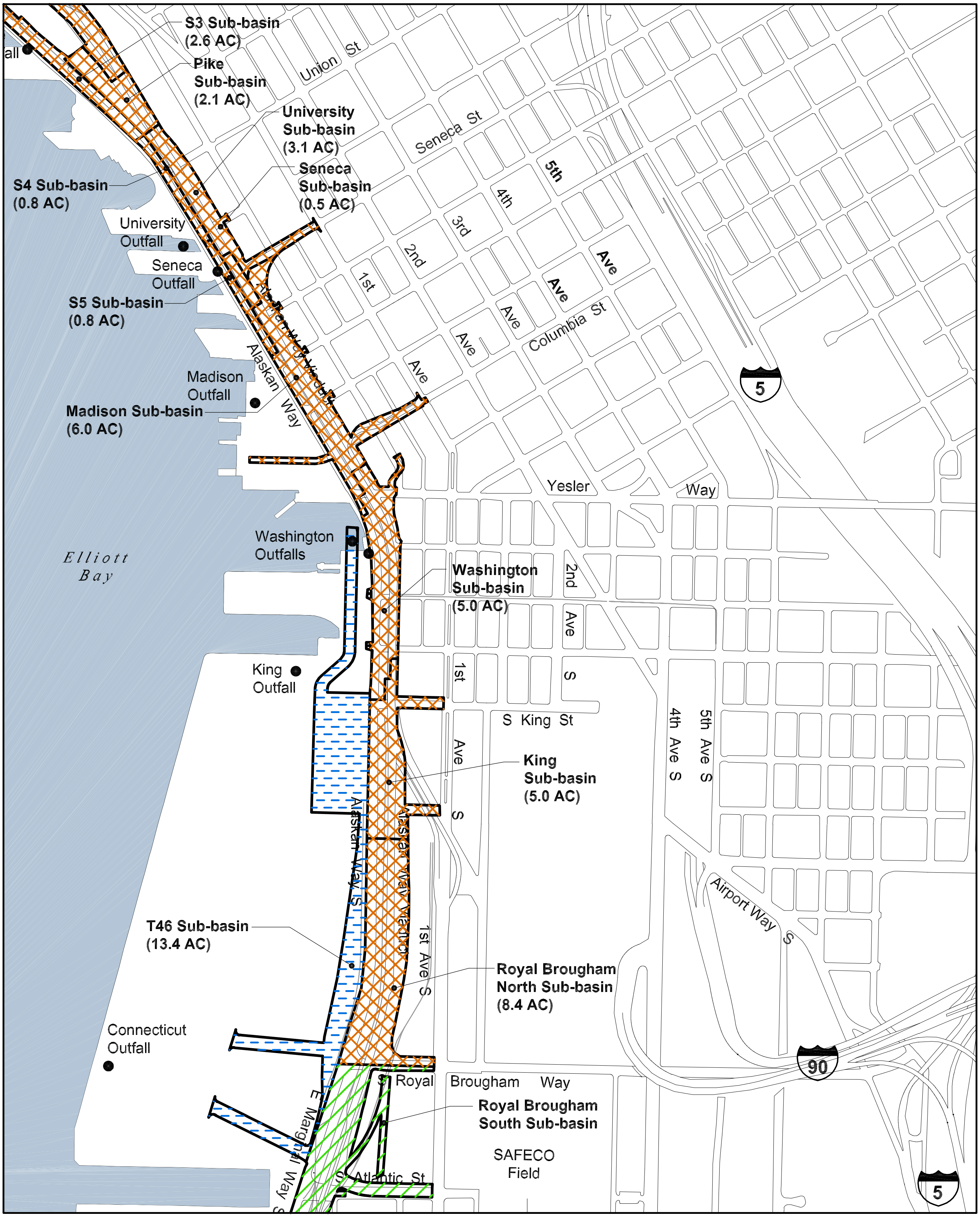

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Note: Each of the Proposed Alternatives have a different footprint within the Sub-basins shown.

[1] A volume of runoff equivalent to the first flush is diverted to combined sewer with a diversion structure, the remainder discharges to the receiving water.

- Drains to Storm Sewer or Directly to Recieving Water, Treated with BMP's
- Drains to Diversion Structure,[1] treated at West Point Treatment Plant
- Drains to Combined Sewer Systems, treated at West Point Treatment Plant and Royal Brougham Treated Plant
- Sub-Basin Boundary
- Major Outfall

Exhibit 4-5
Convey and Treat Approach Sub-basins Central Business District

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4.2.3 North of Vine Street

Both the BMP Approach and Convey and Treat Approach will use stormwater BMPs to treat and/or detain stormwater north of Vine Street, which includes sub-basins S-1, Lake Union West, Broad, and Denny (Exhibit 4-1). In addition, stormwater runoff from the Broad Sub-basin will be conveyed to the combined sewer system (Exhibits 4-6 and 4-7).

4.3 Stormwater Modeling

A mass balance model was developed to compare annual pollutant load and discharge locations under existing conditions with the BMP and Convey and Treat Approaches. In general, the model is based on the following concept:

(Annual Pollutant Load) – (Treatment Removal) = Annual Load to the Environment

The mass balance model calculates the annual pollutant load discharged to the environment under each alternative and accounts for the following differences:

- Differences in pollutant-generating impervious surfaces (PGIS).
- Differences in treatment removal.
- Differences in the discharge location.

The methods and assumptions used to determine the annual pollutant load and treatment removal for each approach are discussed in the following sections and documented in Attachment B.

4.3.1 Stormwater Model – Inputs

Annual Pollutant Load

The annual pollutant load generated from PGIS within the project area was calculated based on the average annual runoff volume, the average pollutant concentration, and the treatment removal. It was assumed that the entire project area is PGIS (see Exhibit 1-1).

Annual Runoff Volume

The average annual runoff volume is the total volume of stormwater that will run off the project (roadway) area in a year with average precipitation. The project area was divided into sub-basins based on the stormwater discharge locations. Sub-basins were delineated using information from Seattle GIS and Seattle Side Sewer Cards that illustrate the storm and combined sewer drainage network and outfall locations (WSDOT 2002a).

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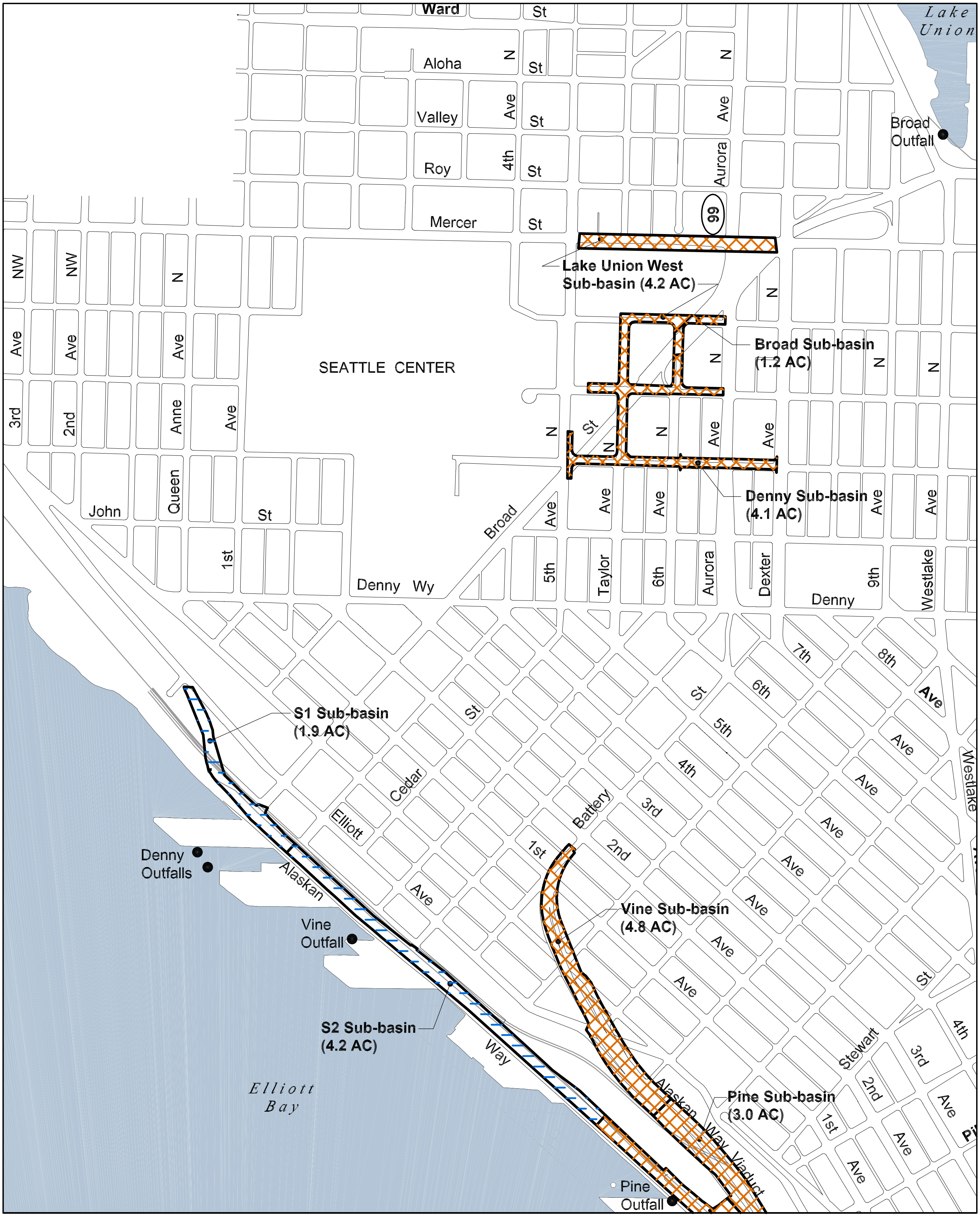

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SCALE IN FEET

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Note: Each of the Proposed Alternatives have a different footprint within the Sub-basins shown.

1 A volume of runoff equivalent to the first flush is diverted to combined sewer with a diversion structure, the remainder discharges to the receiving water.

- Drains to Storm Sewer or Directly to Receiving Water, Treated with BMP's
- Drains to Diversion Structure,[1] treated at West Point Treatment Plant
- Drains to Combined Sewer Systems, treated at West Point Treatment Plant
- Sub-Basin Boundary
- Major Outfall

Exhibit 4-6
BMP Approach Sub-basins North of Vine

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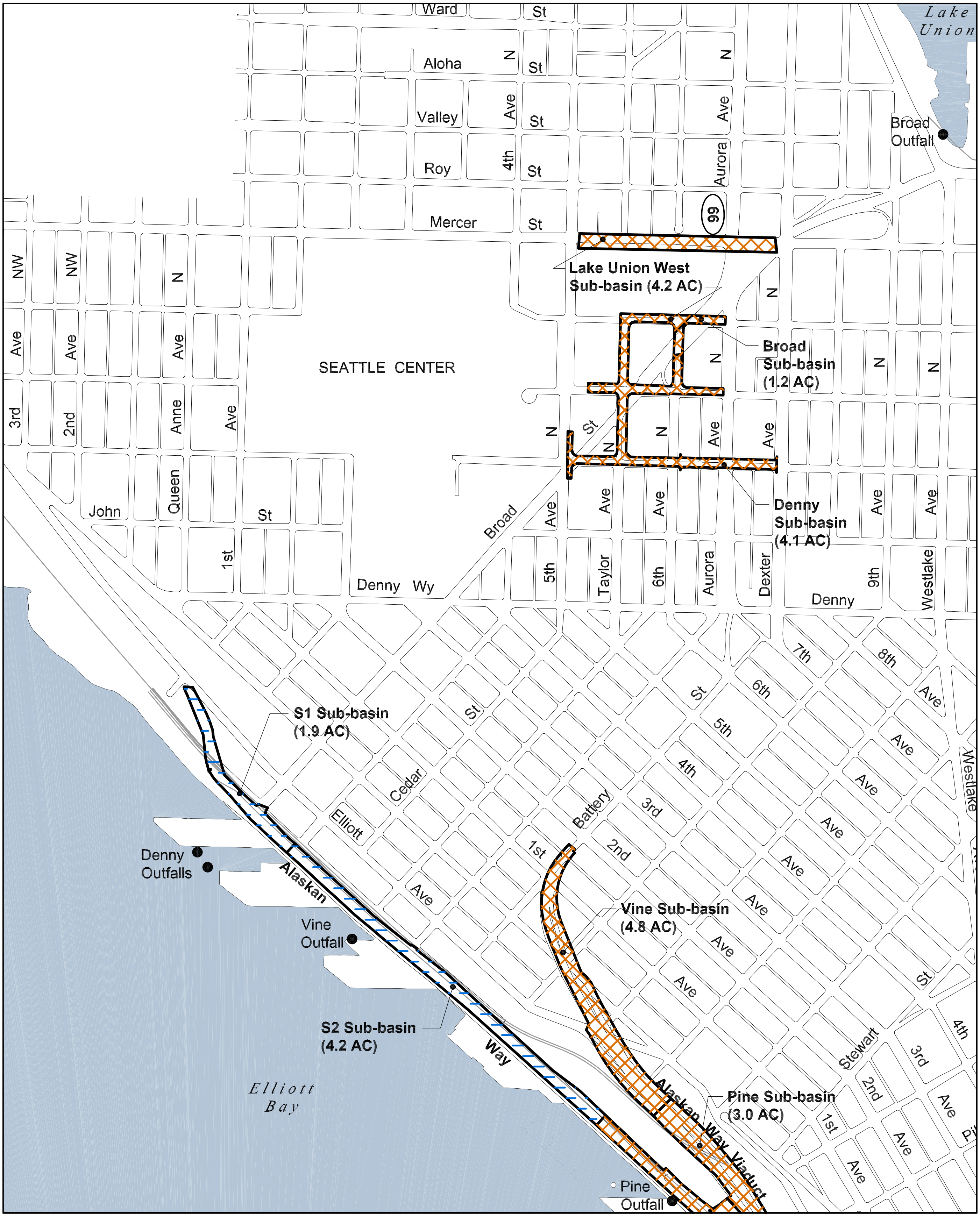

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SCALE IN FEET

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Note: Each of the Proposed Alternatives have a different footprint within the Sub-basins shown.

[1] A volume of runoff equivalent to the first flush is diverted to combined sewer with a diversion structure, the remainder discharges to the receiving water.

- Drains to Storm Sewer or Directly to Receiving Water, Treated with BMP's
- Drains to Diversion Structure,[1] treated at West Point Treatment Plant
- Drains to Combined Sewer Systems, treated at West Point Treatment Plant
- Sub-Basin Boundary
- Major Outfall

Exhibit 4-7 Convey and Treat Approach Sub-basins North of Vine

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The annual runoff volume from each sub-basin area was then calculated using 0.46 inch of rainfall for the mean storm event and 86.7 storms per year (WSDOT 2002b). The values for the mean storm event and the number of storms per year were obtained using WSDOT's approved method for determining annual stormwater runoff volume (WSDOT 2002b).

Pollutant Concentration

The average concentration for each pollutant of concern associated with project area runoff was estimated using agency manuals and guidance documents and by analyzing local highway runoff data. The methods and assumptions used in this analysis are documented in Attachment D. Exhibit 4-8 shows the concentrations of TSS, Cu, and Zn that are representative of highway runoff in the Puget Sound region and were used in this analysis.

Exhibit 4-8. Pollutant Concentrations in Project Stormwater Runoff

Pollutant of Concern	Concentration (mg/L)	Average Event Mean[1]
TSS	91	112
Zn (total)	0.135	0.166
Cu (total)	0.027	0.033

mg/L = milligrams per liter.

[1] Calculated using median concentration reported in Table 2 Attachment D and equation from Step 1 of Method 3 FHWA.

Treatment Removal

Under each proposed alternative, project area stormwater will be treated using one or more of the following methods: Stormwater BMPs, the West Point TP, or the proposed Royal Brougham TP. Each treatment method differs in the removal efficiency and percent of the annual volume that is routed to the facility, which is the annual volume treated.

Removal Efficiency

Because each treatment method relies on different technology, each method has different removal efficiencies for pollutants (Exhibit 4-9).

The assumptions used to determine the removal efficiency for each treatment method are discussed in Attachment E.

Exhibit 4-9. Removal Efficiencies for Each Treatment Method

Treatment Method	Median Removal Efficiency[1] (%)		
	TSS	Zn	Cu
BMP	80	65	58
West Point TP	75	63	77
Royal Brougham TP	80	79	86

[1] Removal efficiency is variable for each treatment method. Attachments D and E discuss the variability in removal efficiencies.
Source: Ecology (2001); Huber (2003 personal communication); WSDOT (2003).

Annual Volume Treated

In addition to differences in removal efficiency, the existing and proposed conveyance systems will route different percentages of the annual runoff volume to each facility (Exhibit 4-10).

Exhibit 4-10. Percent of AWV Project Annual Volume Treated

Treatment Method	% Annual Volume Treated[1]
West Point TP	43.5
Stormwater BMPs	91[2]
Royal Brougham TP	54

[1] See Exhibits 4-13, 4-14, 4-15.
[2] Based on the 6-month storm event.

The West Point TP was assumed to treat 100 percent of the flow conveyed to the facility, but only 43.5 percent of the annual flow goes to the West Point TP. Stormwater BMPs are designed to treat a volume equivalent to the 6-month storm event, which is approximately 91 percent of the annual storm (Ecology 2001). The Royal Brougham TP is intended to treat combined sewer overflows (approximately 54 percent of the annual flow) with an average of one untreated overflow per year (2.5 percent of the annual flow). Additional documentation for the assumptions used to determine the values in Exhibit 4-10 are documented Attachment E.

Discharge Location

The two approaches will differ in the method in which runoff is collected and discharged to the environment. Both approaches will use existing outfalls. However, the annual volume of stormwater discharged at outfalls via a storm drainage system and the annual volume discharged to the combined sewer system in the sub-basins located in the Central Business District differs between approaches (Exhibit 4-11).

Exhibit 4-11. Annual Volume (MG/yr) Discharged to the Storm Drain and Combined Sewer Systems

Basin	Total	Annual Volume Discharged to the Storm Drain System			Annual Volume Discharged to the Combined Sewer System		
		Existing Conditions	BMP Approach	Convey and Treat Approach	Existing Conditions	BMP Approach	Convey and Treat Approach
Lander	13	12	12	12	1	1	1
Royal Brougham South	16	14	14	14	2	2	2
Royal Brougham North	9	8	8	0	1	1	9
Washington	5	5	5	0	0	0	5
T46	15	15	15	15	0	0	0
S1	2	2	2	2	0	0	0
S2	5	5	5	0	0	0	5
S3	3	3	3	0	0	0	3
S4	1	1	1	0	0	0	1
S5	1	1	1	0	0	0	1
Pine	3	3	3	0	0	0	3
Seneca	1	1	1	0	0	0	1
University	3	3	3	0	0	0	3
Madison	7	7	7	0	0	0	7
King	5	0	0	0	5	5	5
Pike	2	0	0	0	2	2	2
Vine	5	0	0	0	5	5	5
Denny	4	0	0	0	4	4	4
Broad	1	1	0	0	0	1	1
Lake Union West	5	0	0	0	5	5	5
Total	**106**	**81**	**80**	**43**	**25**	**26**	**63**

Under the Convey and Treat Approach, the primary receiving water for sub-basins in the Central Business District will change from Elliott Bay to Puget Sound (Exhibit 4-12).

Exhibit 4-12. Differences in Discharge Locations and Receiving Water

Sub-basin	Existing and BMP Approach Receiving Water	Convey and Treat Approach Receiving Water
South of S. Royal Brougham Way		
Lander	Duwamish River[1]	Duwamish River[1]
Royal Brougham South	Elliott Bay	Elliott Bay
Central Business District		
Royal Brougham North	Elliott Bay[2]	Puget Sound[3]
King	Puget Sound[2]	Puget Sound[3]
Washington	Elliott Bay[2]	Puget Sound[3]
T46	Elliott Bay[2]	Elliott Bay[2]
S2	Elliott Bay[2]	Puget Sound[3]
Pike	Puget Sound	Puget Sound
Pine	Elliott Bay[2]	Puget Sound[3]
University	Elliott Bay[2]	Puget Sound[3]
S3	Elliott Bay[2]	Puget Sound[3]
S4	Elliott Bay[2]	Puget Sound[3]
S5	Elliott Bay[2]	Puget Sound[3]
Seneca	Elliott Bay[2]	Puget Sound[3]
Vine	Elliott Bay[2]	Puget Sound[3]
Madison	Elliott Bay[2]	Puget Sound[1]
North of Vine Street		
S1	Elliott Bay[2]	Puget Sound[3]
Denny	Puget Sound[2]	Puget Sound[3]
Lake Union West	Puget Sound[4]	Puget Sound[4]
Broad	Lake Union/Puget Sound[5]	Puget Sound

[1] A diversion structure diverts a volume of water equivalent to the first flush to the West Point TP for treatment and discharge to Puget Sound.

[2] Stormwater runoff will discharge directly to Elliott Bay.

[3] Stormwater runoff will be conveyed to the combined system to the West Point TP for treatment and discharge to Puget Sound at a deep water outfall during normal operating conditions. During CSO events, runoff will discharge to Elliott Bay as a CSO.

[4] Receiving water during normal operating conditions. During CSO events, runoff will be routed to the new Denny Tunnel and will discharge to Elliott Bay as a treated CSO at Denny. During extreme events, runoff will discharge to Lake Union as a CSO.

[5] Under existing conditions stormwater runoff discharges to Lake Union. Under the Aerial, Tunnel, Bypass, and Surface alternatives runoff would be conveyed to the combined sewer system and conveyed to the West Point TP and discharge to Puget Sound. During extreme events, runoff will discharge to Lake Union as a CSO.

Duwamish River

In the Duwamish River Basin, as shown in Exhibit 4-12, both the BMP and Convey and Treat Approaches will discharge stormwater at the same outfalls as existing conditions. In addition, because the project does not create any new impervious surface, the volume discharged at each outfall will also be the same as existing conditions.

Elliott Bay and Puget Sound

The BMP and Convey and Treat Approaches differ in the location stormwater from the project will discharge (Exhibit 4-12). As a result, the volume of water discharged at outfalls in Elliott Bay and at the West Point TP outfall to Puget Sound will be different than existing conditions.

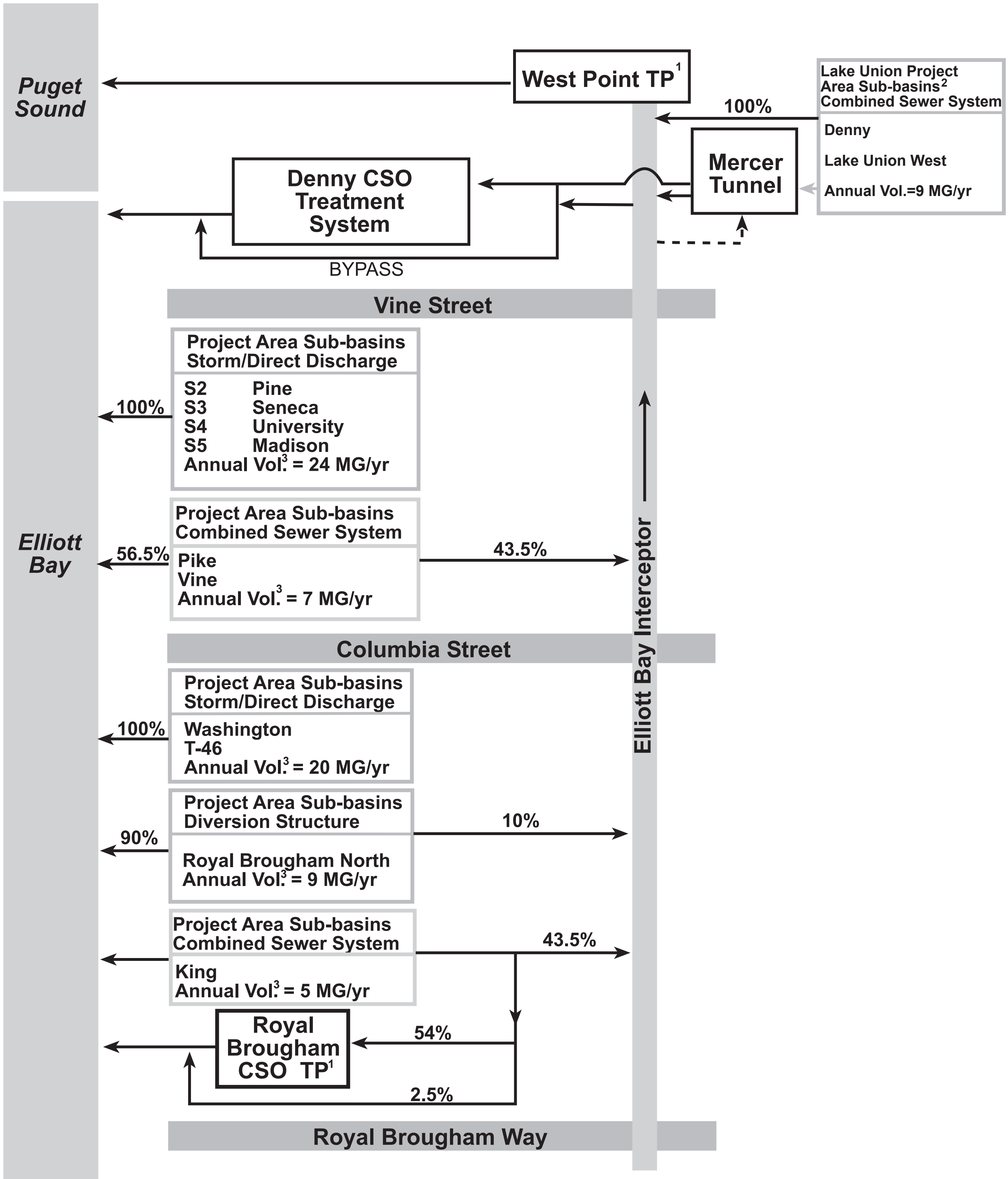
Exhibit 4-13 illustrates the existing flow paths, percentage of the annual runoff volume discharged to Elliott Bay and Puget Sound via stormwater and CSO outfalls, and the existing level of treatment for each of the sub-basins in the Central Business District.

Exhibit 4-14 illustrates the flow paths and percentage of the annual runoff volume discharged to Elliott Bay and Puget Sound via stormwater and CSO outfalls for each of the sub-basins in the Central Business District under the BMP Approach. As shown on this schematic, the flow paths and percentage of the annual runoff volume discharged are the same as existing conditions. However, the annual load is treated prior to discharge to the environment with stormwater BMPs as shown on the schematic.

Exhibit 4-15 illustrates the flow paths and percentage of the annual runoff volume discharged to Elliott Bay and Puget Sound via stormwater and CSO outfalls for each of the sub-basins in the Central Business District under the Convey and Treat Approach. As shown on the schematic, the flow patterns are different than the existing conditions and BMP Approach, and a greater volume of water is discharged to Puget Sound. In addition, the treatment methods are different than the BMP Approach.

Lake Union

In the Lake Union Basin, none of the Build Alternatives will change the amount of PGIS. In addition, under both stormwater management approaches, stormwater runoff from the Broad Sub-basin will be conveyed to the combined sewer system (Exhibits 4-13 and 4-14).

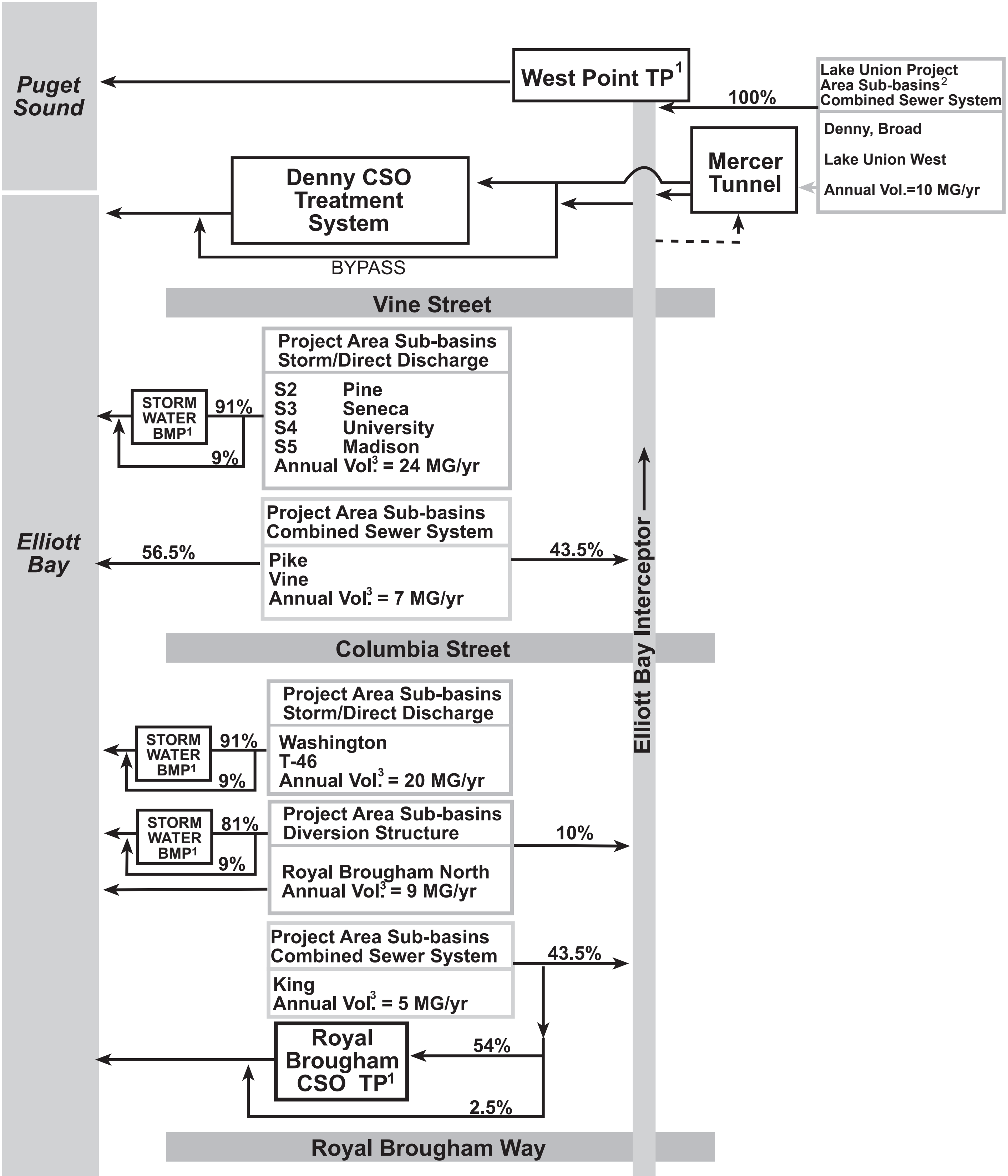


1 Assumptions used for treatment efficiency are reported in Section 4.3.1

2 Both of the proposed stormwater management approaches would add stormwater runoff from the Broad subbasin to the combined system

3 Annual loads discharged to each receiving water are presented by alternative in Section 5

Exhibit 4-13
Existing Conditions
Stormwater Runoff Flow Diagram:
Central Business District

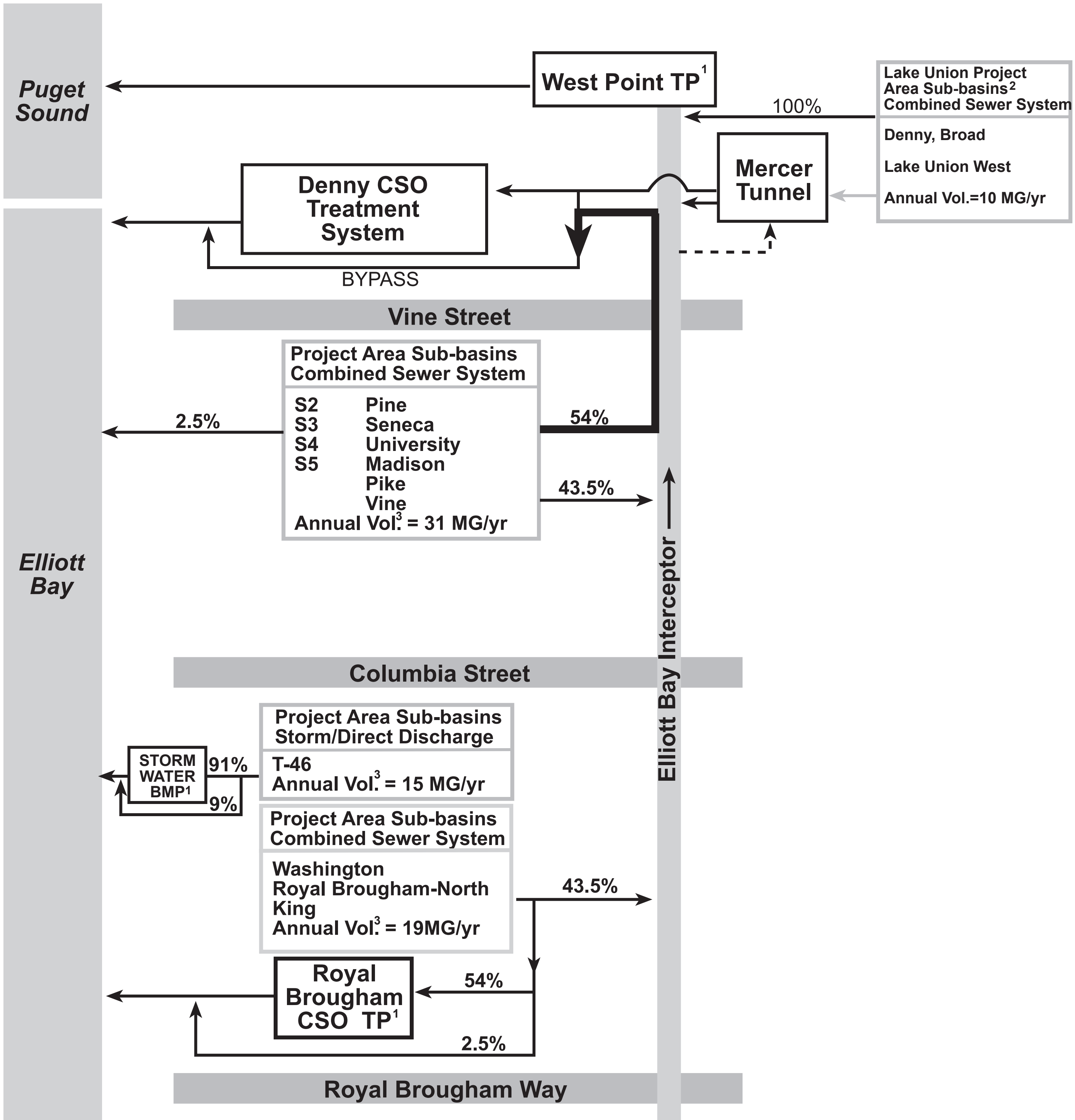


1 Assumptions used for treatment efficiency are reported in Section 4.3.1

2 Both of the proposed stormwater management approaches would add stormwater runoff from the Broad subbasin to the combined system

3 Annual loads discharged to each receiving water are presented by alternative in Section 5

Exhibit 4-14
BMP Approach
Stormwater Runoff Flow Diagram: Central Business District



Alaskan Way Viaduct 554-1585-025/06(0620) 3/04 (K)

1 Assumptions used for treatment efficiency are reported in Section 4.3.1

2 Both of the proposed stormwater management approaches would add stormwater runoff from the Broad subbasin to the combined system

3 Annual loads discharged to each receiving water are presented by alternative in Section 5

Exhibit 4-15
Convey and Treat Approach Stormwater Runoff Flow Diagram: Central Business District

4.3.2 Annual Load to the Environment

The annual load discharged to the environment was calculated for each sub-basin under each alterative based on the annual pollutant load, the amount of pollutants removed by treatment, and the discharge location. The results of this analysis are presented in Chapter 5, Operational Impacts and Benefits.

4.4 Construction Impacts Methods

4.4.1 Temporary Erosion and Sediment Control Measures

Water quality may be affected by construction runoff containing sediment. Under each alternative, potential impacts were evaluated by identifying locations where earthwork could disturb contaminated sediments, as identified in Chapter 3, Affected Environment.

4.4.2 Stormwater Treatment for Temporary Structures

Stormwater water quality treatment for temporary structures for detour routes will be provided in accordance with WSDOT guidelines and will meet Ecology's requirements for construction sites. These measures will prevent or minimize potential temporary impacts and will not vary much among alternatives. Therefore, potential impacts and benefits to water quality were not evaluated.

4.4.3 Dewatering

The evaluation of potential receiving water impacts associated with construction dewatering is based on the extent of subsurface excavation, soil characteristics, and associated dewatering for each alternative.

4.4.4 In-Water Work

Potential impacts associated with in-water work were evaluated by comparing the length of disturbed shoreline and differences in the extent of dredging and/or pile removal between alternatives. In addition, any construction activities in contaminated sediments, as identified in Chapter 3, Affected Environment, were identified and compared between alternatives.

4.4.5 Staging Areas

Because spills, soil stockpiles, and other activities that could temporarily affect water quality are more likely to occur at staging areas, each alternative was analyzed based on the number of proposed staging areas that will be located adjacent to or over the Duwamish River, Elliott Bay, and Lake Union. Furthermore, this analysis assumed that over-water or near-water staging areas will have the greatest potential to temporarily affect water quality.

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Chapter 5 OPERATIONAL IMPACTS AND BENEFITS

It is well documented that runoff from streets and highways, particularly in urban environments, contains pollutants that can impact the water quality of the receiving water. Studies conducted on highway runoff in the Seattle area indicate that highways are a measurable source of suspended solids and metals (zinc and copper), as well as other pollutants (Driscoll et al. 1990).

Pollutant loads contained in stormwater runoff vary depending on the amount and type of PGIS, traffic volumes and average speed, duration and intensity of a storm event, time of year, antecedent weather conditions, and several other factors. All of the proposed alternatives will have similar amounts of PGIS, traffic, and environmental factors; therefore, each of the alternatives will generate similar pollutant loads prior to treatment.

The main difference between each of the Build Alternatives is the proposed approach for managing stormwater runoff. Information on the Build Alternatives is provided in Appendix B, Alternatives Description and Construction Methods Technical Memorandum. For the purposes of this analysis, the Rebuild, Aerial, and Tunnel Alternatives and options will implement the BMP Approach to manage stormwater runoff along the entire length of the project and the Bypass Tunnel and Surface Alternatives and options will implement the Convey and Treat Approach along a portion of the project, with the BMP Approach used for the other portions. It is important to note that at this stage in design, either approach or a combination of both approaches would work under any of the proposed Build Alternatives and that each approach was assigned to a Build Alternative for analysis purposes only. In addition, as stated in Section 4.2, further design could modify the boundaries of either approach. All of the alternatives will result in a net improvement in water quality as compared to existing conditions (Exhibit 5-1). However, the calculated loads are only an indirect indicator of water quality. These Build Alternatives and their associated stormwater treatment approaches are summarized below.

Duwamish River and Lake Union Basins – All of the Build Alternatives will use stormwater BMPs to treat project area runoff. Therefore, differences in the annual project load will only depend on differences in the area of PGIS that is retrofitted.

Elliott Bay and Puget Sound Basins – The Rebuild, Aerial, and Tunnel Alternatives and options will implement the BMP Approach to manage stormwater runoff. The Bypass Tunnel and Surface Alternatives and options will implement the Convey and Treat Approach. In the sub-basins draining to Elliott Bay or Puget Sound, differences in the annual project load depend on differences in the area of PGIS that is retrofitted, the discharge location, and the treatment method.

Exhibit 5-1. Summary of Water Quality Benefits

Parameter[1]	Existing Conditions[2]	Alternative				
		BMP Approach			Convey and Treat Approach	
		Rebuild	Aerial	Tunnel	Bypass Tunnel	Surface
Duwamish River[3]						
Vol (MG/yr)	12	12	12	12	12	12
TSS	10,900	6,000	8,000	6,000	6,000	6,000
Zn	16	10	13	10	10	10
Cu	3	2	3	2	2	2
Elliott Bay[3]						
Vol (MG/yr)	80	80	80	80	68	68
TSS	72,000	35,300	47,300	36,700	37,900	40,000
Zn	107	63	77	65	62	64
Cu	21	13	16	14	13	13
Puget Sound[3]						
Vol (MG/yr)	13	13	14	14	26	26
TSS	3,100	3,100	3,100	3,100	6,000	6,100
Zn	7	7	7	7	13	13
Cu	1	1	1	1	2	2
Lake Union[3,4]						
Vol (MG/yr)	1	1	1	1	1	0
TSS	1,300	1,300	600	600	600	300
Zn	2	2	1	1	1	0
Cu	0	0	0	0	0	0
Total Combined Load						
Vol (MG/yr)	106	106	106	106	106	106
TSS	87,300	45,700	59,000	46,400	50,500	52,400
Zn	132	82	98	83	86	88
Cu	26	17	20	17	17	17

[1] Total suspended solids (TSS) rounded to the nearest 100 pounds, zinc (Zn) and copper (Cu) rounded to the nearest tenth of a pound.

[2] The No Build Alternative is the same as Existing Conditions.

[3] Detailed information on specific sub-basins is provided in Attachment B.

[4] The Rebuild Alternative would not make any road improvements in this basin. Therefore, the runoff volume and pollutant load would be the same as existing conditions.

5.1 No Build Alternative

Under the No Build Alternative, the existing viaduct will not be retrofitted with stormwater treatment, and stormwater runoff will continue to discharge as it does under existing conditions unless major repairs are made as discussed below. However, it is assumed that King County will construct the Royal Brougham TP in approximately 2026 as part of their CSO control plan to reduce CSO events at the King and Royal Brougham outfalls. The three No Build Alternative scenarios are briefly discussed below. Additional information on these scenarios is provided in Appendix B, Alternatives Description and Construction Methods Technical Memorandum.

5.1.1 Scenario 1 – Continued Operation of the Viaduct and Seawall with Continued Maintenance

Under Scenario 1 (continued maintenance of the viaduct and seawall without unexpected loss of use), it is assumed that the existing PGIS associated with the viaduct and seawall will be replaced as the facility is replaced. The replacement facility will be retrofitted with stormwater BMPs in accordance with the WSDOT Highway Runoff Manual. Potential impacts and benefits associated with this scenario were not evaluated because the location and areas that will be retrofitted are unknown at this time.

5.1.2 Scenario 2 – Sudden Unplanned Loss of the Viaduct and/or Seawall Without Major Collapse or Injury

Under Scenario 2 (a moderate-level seismic event), it is assumed that damaged portions of the viaduct would be replaced and retrofitted with stormwater BMPs in accordance with the 2001 Ecology Manual for Western Washington or an approved equivalent WSDOT Highway Runoff equivalent manual. Potential impacts and benefits associated with this scenario were not evaluated because the location and areas that would be retrofitted are unknown at this time.

5.1.3 Scenario 3 – Catastrophic Failure and Collapse of the Viaduct and/or Seawall

Under Scenario 3 (a strong seismic event), it is assumed that a strong seismic event would cause catastrophic failure of the viaduct and seawall. Because many of the diversion structures and interceptor pipes that are part of the combined sewer system are located in the seawall and fill under the Alaskan Way surface street, catastrophic failure of this facility would likely result in substantial impacts to water quality. It is likely that combined and uncombined untreated sewage would be discharged directly to Elliott Bay in numerous locations. In addition, fuel tanks or other sources of contamination located along the waterfront would also likely be damaged or released, which could result in uncontrolled spills into Elliott Bay. Uncontrolled spills would likely result in substantial temporary impacts to water quality. Catastrophic failure could temporarily disturb contaminated sediment along the waterfront and create dust that would also temporarily impact water quality. In addition, long-term impacts could also result due to pollutants accumulating in the nearshore sediment, which would be costly to remediate.

5.2 Rebuild Alternative

The Rebuild Alternative will implement the BMP Approach to treat/detain stormwater runoff from the project area. The treatment will result in a net benefit to the environment as compared to existing conditions (Exhibit 5-2).

Exhibit 5-2. Summary of Water Quality Benefits for the Rebuild Alternative BMP Approach

	Existing Conditions	Rebuild Alternative	Change
Annual Stormwater Volume (MG)	106	106	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	87,300	45,700	48%
Zn	132	82	38%
Cu	26	17	35%

[1] Total suspended solids (TSS), copper (Cu), and zinc (Zn).
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

There will be no other operational impacts to water quality associated with this alternative. Periodic BMP maintenance (annual or bi-annual) would likely be required and could have secondary traffic impacts.

5.2.1 Duwamish River

The Rebuild Alternative will implement the stormwater BMPs to treat stormwater runoff from the project area in the Lander Sub-basin. This alternative will not change the volume of stormwater discharged to the Duwamish River and it will improve the quality of water discharged as compared with existing conditions (Exhibit 5-3).

Exhibit 5-3. Water Quality Benefits to the Duwamish River for the Rebuild Alternative

Duwamish River	Existing Conditions	Rebuild Alternative	Change
Annual Stormwater Volume (MG)	12	12	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	10,900	6,000	45%
Zn	16	10	38%
Cu	3	2	33%

[1] Total suspended solids (TSS), copper (Cu), and zinc (Zn).
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.2.2 Elliott Bay

Stormwater

The Rebuild Alternative will implement the BMP Approach to treat stormwater runoff from the project area. Runoff from the stormwater-only sub-basins (Royal Brougham South, Royal Brougham North, T46, Washington, S1, S2, Pine, University, S3, S4, S5, Seneca, and Madison Sub-basins) will be treated with stormwater BMPs, and runoff from the combined sub-basins (King, Pike, and Vine) will be detained prior to discharge to the combined sewer system, where it will be treated at the West Point TP, Royal Brougham TP, or discharged untreated as part of a CSO.

This alternative will not change the volume of stormwater discharged to Elliott Bay and it will improve the quality of water discharged as compared with existing conditions (Exhibit 5-4).

Exhibit 5-4. Water Quality Benefits to Elliott Bay for the Rebuild Alternative

Elliott Bay	Existing Condition	Rebuild Alternative	Change
Annual Stormwater Volume (MG)	80	80	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	72,000	35,300	51%
Zn	107	63	41%
Cu	21	13	38%

[1] Total suspended solids (TSS) rounded to the nearest 100 pounds, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

In addition, because this alternative will provide detention for sub-basins that drain to the combined sewer system, it could delay flows, which would decrease CSOs by allowing more flow and pollutants to get to the West Point TP for treatment and discharge to Puget Sound.

Seawall

There are no operational impacts from the seawall replacement.

5.2.3 Puget Sound

The Rebuild Alternative will not substantially change the volume of stormwater diverted into the combined sewer system or the amount of pollutants discharged to Puget Sound (Exhibit 5-5).

Exhibit 5-5. Water Quality Benefits to Puget Sound for the Rebuild Alternative

Puget Sound	Existing Conditions	Rebuild Alternative	Change
Annual Stormwater Volume (MG)	13	13	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	3,100	3,100	0 %
Zn	7	7	0 %
Cu	1	1	0 %

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

This alternative will provide detention in the King Sub-basin, which could benefit the existing combined sewer system by providing additional capacity.

5.2.4 Lake Union

The Rebuild Alternative will not make any improvements in this area. Therefore, there will be no benefit or impact to water quality in the Lake Union Basin.

5.3 Aerial Alternative

The Aerial Alternative will use the BMP Approach for stormwater management. Although the footprint of the viaduct will be wider with the Aerial Alternative than with the Rebuild Alternative, it is assumed that the footprint of the Aerial Alternative (other than roofs) will have the same area of PGIS as the Rebuild Alternative. This was assumed because the footprint required for the viaduct under the Aerial Alternative consists entirely of PGIS. Therefore, the Aerial Alternative will have benefits similar to those discussed under the Rebuild Alternative, and it will result in a net benefit to the environment as compared to existing conditions (Exhibit 5-6).

Exhibit 5-6. Summary of Water Benefits for the Aerial Alternative BMP Approach

	Existing Conditions	Aerial Alternative	Change
Annual Stormwater Volume (MG)	106	106	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	87,300	59,000	32%
Zn	132	98	26%
Cu	26	20	23%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.3.1 Duwamish River

The Aerial Alternative will implement the BMP Approach to treat stormwater runoff from the project area in the Lander Sub-basin. This alternative will not change the volume of stormwater discharged to the Duwamish River, and it will improve water quality (Exhibit 5-7).

Exhibit 5-7. Water Quality Benefits to the Duwamish River for the Aerial Alternative

Duwamish River	Existing Conditions	Aerial Alternative	Change
Annual Stormwater Volume (MG)	12	12	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	10,900	8,000	27%
Zn	16	13	19%
Cu	3	3	0%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.3.2 Elliott Bay

Stormwater

The Aerial Alternative will implement the BMP Approach to treat stormwater runoff from the project area in the Royal Brougham South, Royal Brougham North, King, T46, Washington, S1, S2, Pike, Pine, University, S3, S4, S5, Seneca, Vine, and Madison Sub-basins. Benefits to water quality in Elliott Bay are expected to be similar to but slightly greater than those described under the Rebuild Alternative. This alternative will not change the volume of stormwater discharged to Elliott Bay, and it will improve water quality (Exhibit 5-8).

Exhibit 5-8. Water Quality Benefits to Elliott Bay for the Aerial Alternative

Elliott Bay	Existing Condition	Aerial Alternative	Change
Annual Stormwater Volume (MG)	80	80	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	72,000	47,300	34%
Zn	107	77	28 %
Cu	21	16	24 %

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

In addition, because this alternative will provide detention for sub-basins that drain to the combined sewer system, it could delay flows, which would decrease CSOs by allowing more flow and pollutants to get to the West Point TP for treatment and discharge to Puget Sound.

Seawall

There are no operational impacts from the seawall replacement portion of this alternative.

Battery Street Tunnel

The Battery Street Tunnel will be improved by adding fire and life safety improvements. One of these improvements includes installation of a fire suppression system. The proposed fire suppression system will use aqueous film-forming foam (AFFF) to suppress fires in the tunnel. During testing events, runoff and foam from the fire suppression system will be discharged to the combined sewer system and treated at the West Point TP. Although AFFF has a high biological oxygen demand, because it is biodegradable in conventional wastewater treatment plants, it was assumed that the West Point TP will provide adequate treatment. In addition, test events will be scheduled and conducted in a way to ensure that no impacts due to lack of capacity will occur. A preliminary capacity analysis was performed for tunnel pump out. The system was designed with vaults so that the pipe capacity will not be exceeded (WSDOT 2002a). Therefore, there will be no impacts to capacity.

During actual emergency events, runoff from the fire suppression system (potentially including flammable or explosive material and AFFF) will be discharged directly to Elliott Bay. Although some toxicity to specific species was noted, none of the compounds evaluated were found to be highly toxic to freshwater or marine species. However, if the fluids were discharged to an aquatic environment in the concentrations applied (3 percent), localized toxicity impacts could occur (Attachment G). In addition, because AFFF has high biological oxygen demand, localized dissolved oxygen depressions could occur. Potential short-term impacts will be allowed under WAC 201A-110.

5.3.3 Puget Sound

The Aerial Alternative will not substantially change the volume of stormwater diverted into the combined sewer system or the amount of pollutants discharged to Puget Sound (Exhibit 5-9). This alternative is similar to the Rebuild Alternative.

Exhibit 5-9. Water Quality Benefits to Puget Sound for the Aerial Alternative

Puget Sound	Existing Condition	Aerial Alternative	Change
Annual Stormwater Volume (MG)	13	14	+ 1
Annual Pollutant Load (lbs/year)[1,2]			% Increase
TSS	3,100	3,100	0%
Zn	7	7	0%
Cu	1	1	0%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.3.4 Lake Union

The Aerial Alternative will divert stormwater runoff from the north portion of the project area in the Broad Sub-basin to the combined sewer system. However, because this sub-basin is so small, it will not measurable change the volume of stormwater discharged to Lake Union. This alternative will improve the quality of water discharged to Lake Union (Exhibit 5-10).

Exhibit 5-10. Water Quality Benefits to Lake Union for the Aerial Alternative

Lake Union	Existing Condition	Aerial Alternative	Change
Annual Stormwater Volume (MG)	1	1	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	1,300	600	54%
Zn	2	1	50%
Cu	0	0	0%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.4 Tunnel Alternative

The Tunnel Alternative will use the BMP Approach for stormwater management. Although the footprint of the replaced viaduct will be in a tunnel, the reconstructed surface streets will be a similar area of PGIS as the Rebuild Alternative. In addition, because it was assumed that the entire project area (other than roofs) is PGIS, the Tunnel Alternative will have impacts and benefits similar to those discussed under the Rebuild Alternative, and it will result in a net benefit to the environment as compared to existing conditions (Exhibit 5-11).

Exhibit 5-11. Summary of Water Benefits for the Tunnel Alternative BMP Approach

	Existing Conditions	Tunnel Alternative	Change
Annual Stormwater Volume (MG)	106	106	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	87,300	46,400	47%
Zn	132	83	37%
Cu	26	17	35%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.4.1 Duwamish River

The Tunnel Alternative will implement the BMP Approach to treat stormwater runoff from the project area in the Lander Sub-basin. This Alternative will have the same benefits as those discussed under the Rebuild Alternative. This alternative will not change the volume of stormwater discharged to the Duwamish River, and it will improve the quality of water discharged as compared to existing conditions (Exhibit 5-12).

Exhibit 5-12. Water Quality Benefits to the Duwamish River for the Tunnel Alternative

Duwamish River	Existing Condition	Tunnel Alternative	Change
Annual Stormwater Volume (MG)	12	12	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	10,900	6,000	45%
Zn	16	10	38%
Cu	3	2	33%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.4.2 Elliott Bay

Stormwater

The Tunnel Alternative will implement the BMP Approach to treat stormwater runoff from the project area in the Royal Brougham South, Royal Brougham North, King, Washington, S1, S2, Pike, Pine, University, S3, S4, S5, Seneca, Vine, and Madison Sub-basins. Benefits to water quality in Elliott Bay are expected to be similar to those described under the Rebuild and Aerial Alternatives. This alternative will not change the volume of stormwater discharged to Elliott Bay, and it will improve the quality of water discharged as compared to existing conditions (Exhibit 5-13).

Exhibit 5-13. Water Quality Benefits to Elliott Bay for the Tunnel Alternative

Elliott Bay	Existing Conditions	Tunnel Alternative	Change
Annual Stormwater Volume (MG)	80	80	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	72,000	36,700	51%
Zn	107	65	41%
Cu	21	14	38%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

In addition, because this alternative will provide detention for sub-basins that drain to the combined sewer system, it could delay flows, which will decrease CSOs by allowing more flow and pollutants to get to the West Point TP for treatment and discharge to Puget Sound.

Seawall

There are no operational impacts from the seawall replacement portion of this alternative. The portion of the tunnel located west of the existing seawall may have a benefit to the environment by removing contaminated sediment.

Groundwater

In addition to potential stormwater impacts as well as the benefits of stormwater runoff control and treatment from the project area, local groundwater management must be considered under this Tunnel Alternative. However, current tunnel designs are watertight structures designed to withstand groundwater hydraulic pressures, and no long-term tunnel dewatering is planned (WSDOT 2003). Any groundwater flow in the tunnel vicinity will flow around, under, or over the tunnel structure. Consequently, there will be no long-term operational impacts on water quality from affected groundwater (Appendix T; WSDOT 2003).

Fire Suppression System

The Tunnel Alternative will have a fire suppression system that has the potential to discharge AFFF to the environment. Potential water quality impacts related to the discharge of AFFF for the tunnel portion of this alternative will be similar but potentially greater than discussed under the Aerial Alternative because the Tunnel Alternative could result in a greater volume of AFFF being discharged to the environment during an emergency event. Potential water quality impacts for the Battery Street Tunnel Improvements will be the same as those discussed under the Aerial Alternative.

5.4.3 Puget Sound

The Tunnel Alternative will not substantially change the volume of stormwater diverted into the combined sewer system or the amount of pollutants discharged to Puget Sound (Exhibit 5-14). This alternative is similar to the Rebuild Alternative.

Exhibit 5-14. Water Quality Benefits to Puget Sound for the Tunnel Alternative

Puget Sound	Existing Conditions	Tunnel Alternative	Change
Annual Stormwater Volume (MG)	13	14	+ 1
Annual Pollutant Load (lbs/year)[1,2]			% Increase
TSS	3,100	3,100	0%
Zn	7	7	0%
Cu	1	1	0%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the BMP Approach.

5.4.4 Lake Union

Stormwater runoff will be diverted to the combined sewer system for treatment. Water quality benefits in the Broad and Lake Union West Sub-basins will be the same as those discussed under the Aerial Alternative.

5.5 Bypass Tunnel Alternative

The Bypass Tunnel Alternative will use the Convey and Treat Approach for stormwater management for the sub-basins north of S. Royal Brougham Way and south of Vine Street. In the other sub-basins, the Bypass Tunnel Alternative proposes to use the BMP Approach to treat stormwater runoff. Use of these treatment approaches will result in a net benefit to the environment as compared to existing conditions (Exhibit 5-15).

Exhibit 5-15. Summary of Water Benefits for the Bypass Tunnel Alternative Convey and Treat Approach

	Existing Conditions	Bypass Tunnel Alternative	Change
Annual Stormwater Volume (MG)	106	106	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	87,300	50,500	42%
Zn	132	86	35%
Cu	26	17	35%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

5.5.1 Duwamish River

The Bypass Tunnel Alternative will implement the BMP Approach to treat stormwater runoff from the project area in the Lander Sub-basin. Therefore, the annual volume of stormwater and the annual pollutant load discharged to the Duwamish River will be the same as the Tunnel Alternative and will have the same benefit to the environment in the Duwamish River Basin.

5.5.2 Elliott Bay

Stormwater

Although the Bypass Tunnel Alternative will redevelop a similar area of PGIS as the Tunnel Alternative in the Royal Brougham South, Royal Brougham North, King, T46, Washington, S1, S2, Pike, Pine, University, S3, S4, S5, Seneca, Vine, and Madison Sub-basins, the annual volume of stormwater and pollutant load discharged to Elliott Bay will be less than the Tunnel Alternative because the Convey and Treat Approach will be used to manage stormwater runoff (Exhibit 5-16).

Exhibit 5-16. Water Quality Benefits to Elliott Bay for the Bypass Tunnel Alternative

	Existing Conditions	Bypass Tunnel Alternative	Change
Annual Stormwater Volume (MG)	80	68	-12
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	72,000	37,900	47%
Zn	107	62	42%
Cu	21	13	38%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

This alternative will change the volume of stormwater discharged to Elliott Bay because runoff in the Royal Brougham North, Washington, S2, Pine, University, S3, S4, S5, Seneca, Vine, and Madison Sub-basins will be conveyed to the combined system instead of discharging to Elliott Bay via a separated stormwater system. Only the runoff from the T46 Sub-basin would be treated with BMPs and discharged to Elliott Bay via a stormwater system. As part of this alternative, a CSO treatment facility will be constructed in the vicinity of S. Royal Brougham Way and First Avenue to treat CSO events at this location.

Seawall

There are no operational impacts from the seawall replacement portion of this alternative. The portion of the tunnel located west of the existing seawall may have a benefit to the environment by removing contaminated sediment. Benefits will be similar to but greater than the Tunnel Alternative.

Groundwater

As discussed under the Tunnel Alternative, there will be no long-term operational impacts on water quality from affected groundwater.

Fire Suppression System

The Bypass Tunnel Alternative will have a fire suppression system that has the potential to discharge AFFF to the environment. Potential water quality impacts related to the discharge of AFFF during emergency events will be similar to those discussed under the Tunnel Alternative but could be less because of the smaller tunnel size. Potential water quality impacts for the Battery Street Tunnel Improvements will be the same as those discussed under the Aerial Alternative.

5.5.3 Puget Sound

The Bypass Tunnel Alternative will also increase the volume of stormwater discharged to Puget Sound because runoff currently discharging directly to Elliott Bay will be conveyed to the combined sewer system to the West Point TP (Exhibit 5-16). In addition to the increase in volume, there will be an increase in the pollutant load discharged to Puget Sound as compared to existing conditions (Exhibit 5-17).

The West Point TP treats 133 MG per day on average, which is approximately 48,545 MG annually (King County 2004). Therefore, the change due to the proposed alternative would be less than 0.03 percent. Under this alternative, the pollutant load discharged to Puget Sound will increase because the total volume of stormwater conveyed to the West Point TP will increase. In addition, the treatment efficiency of the West Point TP will decrease as stormwater dilutes flows; however, the reduced treatment efficiency was not accounted for in this analysis.

Exhibit 5-17. Water Quality Impacts to Puget Sound for the Bypass Tunnel Alternative

	Existing Condition	Bypass Tunnel Alternative	Change
Annual Stormwater Volume (MG)	13	26	+ 13
Annual Pollutant Load (lbs/year)[1,2]			% Increase
TSS	3,100	6,000	94%
Zn	7	13	86%
Cu	1	2	100%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

5.5.4 Lake Union

Stormwater runoff will be diverted into the combined sewer system for treatment. Water quality benefits in the Broad and Lake Union West Sub-basins will be the same as those discussed under the Aerial Alternative.

5.6 Surface Alternative

The Surface Alternative will use the Convey and Treat Approach for stormwater management for the sub-basins north of S. Royal Brougham Way and south of Vine Street. In the other sub-basins, the Bypass Tunnel Alternative proposes to use the BMP Approach to treat stormwater runoff. Impacts and benefits will be similar to those discussed under the Bypass Tunnel Alternative and could result in a net benefit to the environment as compared to existing conditions (Exhibit 5-18).

Exhibit 5-18. Summary of Water Benefits for the Surface Alternative: Convey and Treat Approach

	Existing Conditions	Surface Alternative	Change
Annual Stormwater Volume (MG)	106	106	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	87,300	52,400	40%
Zn	132	88	33%
Cu	26	17	35%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from projectarea PGIS after treatment with the Convey and Treat Approach.

5.6.1 Duwamish River

Within this segment, the Surface Alternative will have similar but slightly greater benefits to water quality than the Bypass Tunnel Alternative because this alternative will retrofit more impervious surface (Exhibit 5-19).

Exhibit 5-19. Water Quality Benefits to the Duwamish River for the Surface Alternative

Duwamish River	Existing Conditions	Surface Alternative	Change
Annual Stormwater Volume (MG)	12	12	0
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	10,900	6,000	45%
Zn	16	10	38%
Cu	3	2	33%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

5.6.2 Elliott Bay

Stormwater

Benefits to water quality will be similar but slightly more than those discussed under the Bypass Tunnel Alternative because this alternative will retrofit more impervious surface (Exhibit 5-20).

Exhibit 5-20. Water Quality Benefits to Elliott Bay for the Surface Alternative

Elliott Bay	Existing Conditions	Surface Alternative	Change
Annual Stormwater Volume (MG)	80	68	-12
Annual Pollutant Load (lbs/year)[1,2]			% Reduction
TSS	72,000	40,000	44%
Zn	107	64	40%
Cu	21	13	38%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.
[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

In addition, this alternative could affect the current operation of the Washington, Madison, and University CSOs that are located along the waterfront because more water will be discharged to the combined sewer than under existing conditions.

Seawall

There are no operational impacts from the seawall replacement portion of this alternative.

Fire Suppression System

Impacts related to fire suppression system upgrades in the Battery Street Tunnel are the same as those discussed under the Aerial Alternative.

5.6.3 Puget Sound

Similar to the Bypass Tunnel Alternative, the Surface Alternative will increase the volume of stormwater discharged to Puget Sound because runoff from the existing stormwater-only sub-basins will be conveyed to the combined sewer system and to the West Point TP. Therefore, there will be an increase in the volume and pollutant load discharged to Puget Sound as compared to existing conditions (Exhibit 5-21).

Exhibit 5-21. Water Quality Impacts to Puget Sound for the Surface Alternative

Puget Sound	Existing Conditions	Surface Alternative	Change
Annual Stormwater Volume (MG)	13	26	+ 13
Annual Pollutant Load (lbs/year)[1,2]			% Increase
TSS	3,100	6,100	97%
Zn	7	13	86%
Cu	1	2	100%

[1] Total suspended solids (TSS) rounded to the nearest 100 lbs, copper (Cu) and zinc (Zn) rounded to the nearest pound.

[2] Annual pollutant load from project area PGIS after treatment with the Convey and Treat Approach.

5.6.4 Lake Union

Stormwater runoff will be diverted into the combined sewer system for treatment. Water quality benefits in Lake Union West, and Broad Sub-basins will be the same as those discussed under the Aerial Alternative.

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Chapter 6 CONSTRUCTION IMPACTS

Construction-related impacts will be temporary and could be minimized or prevented through the proper implementation of BMPs. Construction impacts are grouped into four general categories based on the type of impacts: (1) earthwork and staging; (2) seawall, in-water, and over-water work; (3) soil improvement; and (4) dewatering. Construction-related impacts to receiving waters associated with each Build Alternative are discussed in the following sections. Additional construction impacts associated with spoils removal and hazardous materials is discussed in Appendix U, Hazardous Materials Discipline Report.

All of the proposed Build Alternatives will rebuild the existing seawall. The construction methods used will depend on the configuration of the existing seawall, which has been classified as either Pile-Supported Gravity Wall or Type A or Type B Seawall. More information about the classifications of the seawall can be found in Appendix B, Alternatives Description and Construction Methods Technical Memorandum. The construction method will also depend on the final configuration of the proposed seawall, which will vary under each Build Alternative (Exhibit 6-1).

Exhibit 6-1. Proposed Seawall Configurations for the Build Alternatives

Existing Seawall Configuration	Seawall Length (feet)	Rebuild Alternative	Aerial Alternative		Tunnel Alternative	Bypass Alternative	Surface Alternative
			Rebuild	Frame Option			
Pier 48	520	Rebuild	Rebuild	Frame	Rebuild	Rebuild	Rebuild
Colman Curve							
Pile-Supported Gravity Wall	1,274	Rebuild	Rebuild	Frame	Tunnel	Tunnel	Rebuild
North of the Colman Curve							
Type B Seawall	1,544	Rebuild	Rebuild	Frame	Tunnel[1]	Tunnel[1]	Rebuild
Type A Seawall	4,414	Rebuild	Rebuild	Frame	Rebuild[2]	Rebuild[2]	Rebuild
No Existing Seawall	784	Rebuild	Rebuild	Frame	Rebuild	Rebuild	Rebuild

[1] Approximately 255 feet will be replaced using the Rebuild Seawall configuration.

[2] Approximately 303 feet will be replaced with a tunnel.

Temporary impacts are discussed below in the seawall, In-Water, and Over-Water Work sub-sections for each of the Build Alternatives.

All of the proposed Build Alternatives will demolish the existing viaduct structure except for the Rebuild Alternative, which will demolish a portion of the existing viaduct. Demolition of the existing structure could result in a fine dust that could raise the pH of stormwater runoff. Potential increases of pH in receiving waters will be minimized or prevented through the proper implementation of BMPs.

All of the proposed Build Alternatives will create detour routes for existing traffic. Pollutant loads associated with road runoff will be the same as existing conditions, so no impacts are anticipated. In addition, runoff from temporary detour routes will be managed according to the TESC Plan developed for the project (Chapter 9, Construction Mitigation), which may provide some treatment prior to discharge.

6.1 Rebuild Alternative

6.1.1 Duwamish River

Earthwork and Staging

Any construction-related water quality impacts will be temporary and will likely be caused by erosion of disturbed soil areas or soil stockpiles resulting in silt and sediment transport to receiving water by stormwater runoff. Stormwater runoff may also carry other contaminants, such as fuel or oil from construction operations, particularly at staging areas. Sediment and other contaminants can increase turbidity and affect other water quality parameters, such as the amounts of available oxygen in the water. In addition, pH can be altered if runoff is in contact with concrete during the curing process. The highest probability for impacts associated with spills is at staging areas. There are no staging areas proposed in this basin.

Seawall, In-Water, and Over-Water Work

There will be no improvements to the seawall in this basin. No in-water or over-water work will occur in this basin. Therefore, there will be no impacts associated with these activities in this basin.

Soil Improvement

There will be no soil improvement work required in this basin. Therefore, there will be no impacts associated with this activity in this basin.

Dewatering

There will be no dewatering work required in this basin. Therefore, there will be no impacts associated with this activity in this basin.

6.1.2 Elliott Bay

Earthwork and Staging

Impacts associated with earthwork and staging will be the same as those discussed for the Duwamish River in Section 6.1.1.

The Rebuild Alternative will have staging areas adjacent to Elliott Bay at Terminal 46 and Pier 48. In addition, Pier 56 and Piers 64/65 will likely be used for off-loading and on-loading construction materials. Other staging areas are also proposed as described in Appendix B, Alternatives Description and Construction Methods Technical Memorandum. However, the locations adjacent to Elliott Bay have a higher probability for spill, which could temporarily impact water quality.

Seawall, In-Water, and Over-Water Work

The Rebuild Alternative will rebuild the existing seawall between S. King Street and Myrtle Edwards Park. Construction is anticipated to take approximately 25 months to complete. Construction methods used to rebuild the seawall depend on the condition of the existing seawall (Exhibit 6-1). The lengths of shoreline that could be disturbed under each method are summarized in Exhibit 6-1. Temporary water quality impacts associated with each construction method are summarized in the following paragraphs.

Rebuilding segments of the seawall in locations where the existing seawall is a Pile-Supported Gravity Wall will require removal of the upper portion of the existing piles waterward of the new seawall and extending the slope protection to the new seawall. This method may require in-water work that could temporarily disturb the sediments. However, if work is conducted below the water line, BMPs developed during the permitting and design phases of the project will be implemented as needed to minimize the potentially impacted area.

As discussed in the Elliott Bay Section (Section 3.4), water currents along the waterfront are generally low velocity and run parallel to the end of the piers. Therefore, it was assumed that any temporary increase in turbidity will be adjacent to the work area and will not have substantial off-site impacts.

Rebuilding segments of the seawall in locations where the existing seawall is a Type A Seawall may require in-water work; therefore, there could be temporary impacts to water quality. The Seattle Aquarium is located adjacent to a Type A portion of the existing seawall. Therefore, it is possible that there will be temporary water quality impacts that could affect the Aquarium. However, if work is conducted below the water line, BMPs will be implemented as needed to minimize the potentially impacted area as discussed in Chapter 9, Construction Mitigation.

Rebuilding segments of the seawall in locations where the existing seawall is a Type B Seawall will require removal of the existing Ekki wood facing, cantilever, and steel sheet pile waterward of the new seawall. The work area will be below the water level, so disturbed sediments will contact surface water and could temporarily impact water quality. BMPs will be implemented as needed to minimize impacts.

Soil Improvement

Under the Rebuild Alternative, jet grouting or another soil improvement method will be used to amend the soils for seawall construction. Approximately 250,000 cubic yards of spoils are anticipated under this alternative. The spoils are likely to be commingled and will be dried on-site prior to off-site disposal. The spoils are likely to have a high water fraction. This water will be contained and could have a pH of approximately 10. This water will be treated as necessary prior to discharge to reduce pH, TSS, and other pollutants as needed. The type of treatment will be determined during the permitting and design phases of the project.

Dewatering

Drilled shafts will likely not be dewatered. Work will be performed in a wet environment and water will be contained in the shaft. A bentonite slurry may be used, which could increase the pH of the groundwater in the shaft. This water will be contained and could have a pH of approximately 10. This water will be treated as necessary prior to discharge to reduce pH, TSS, and other pollutants as needed. The type of treatment will be determined during the permitting and design phases of the project.

6.1.3 Puget Sound

No construction activities will occur in this basin.

6.1.4 Lake Union

No construction activities will occur in this basin. A staging area at the Seattle Center Parking Lot may be used during construction. Temporary impacts would be similar to those discussed for the Duwamish River under Section 6.1.1.

6.2 Aerial Alternative

6.2.1 Duwamish River

Earthwork and Staging

Temporary impacts will be the same as those discussed under the Rebuild Alternative.

Seawall, In-Water, and Over-Water Work

As discussed under the Rebuild Alternative, there will be no seawall, in-water, or over-water work in this basin, so there will be no potential impacts related to these activities.

Soil Improvement

As discussed under the Rebuild Alternative, there will be no soil improvement in this basin, so there will be no potential impacts related to this activity.

Dewatering

As discussed under the Rebuild Alternative, there will be no dewatering in this basin, so there will be no potential impacts related to this activity.

6.2.2 Elliott Bay

Earthwork and Staging

The Aerial Alternative proposes the same over-water staging areas as the Rebuild Alternative; so temporary impacts at these locations will be the same as those discussed under the Rebuild Alternative.

Seawall, In-Water, and Over-Water Work

The Aerial Alternative will rebuild the seawall using either the Rebuild or Frame Option (Exhibit 6-1). Impacts associated with construction will generally be similar to those discussed under the Rebuild Alternative, except that the construction duration is expected to be approximately 31 months.

Rebuilding segments of the seawall in locations where the existing seawall is a Pile-Supported Gravity Wall will require removal of the existing wall to the top of the existing piles waterward of the new seawall and extending the slope protection to the new seawall. Temporary impacts will be similar to those described under the Rebuild Seawall at the Pile-Supported Gravity Wall under the Rebuild Alternative.

Rebuilding segments of the seawall in locations where the existing seawall is a Type A Seawall may require in-water work; therefore, water quality could be temporarily impacted.

Rebuilding segments of the seawall in locations where the existing seawall is a Type B will require removal of the existing wall, cantilever, and sheet pile waterward of the new seawall. Temporary impacts will be similar to those described under the Rebuild Seawall at the Pile-Supported Gravity Wall under the Rebuild Alternative.

Soil Improvement

Under the Aerial Alternative, soil improvements will be used to amend the soils for seawall construction. Approximately 248,000 cubic yards of spoils are anticipated under this alternative. Impacts will be similar to the Rebuild Alternative.

Dewatering

Temporary impacts associated with drilled shafts will be similar to those discussed under the Rebuild Alternative.

6.2.3 Puget Sound

No construction activities will occur in this basin.

6.2.4 Lake Union

Earthwork and Staging

The Aerial Alternative will require some earthwork to reconstruct the Mercer underpass and surface streets. Temporary impacts associated with construction and staging will be similar to those discussed for the Duwamish River in Section 6.1.1.

Seawall, In-Water, and Over-Water Work

There will be no improvements to the seawall in this basin. No in-water or over-water work will occur in this basin. Therefore, there will be no impacts associated with these activities in this basin.

Soil Improvement

There will be no soil improvement in this basin. Therefore, there will be no impacts associated with this activity in this basin.

Dewatering

There will be no dewatering work required in this basin. Therefore, there will be no impacts associated with this activity in this basin.

6.3 Tunnel Alternative

6.3.1 Duwamish River

The Tunnel Alternative will have the same impacts as those discussed under the Rebuild Alternative.

6.3.2 Elliott Bay

Earthwork and Staging

The Tunnel Alternative proposes the same over-water staging areas as the Rebuild and Aerial Alternatives; therefore, this alternative will have the same temporary impacts as those described for Elliott Bay under the Rebuild Alternative (Section 6.1.2).

Seawall, In-Water, and Over-Water Work

The Tunnel Alternative will replace the existing seawall with both the Rebuild Seawall and a tunnel. Impacts at Pier 48 and north of the Colman Curve will be similar to those discussed under the Rebuild Alternative.

However, the existing seawall will be replaced with a tunnel, located a maximum of 21 feet west of the existing seawall at the Colman Curve and tapering into the existing seawall location. This segment will require in-water work west of the existing seawall over a distance of 1,274 feet, parallel to the seawall. Construction of the tunnel and seawall is anticipated to last approximately 23 months. In addition, surface sediments exceed CSLs for mercury, silver, lead, and zinc in this location (see the Nearshore Sediments Section [Section 3.7.2]). The proposed construction will likely disturb sediments and temporarily impact water quality. However, proper installation of BMPs could minimize impacts.

Currently, there are two existing Washington Street outfalls. The 72-inch stormwater outfall, which extends approximately 5 feet beyond the existing seawall, will be extended west of the new seawall, which is 21 feet west of the existing seawall. The 24-inch CSO outfall, which extends approximately 157 feet from the seawall, will not have to be modified.

Soil Improvement

Under the Tunnel Alternative, soil improvements will be used to amend the soils for seawall construction. Approximately 125,000 cubic yards of spoils are anticipated under this alternative. Impacts will be similar to but less than the Rebuild Alternative.

Dewatering

Construction of the approximately 4,300-foot-long cut-and-cover tunnel will be likely to require continuous dewatering of the exposed excavation. The following assumptions have been used in developing an estimate of the impacts of construction dewatering:

- Excavation and construction will proceed from south to north, and along an excavation distance of 4,300 feet; of this, 800 feet will be north of University Street.
- Southbound lanes will be constructed first over a 3-year period, followed by construction of the northbound lanes over a 2-year period.
- The total length of exposed excavation requiring dewatering will be no more than 1,500 feet at any one time as excavation and construction proceeds.

- Dewatering flow rates south of University Street will average 0.7 gallon per minute (gpm) per lineal foot of excavation; flow rates north of University Street will average 7.0 gpm per lineal foot of excavation (Martin, 2003).

Based on preliminary monitoring data, potential contaminants of concern are TSS, turbidity, and trace organic compounds.

Dewatering flow rates will vary over the 5-year excavation and construction period based on location and other factors normally affecting groundwater flow. However, current estimates range from 1,050 gpm to 6,090 gpm. The higher flow rates are primarily associated with work north of University Street. Dewatering pumps will convey water to a treatment system and will be treated prior to discharge to Elliott Bay.

6.3.3 Puget Sound

No construction activities will occur in this basin.

6.3.4 Lake Union

The Tunnel Alternative will have the same impacts as those discussed under the Aerial Alternative.

6.4 Bypass Tunnel Alternative

6.4.1 Duwamish River

The Bypass Tunnel Alternative will have the same impacts as those discussed under the Rebuild Alternative.

6.4.2 Elliott Bay

Earthwork and Staging

The Bypass Tunnel Alternative proposes the same over-water staging areas as the Rebuild Alternative; therefore, this alternative will have the same temporary impacts as those described for Elliott Bay under the Rebuild Alternative (Section 6.1.2).

Seawall, In-Water, and Over-Water Work

The Bypass Tunnel Alternative will replace the existing seawall with both the Rebuild Seawall and a tunnel. Temporary impacts at Pier 48 and north of the Colman Curve will be similar to those discussed under the Rebuild Alternative.

However, the existing seawall will be replaced with a bypass tunnel, located with an approximately 58-foot maximum extent into Elliott Bay west of the existing seawall at the Colman Curve. This segment will require in-water work west of the existing seawall over a distance of 1,274 feet, parallel to the seawall. Construction of the tunnel and seawall is anticipated to last approximately 39 months. As discussed under the Tunnel Alternative, the Bypass Tunnel Alternative is likely to disturb contaminated sediment, which could temporarily impact water quality. Because the Bypass Tunnel Alternative will disturb a greater area, temporary impacts will be similar to but greater than impacts discussed under the Tunnel Alternative.

Soil Improvement

Under the Bypass Tunnel Alternative, soil improvements will be used to amend the soils for seawall construction. Approximately 147,000 cubic yards of spoils are anticipated under this alternative. Impacts will be similar to but less than the Rebuild Alternative.

Dewatering

Construction of the approximately 4,300-foot-long cut-and-cover bypass tunnel will require continuous dewatering of the exposed excavation. Impacts are expected to be identical to the impacts for the construction of the southbound lanes of the Tunnel Alternative because their footprints are identical. The assumptions used to estimate potential impacts of construction dewatering were the same as for the southbound lane of the Tunnel Alternative.

Dewatering water was assumed to have the same potential contaminants of concern as those discussed under the Tunnel Alternative. Dewatering flow rates will vary over the 3-year excavation and construction period based on location and other factors normally affecting groundwater flow. However, current estimates range from 1,050 gpm to 6,090 gpm. The higher flow rates are primarily associated with work north of University Street. Dewatering pumps will convey water to a central treatment system.

6.4.3 Puget Sound

No construction activities will occur in this basin.

6.4.4 Lake Union

The Bypass Tunnel Alternative will have the same impacts as those discussed under the Aerial Alternative.

6.5 Surface Alternative

6.5.1 Duwamish River

The Surface Alternative will have the same impacts as those discussed under the Rebuild Alternative.

6.5.2 Elliott Bay

Earthwork and Staging

The Surface Alternative will have construction-related impacts similar to those discussed under the Rebuild Alternative. In addition, the Surface Alternative will have the same over-water staging areas as the Rebuild Alternative, except it will use all of Pier 48 for staging, so it will have additional over-water staging areas (and thus a higher potential for temporary impacts at this location).

Seawall, In-Water, and Over-Water Work

Temporary impacts associated with rebuilding the seawall are generally the same as those discussed under the Rebuild Alternative. Construction is expected to take approximately 24 months.

Soil Improvement

Under the Surface Alternative, soil improvements will be used to amend the soils for seawall construction. Approximately 250,000 cubic yards of spoils are anticipated under this alternative. Impacts will be similar to the Rebuild Alternative.

Dewatering

Temporary impacts associated with drilled shafts will be similar to those described under the Rebuild Alternative.

6.5.3 Puget Sound

No construction activities will occur in this basin.

6.5.4 Lake Union

The Surface Alternative will have the same impacts as those discussed under the Aerial Alternative.

6.6 Comparison of Alternatives

Potential construction related impacts to water quality due to disturbed contaminated sediments are similar amongst the alternatives along the seawall and are related to the likelihood of disturbance during in-water construction activities. The Tunnel and Bypass Alternatives would have a higher potential for temporary water quality impacts due to disturbed contaminated sediments during construction of the portion of the tunnel in the vicinity of the Washington Street outfall, a location with known contaminated sediments. However, BMPs will be used to reduce or minimize potential impacts.

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Chapter 7 SECONDARY AND CUMULATIVE IMPACTS

7.1 Secondary and Cumulative Impacts Common to All Build Alternatives

Secondary impacts are impacts that could result from the incremental effect of the proposed action when added to other past, present, or future projects. Cumulative impacts are impacts that could result when relatively minor independent impacts from multiple projects become collectively substantial over time if not properly mitigated.

As presented in Chapter 3, Affected Environment, the water quality adjacent to the project area has been impacted by development over the last 100 years. This project will provide a benefit to water quality by providing water quality treatment for stormwater runoff from PGIS.

The project is a replacement project and will not substantially increase the number of trips to the project area. As a result, there will not be any secondary impacts associated with increased traffic volumes. In addition, the proposed project is located in a highly developed corridor; therefore, it is unlikely that there will be secondary impacts to water quality as a result of future redevelopment in the project area.

7.1.1 Duwamish River

There are no secondary or cumulative impacts common to all of the proposed Build Alternatives in the Duwamish River Basin.

7.1.2 Elliott Bay

Washington State Ferries plans to expand Colman Dock to provide additional parking capacity. It is likely that Washington State Ferries will be required to install stormwater treatment BMPs. In addition, all of the proposed Build Alternatives for the AWV will construct a new over-water structure to provide access to the expanded Colman Dock. Both projects will increase PGIS located over Elliott Bay, which could have long-term impacts to water quality and sediment in this vicinity. In addition, Washington State Ferries also plans to remove Pier 48 as part of the Colman Dock Ferry Terminal expansion project. This could result in temporary impacts associated with disturbed sediments during demolition and pier removal.

7.1.3 Puget Sound

There are no secondary or cumulative impacts common to all of the proposed Build Alternatives in the Puget Sound Basin.

7.1.4 Lake Union

There are no secondary or cumulative impacts common to all of the proposed Build Alternatives in the Lake Union Basin.

7.2 No Build Alternative

Only under Scenario 3 of the No Build Alternative, which is catastrophic failure and collapse of the viaduct and/or seawall, is it likely that there will be secondary impacts from contaminated sediments. Cumulative impacts are not likely from any of the No Build Alternatives.

7.3 Rebuild Alternative

There are no secondary or cumulative impacts unique to the Rebuild Alternative.

7.4 Aerial Alternative

Testing of the fire suppression system for the Battery Street Tunnel could have minor secondary impacts to the West Point TP, if AFFF temporarily affects the efficiency or operation of the facility.

7.5 Tunnel Alternative

Testing of the fire suppression system could have minor secondary impacts to the West Point TP, if AFFF temporarily affects the efficiency or operation of the facility.

7.6 Bypass Tunnel Alternative

The Bypass Tunnel Alternative will use the Convey and Treat Approach to manage stormwater runoff from the project area. This approach will collect stormwater runoff from the project area and combine it with the combined sewer system. This will increase the volume of stormwater in the combined sewer system as compared to existing conditions. This will affect the efficiency and operation of the West Point TP and could affect the volume and/or duration of CSOs during large storm events in the project area, but as discussed in Section 5.5.3, this is a very small volume compared to the total volume.

The proposed Royal Brougham TP was sized to treat a CSO volume equivalent to the volume of recombined stormwater from the project area. However, the Royal Brougham TP will be off-site mitigation, and although the volumes are equivalent, the effectiveness of the Royal Brougham TP to mitigate the additional volume will need to be evaluated using a continuous hydraulic model of the system prior to final design.

In addition, due to the current funding schedule, it is possible that acceleration of the Royal Brougham TP could delay the CSO reduction project proposed for the Hanford CSO, which is currently scheduled for construction before the Royal Brougham TP. Because King County prioritized the CSO reduction project to improve the worst problems first, delay of the Hanford CSO project could have indirect impact to water quality in the Duwamish River.

Testing of the fire suppression system could have minor secondary impacts to the West Point TP, if AFFF temporarily affects the efficiency or operation of the facility.

7.7 Surface Alternative

The Surface Alternative will also use the Convey and Treat Approach to manage stormwater runoff from the project area. Secondary and cumulative impacts will be similar to those discussed under the Bypass Tunnel Alternative.

7.8 Significant Unavoidable Adverse Impacts

There are no significant unavoidable adverse water quality impacts associated with the proposed Build Alternatives.

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Chapter 8 OPERATIONAL MITIGATION

Since treatment of stormwater runoff is included in all of the proposed Build Alternatives, all of the alternatives will improve water quality as compared to existing conditions. Both the BMP and Convey and Treat Approaches will reduce the annual pollutant load discharged to the environment as compared to existing conditions. Therefore, no long-term mitigation is proposed for the Build Alternatives.

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Chapter 9 CONSTRUCTION MITIGATION

9.1 Mitigation Common to All Build Alternatives

All of the proposed alternatives will disturb soils, which could result in turbid stormwater runoff. Stormwater runoff from active construction sites will be treated prior to discharge as necessary to comply with the requirements of the WAC and/or the construction NPDES permit. During the permitting and design processes, a TESC Plan, a Spill Containment and Countermeasures Plan, and a Surface Water Pollution Prevention Plan will be developed for the project. The purpose of these plans is to ensure that pollutants (including sediment) associated with active construction sites and staging areas are controlled and that temporary impacts to water quality are minimized or prevented. Water quality monitoring will be performed in accordance with Ecology's standards. Additional information on the removal of soils and hazardous materials from the site is provided in Appendix U, Hazardous Materials Discipline Report (WSDOT 2003).

All of the proposed alternatives will rebuild the existing seawall. At existing seawall configuration Type A, it is likely that no work will be performed waterward of the existing seawall; however, a sediment barrier will be used to minimize the possibility of fine material being transported through joints. For work required to rebuild the existing seawall that will occur waterward of the existing seawall, particularly at Pile-Supported Gravity Walls and Type B Seawall, it is likely that a barrier will be installed prior to removal of the existing seawall and construction of the new seawall to contain turbid water and minimize or prevent temporary water quality impacts outside the work area.

All of the proposed Build Alternatives will use jet grouting or another method of soil improvement to amend soils. If the spoils are dewatered on-site, a treatment plant will likely be required to treat the water prior to discharge.

All of the proposed Build Alternatives will demolish the existing AWV. Dust from the demolition process could increase the pH of stormwater runoff. This water will be contained on-site and treated as necessary to reduce impacts to receiving waters.

9.2 Rebuild Alternative

The Rebuild Alternative will not require any special mitigation.

9.3 Aerial Alternative

The Aerial Alternative will not require any special mitigation.

9.4 Tunnel Alternative

Construction dewatering water will be treated prior to discharge as necessary to comply with the requirements of the WAC and/or the construction NPDES permit. Treatment of dewatering water is discussed in more detail in Section 6.3.2. Water quality monitoring will be performed as necessary to demonstrate compliance. Construction dewatering water may be discharged to Elliott Bay via temporary outfall piping or through existing outfalls.

9.5 Bypass Tunnel Alternative

Dewatering water will be treated using the same methods discussed under the Tunnel Alternative.

9.6 Surface Alternative

The Surface Alternative will not require any special mitigation.

Chapter 10 PERMITS AND APPROVALS

In general, the proposed BMP and Convey and Treat Approaches will comply with most of the applicable federal, state, and local surface water related plans and policies. This chapter summarizes the applicable regulations and the associated permits and approval process. A complete list of permits is provided in the Draft Environmental Impact Statement.

Any activity that discharges stormwater into navigable waters must comply with the applicable provisions of Sections 301, 302, 306, and 307 of the Clean Water Act (CWA). Projects must also comply with all known, available, and reasonable technology for prevention, control and treatment (AKART) under state law, including effluent limitations under CWA, and any applicable more stringent county or local limitations. The point of compliance has not been determined for this project, but it is assumed that the point of compliance is the point at which runoff from the project site combines with the existing drainage system. However, if treatment cannot be performed prior to connection with the upstream basin, then the point of compliance may be the outfall.

10.1 Federal Regulations

Under the Clean Water Act Section 402: NPDES State Waste Discharge Individual Permit for Process Water and Storm Water, an NPDES permit is required for any discharge of pollutants into the waters of the United States. Permitted discharges must satisfy discharge permit requirements under Section 402 of the CWA and 90.48 RCW. King County currently has an NPDES permit for the West Point TP and its combined sewer system (NPDES Permit No. WA-002918-1). Compliance with King County's NPDES permit conditions and regulations for water quality, volume, and length of discharge will be required to prevent pollution "pass through" at the treatment plant, or system overflows (King County Ordinance No. 13680). In addition, the project will have to comply with WSDOT's NPDES stormwater permit and the City of Seattle's NPDES wastewater and stormwater permits.

In addition, an NPDES permit may be required for modification of an existing outfall. If discharge is into the combined system, the Municipal & Construction stormwater general NPDES permit participation must comply with this permit in terms of discharge limits and technology requirements. A construction stormwater general permit will also be required for all of the Build Alternatives because more than 1 acre of land will be disturbed. An Army Corps of Engineers Section 404 Permit will be required for any discharge of dredge or fill material into waters of the US. In addition, an Army Corps of Engineers Section 10 Permit is required for any work in navigable waters of the US. Work in the water will be required to construct the new seawall south of Colman Dock and to remove the existing seawall. A Rivers and Harbor permit will also be required and will be related to the Army Corps of Engineers Section 10 permit.

10.2 State Regulations: Washington Administrative Code

Through the WAC, Ecology regulates discharges to surface waters of the state. Several chapters in the WAC address water quality.

10.2.1 Chapter 173-201A WAC: Water Quality Standards for Surface Waters of the State of Washington

Chapter 173-201A WAC, Water Quality Standards for Surface Waters of the State of Washington, summarizes the state water quality standards for ambient water quality and is part of the Section 401 Water Quality Certification, which certifies compliance with state water quality standards. The certification process examines effects of the proposed project related to the state water quality standards and beneficial use. Any activity resulting in any discharge into navigable waters must comply with the applicable provisions of Sections 301, 302, 306, and 307 of the CWA.

Ecology has defined water quality standards for surface water in the state of Washington. Based on the presumptive approach of the Ecology manual (2001), it is assumed that the BMP Approach will meet water quality standards by installing stormwater treatment BMPs. Based on published concentrations of pollutants in highway runoff, it is assumed that runoff from highways without treatment will not meet these standards for copper, lead, and zinc in effluent at the end of the pipe (WSDOT 2002b).

Chapter 173-201A-070 is the Antidegradation policy for water quality. Since this project will improve the quality of stormwater runoff from the project area, it will comply with this section of the WAC.

10.2.2 Chapter 173-204 WAC: Sediment Management Standards

This chapter sets the standards for sediment quality in Puget Sound. Ecology program guidance recommends that models be used to evaluate the effect of a discharge on sediments.

10.2.3 Chapter 173-221 WAC: Discharge Standards and Effluent Limitations for Domestic Wastewater Facilities

Chapter 173-221 WAC, Discharge Standards and Effluent Limitations for Domestic Wastewater Facilities, states that facilities receiving flows from combined sewers should be designed using AKART and that Ecology reviews projects on a case-by-case basis to determine attainable percent removal for wet weather events. Therefore, it is likely that the final treatment standards will be subject to negotiation with Ecology.

10.2.4 Chapter 173-226 WAC: Waste Discharge General Discharge Program

Chapter 173-226 WAC, Waste Discharge General Discharge Program, establishes the state permit program for discharges to waters of the state, including municipal sewer systems. Chapter 173-226-100(2)(h) prohibits discharge of stormwater to the sewer system unless approved by Ecology under "extraordinary circumstances" (such as lack of direct discharge alternatives due to combined sewer service).

10.2.5 Chapter 173-245 WAC: Submission of Plans and Reports for Construction and Operation of Combined Sewer Overflow Reduction Facilities

Chapter 173-245 WAC, Submission of Plans and Reports for Construction and Operation of Combined Sewer Overflow Reduction Facilities, states that all CSO sites:

> "shall achieve and at least maintain the greatest reasonable reduction, and neither cause violations of applicable water quality standards, nor restrictions to the characteristic uses of the receiving water, nor accumulation of deposits which: (a) exceed sediment criteria or standards; or (b) have an adverse biological effect."

This section also states that storm sewer/sanitary sewer separation shall receive consideration as a control/treatment alternative.

Ecology also requires that no more than one untreated CSO event on average occurs per year and that there cannot be an increase in CSO flow above baseline values. This chapter provides general rules for preparation of a CSO reduction plan that includes field measurements of the existing combined system, mathematical models and analysis, and estimation of water quality impacts. Plans and specifications must be prepared in accordance with the State of Washington Criteria for Sewage Works Design (Ecology 1998b); Section C3-1.1 of this document states that no new combined sewers may be built (Ecology 1998b).

10.2.6 Chapter 173-270 WAC: Puget Sound Highway Runoff Program

Chapter 173-270 WAC, Puget Sound Highway Runoff Program, has a sub-chapter (173-270-060, Existing Facilities) that requires that all existing highways with greater than 50,000 average daily trips be retrofitted with all practicable BMP projects by the end of 2005, or that highway runoff be transferred to tribes or local governments for treatment as funding is appropriated. Projects will be identified through an inventory of fiscal, technical, work force, and legislative requirements, restrictions, and priorities.

10.3 State Regulations: Department of Fish and Wildlife

A hydraulic project approval (HPA) would be required for all work performed within the ordinary high water mark.

10.4 Department of Transportation Requirements

WSDOT has developed a Highway Runoff Manual for design and water quality treatment BMPs for road runoff. In addition, Instructional Letter 4020.02 provides guidance on sizing water quality BMPs to address concerns raised by the Endangered Species Act.

10.5 King County Regulations

10.5.1 King County Ordinance No. 13680

King County Ordinance 13680 provides policy guidance through the year 2030 and is intended to provide direction for operation and further development of the wastewater systems and policies. The following is included in this ordinance:

- "King County's wastewater collection system is impacted by the intrusion of clean stormwater and conveyance and treatment facilities shall not be designed for the interception, collection and treatment of clean stormwater."
- "Any changes in facilities to the West Point TP shall comply with the terms of the West Point Settlement Agreement."

10.5.2 Interlocal Agreement for Combined Sewer System

Currently King County operates a system for conveyance, treatment, and storage of sewage consistent with the terms of agreement between King County and the City of Seattle, which is the local sewer utility.

10.5.3 1999 Regional Wastewater System Plan

The Regional Wastewater System Plan (King County 2000) update is scheduled for 2005. This plan will also address CSO treatment facilities. Currently, there are no specific plans along the waterfront.

10.6 City of Seattle Regulations

The City's Drainage Code (2001b) requires that stormwater detention and water quality treatment facilities shall be installed and maintained to treat that portion of the site being developed. Section 22.802.012 prohibits discharge to the sewer or combined sewer unless the Director of Seattle Public Utilities (in consultation with the local sewage treatment agency) determines that other methods to control stormwater are not adequate or reasonable. The Seattle 1988 CSO Control Plan outlines a program to reduce CSOs. This plan was updated in 2001 for seven priority basins (Seattle 2001c). This plan is intended to reduce CSOs in Portage Bay and the Montlake Cut, Elliott Bay, the Duwamish River, Lake Union, and the Ship Canal.

The City's Drainage Code has requirements for detention and treatment of stormwater (Seattle 2001b). The code states that detention should be provided so that the:

> "peak drainage water discharge rate from the portion of the site being developed shall not exceed 0.2 cubic feet per second per acre under 25-year 24-hour design storm conditions or 0.15 cubic feet per second per acre under 2-year, 24-hour design storm conditions unless the site discharges water directly to a designated receiving water (such as Elliott Bay) or to a public storm drain which the Director of SPU determines has sufficient capacity to carry existing and anticipated loads from the point of connection to a designated receiving water body."

The City's Drainage Code also requires that stormwater quality treatment facilities shall be installed and maintained to treat that portion of the site being developed.

In addition to the Drainage Code, the Seattle Municipal Code (Section 21.16) also applies to the project. This code regulates connections and modifications to Seattle side sewers.

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ATTACHMENT A

List of Preparers

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List of Preparers

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ATTACHMENT B

Mass Balance Model: Methods Documentation, Input, and Results

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B. INTRODUCTION

The following text describes the process used for the mass balance model to calculate the pollutant load associated with stormwater runoff discharged to the environment from the project area under existing conditions and under each of the build alternatives. In general, four steps were used to calculate the final annual pollutant load discharged to the environment:

Step 1 Calculate the annual pollutant load from the project sub-basin prior to treatment.

Step 2 Distribute the annual pollutant load to the treatment appropriate for each sub-basin under existing conditions and under each of the build alternatives.

Step 3 Apply treatment to the percentage of the annual pollutant load routed to treatment facilities (Stormwater BMPs, Royal Brougham TP, or West Point TP) to reduce the annual pollutant load.

Step 4 Calculate the annual pollutant load discharged to the environment (Duwamish River, Elliott Bay, Puget Sound, and Lake Union).

Each step for the mass balance model is discussed in detail in the following sections.

B.1 MASS BALANCE STEP 1: CALCULATE THE ANNUAL POLLUTANT LOAD PRIOR TO TREATMENT

The annual pollutant load (without treatment) was calculated for each sub-basin using the WSDOT Method 3: FHWA (WSDOT 2002b). WSDOT Method 3 includes the following steps:

B.1.1 WSDOT Method 3 Step 1

Step 1 converts the site median pollutant concentration (Cmed) to average event mean concentration (Cm):

$Cm = Cmed * (1+CV2)^{0.5}$

Where:

Cm = Average Event Mean Concentration (Exhibit B-1)
Cmed = Site Median Pollutant Concentration (Exhibit B-1; Attachment D)
CV = Coefficient of Variation of Event Mean (CV = 0.71 [WSDOT 2002])

Exhibit B-1. Summary of Pollutant Concentrations (mg/L)

	TSS	Zinc	Copper
Cmed	91	0.135	0.027
Cm	112	0.166	0.033

B.1.2 WSDOT Method 3 Step 2

Step 2 calculates the mean event mass pollutant load:

Lm = Cm * (Vm/1,000)

Where:

Lm = Mean pollutant mass loading (Kg per event)
Cm = Average Event Mean Concentration
Vm = Volume of rainfall for mean storm event (Vm = 11.7 mm/unit area for Seattle) [WSDOT 2002b]). Unit areas correspond to the acreage for each alternative (Exhibit B-2).

B.1.3 WSDOT Method 3 Step 3

Step 3 calculates the annual load using the equation below:

La = Lm * Ns

Where:

La = Annual mass loading of pollutant
Lm = Mass load for mean event (Kg per event)
Ns = Number of storms per year (86.7 for Seattle [WSDOT 2002])

The results of Mass Balance Step 1 are report in Exhibit B-3. The annual pollutant load was calculated for each alternative by sub-basin and it was assumed that the annual load prior to treatment was the same under each alternative within each sub-basin.

B.2 MASS BALANCE STEP 2: DISTRIBUTE THE ANNUAL POLLUTANT LOAD

The percentage of the annual stormwater runoff volume (and associated pollutant load) treated varies between sub-basin, alternative, and stormwater management approach. To account for these differences, different percentages of the annual load were routed to each of the treatment facilities and, as a result, to different the receiving water (Exhibit B-4).

Exhibit B-2. Areas of PGIS[1] for each sub-basin (acres)

Sub-Basin	Existing	Rebuild Project	Rebuild Non-Project	Aerial Project	Aerial Non-Project	Tunnel Project	Tunnel Non-Project	Bypass Project	Bypass Non-Project	Surface Project	Surface Non-Project
Lander	12.0	7.5	4.5	4.4	7.6	7.5	4.5	7.5	4.5	7.7	4.4
Royal Brougham South	14.7	13.0	1.7	7.6	7.1	13.0	1.7	13.0	1.7	13.0	1.7
Royal Brougham North	8.4	6.7	1.7	5.9	2.5	6.7	1.7	7.0	1.4	5.6	2.8
Washington	5.0	3.9	1.2	4.1	0.9	4.2	0.9	3.9	1.1	4.4	0.6
T46	13.4	11.1	2.3	0.1	13.3	10.8	2.5	12.0	1.4	9.7	3.6
S1	1.9	1.7	0.3	1.5	0.4	1.5	0.4	1.5	0.4	1.6	0.3
S2	4.2	4.2	0.0	3.3	0.9	3.3	1.0	3.3	0.9	3.7	0.5
S3	2.6	2.1	0.5	2.0	0.6	1.9	0.7	1.4	1.2	1.6	1.0
S4	0.8	0.8	0.0	0.6	0.2	0.6	0.2	0.6	0.2	0.6	0.2
S5	0.8	0.8	0.0	0.7	0.1	0.7	0.1	0.7	0.1	0.7	0.1
Pine	3.0	2.4	0.6	2.8	0.3	2.1	1.0	2.8	0.2	2.2	0.8
Seneca	0.5	0.3	0.2	0.5	0.0	0.5	0.0	0.5	0.0	0.5	0.0
University	3.1	1.7	1.5	2.0	1.1	1.7	1.4	2.9	0.3	2.9	0.2
Madison	6.0	3.3	2.7	4.6	1.5	3.8	2.2	4.2	1.9	5.0	1.1
King	5.0	4.5	0.5	3.4	1.6	4.5	0.5	4.1	0.9	4.1	0.9
Pike	2.1	0.6	1.4	2.0	0.1	0.6	1.5	1.3	0.8	1.3	0.8
Vine	4.8	3.4	1.4	3.6	1.1	4.1	0.6	3.3	1.5	3.9	0.9
Denny	4.1	0.0	4.1	2.3	1.8	2.3	1.8	2.3	1.8	3.9	0.2
Broad	1.2	0.0	1.2	0.7	0.5	0.7	0.5	0.7	0.5	1.1	0.1
Lake Union West	4.2	0.0	4.2	4.0	0.2	4.0	0.2	4.0	0.2	4.0	0.2

[1] PGIS = Pollutant Generating Impervious Surface

Exhibit B-3. Annual Pollutant Load for each Sub-basin Prior to Treatment

Sub-Basin	Annual Vol. (MG/yr)	Annual Load (lbs/yr)		
		TSS	Zn	Cu
Lander	13.0	12,100	18.0	3.6
Royal Brougham South	15.9	14,800	22.0	4.4
Royal Brougham North	9.1	8,500	12.6	2.5
Washington	5.5	5,100	7.6	1.5
T46	14.5	13,500	20.1	4.0
S1	2.1	1,900	2.8	0.6
S2	4.6	4,300	6.3	1.3
S3	2.8	2,600	3.9	0.8
S4	0.9	800	1.2	0.2
S5	0.9	800	1.2	0.2
Pine	3.3	3,000	4.5	0.9
Seneca	0.6	554	0.8	0.2
University	3.4	3,100	4.7	0.9
Madison	6.5	6,100	9.0	1.8
King	5.4	5,000	7.5	1.5
Pike	2.3	2,100	3.1	0.6
Vine	5.2	4,800	7.1	1.4
Denny	4.5	4,200	6.2	1.2
Broad	1.3	1,200	1.8	0.4
Lake Union West	4.6	4,300	6.3	1.3

Exhibit B-4. Summary of Annual Runoff Volume Distribution

Existing Condition	% Discharged Untreated	% Treated with BMPs	% Treated at West Point TP	% Treated at Royal Brougham TP
Storm	100%	0%	0%	0%
Combined	56.5%	0%	43.5%	0%
Diversion Structure[1]	90%	0%	10%	0%
King[2]	2.5%	0%	43.5%	54%
BMP Approach	**% Discharged Untreated**	**% Treated with BMPs**	**% Treated at West Point TP**	**% Treated at Royal Brougham TP**
Storm	9%	91%	0%	0%
Combined	56.5%	0%	43.5%	0%
Diversion Structure[1]	9%	81%	10%	0%
King[2]	2.5%	0%	43.5%	54%
Convey & Treat Approach	**% Discharged Untreated**	**% Treated with BMPs**	**% Treated at West Point TP**	**% Treated at Royal Brougham TP**
Storm	9%	91%	0%	0%
Combined[3]	56.5%	0%	43.5%	0%
Lander[1]	9%	81%	10%	0%
King, Royal Brougham North, Washington[4]	2.5%	0%	43.5%	54%

1 A low flow diversion structure that diverts the first flush to the combined sewer system

2 It was assumed that the Royal Brougham TP would be in operation for the design year (2030) and constructed per the existing King County Plan, which would divert overflows from the King Sub-basin to the Royal Brougham TP.

3 Stormwater runoff from sub-basins north of Columbia Street would be collected in the City's combined sewer system and routed to the County's combined sewer system via the return pipe under Pike Street

4 Stormwater runoff from these sub-basins will be collected and conveyed to the combined sewer system at Royal Brougham and would be treated by the Royal Brougham TP.

These assumptions were applied to each sub-basin as shown in Exhibit B-5.

Exhibit B-5. Annual Runoff Volume Distribution by Sub-basin

Sub-Basin	Existing Condition				BMP Approach				Convey & Treat Approach			
	No Treatment	Treatment w/ BMP	Treatment at RB TP	Treatment at WP WTP	No Treatment	Treatment w/ BMP	Treatment at RB TP	Treatment at WP WTP	No Treatment	Treatment w/ BMP	Treatment at RB TP	Treatment at WP WTP
Lander	90%	0%	0%	10%	9%	81%	0%	10%	9%	81%	0%	10%
Royal Brougham South	90%	0%	0%	10%	9%	81%	0%	10%	9%	81%	0%	10%
Royal Brougham North	90%	0%	0%	10%	9%	81%	0%	10%	2.5%	0%	54%	43.5%
Washington	100%	0%	0%	0%	9%	91%	0%	0%	2.5%	0%	54%	43.5%
T46	100%	0%	0%	0%	9%	91%	0%	0%	9%	91%	0%	0%
S1	100%	0%	0%	0%	9%	91%	0%	0%	9%	91%	0%	0%
S2	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
S3	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
S4	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
S5	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
Pine	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
Seneca	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
Union	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
Madison	100%	0%	0%	0%	9%	91%	0%	0%	56.5%	0%	0%	43.5%
King	2.5%	0%	54%	43.5%	2.5%	0%	54%	43.5%	2.5%	0%	54%	43.5%
Pike	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%
Vine	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%
Denny	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%	56.5%	0%	0%	43.5%
Broad	100%	0%	0%	0%	56.5%[1]	0%	0%	43.5%	56.5%[1]	0%	0%	43.5%
Lake Union West	56.5%[1]	0%	0%	43.5%	56.5%[1]	0%	0%	43.5%	56.5%[1]	0%	0%	43.5%

[1]54 percent discharges untreated to Elliott Bay at the Denny outfall, 2.5 percent discharges untreated to Lake Union

Documentation of the annual volume distribution is provided in Attachment E. Since the sub-basins were delineated to include primarily road surfaces, it was assumed that the pollutant load prior to treatment would be the same for all of the alternatives within each sub-basin.

B.3 MASS BALANCE STEP 3: APPLY TREATMENT REMOVAL EFFICIENCY

Once the annual project load was calculated for each sub-basin and routed to the applicable treatment option, removal of pollutants using treatment was applied to the mass balance model. The treatment removal efficiency for each treatment option (No Treatment, West Point TP, stormwater BMPs, and Royal Brougham TP) was used to calculate the percentage of the pollutant load that would be reduced by treatment (Exhibit B-6).

Exhibit B-6. Summary of Treatment Removal Efficiency

	Treatment Removal Efficiency (%)		
Treatment Option	TSS	Zn	Cu
BMPs	80	65	58
West Point TP	75	63	77
Royal Brougham TP	80	79	86

Documentation for the assumptions used to determine treatment removal efficiency is provided in Appendix E. Treatment was only applied to the project areas; it was assumed that only the project areas would be retrofitted with BMPs. As a result, in existing combined sewer sub-basins neither stormwater management approach would change the existing level of treatment.

B.4 MASS BALANCE STEP 4: CALCULATE THE ANNUAL POLLUTANT LOAD DISCHARGED TO THE ENVIRONMENT FOLLOWING TREATMENT

The pollutant load discharged to the environment was calculated by summing the pollutant load that would be discharged to each receiving water after treatment is applied (Exhibits B-7 through B-15 [Attached]).

B.5 REFERENCES

WSDOT (Washington State Department of Transportation). 2002. WSDOT Water Resources Discipline Study Guidance: Quantitative Procedures for Water Quality Impact Assessments. November 2002.

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Exhibit B-7

EXISTING PROJECT AREA

	No Treatment: Annual Vol. (MG/yr)	No Treatment: TSS	No Treatment: Zn	No Treatment: Cu	Stormwater BMPs: Annual Vol. (MG/yr)	Stormwater BMPs: TSS	Stormwater BMPs: Zn	Stormwater BMPs: Cu	Royal Brougham TP: Annual Vol. (MG/yr)	Royal Brougham TP: TSS	Royal Brougham TP: Zn	Royal Brougham TP: Cu	West Point TP: Annual Vol. (MG/yr)	West Point TP: TSS	West Point TP: Zn	West Point TP: Cu
DUWAMISH RIVER	12	10,900	16.2	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ELLIOTT BAY	74	69,200	102.6	20.5	0.0	0.0	0.0	0.0	2.9	500	0.8	0.1	0.0	0.0	0.0	0.0
PUGET SOUND	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3	3,100	6.9	0.9
LAKE UNION	4	3,600	5.4	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Annual Pollutant Load (lbs/yr) / **NO TREATMENT** — Treatment Efficiency: TSS 0%, Zn 0%, Cu 0% — L_A Discharged (lbs/yr)

Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	12,149	18.0	3.6	13	90%	12	10,934	16.2	3.2
RB-S	14,805	22.0	4.4	16	90%	14	13,325	19.8	4.0
RB-N	8,465	12.6	2.5	9	90%	8	7,618	11.3	2.3
WA	5,095	7.6	1.5	5	100.0%	5	5,095	7.6	1.5
T46	13,515	20.1	4.0	15	100%	15	13,515	20.1	4.0
S1	1,921	2.8	0.6	2	100.0%	2	1,921	2.8	0.6
S2	4,252	6.3	1.3	5	100%	5	4,252	6.3	1.3
S3	2,625	3.9	0.8	3	100%	3	2,625	3.9	0.8
S4	807	1.2	0.2	1	100%	1	807	1.2	0.2
S5	798	1.2	0.2	1	100%	1	798	1.2	0.2
PN	3,046	4.5	0.9	3	100%	3	3,046	4.5	0.9
SC	554	0.8	0.2	1	100%	1	554	0.8	0.2
UN	3,141	4.7	0.9	3	100%	3	3,141	4.7	0.9
MD	6,097	9.0	1.8	7	100%	7	6,097	9.0	1.8
KS	5,035	7.5	1.5	5	2.5%	0	126	0.2	0.0
PK	2,101	3.1	0.6	2	57%	1	1,187	1.8	0.4
V	4,805	7.1	1.4	5	57%	3	2,715	4.0	0.8
D	4,166	6.2	1.2	4	57%	3	2,354	3.5	0.7
B	1,212	1.8	0.4	1	100%	1	1,212	1.8	0.4
0	-	0.0	0.0	0	0%	0	-	0.0	0.0
0	-	0.0	0.0	0	0%	0	-	0.0	0.0
LUW	4,256	6.3	1.3	5	57%	3	2,405	3.6	0.7

STORMWATER BMPS — Treatment Efficiency: TSS 80%, Zn 65%, Cu 58% — L_A Discharged (lbs/yr)

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0.0	-	0.0	0.0
RB-S	0%	0.0	-	0.0	0.0
RB-N	0%	0.0	-	0.0	0.0
WA	0%	0.0	-	0.0	0.0
T46	0%	0.0	-	0.0	0.0
S1	0%	0.0	-	0.0	0.0
S2	0%	0.0	-	0.0	0.0
S3	0%	0.0	-	0.0	0.0
S4	0%	0.0	-	0.0	0.0
S5	0%	0.0	-	0.0	0.0
PN	0%	0.0	-	0.0	0.0
SC	0%	0.0	-	0.0	0.0
UN	0%	0.0	-	0.0	0.0
MD	0%	0.0	-	0.0	0.0
KS	0%	0.0	-	0.0	0.0
PK	0%	0.0	-	0.0	0.0
V	0%	0.0	-	0.0	0.0
D	0%	0.0	-	0.0	0.0
B	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
LUW	0%	0.0	-	0.0	0.0

ROYAL BROUGHAM TP — Treatment Efficiency: TSS 80%, Zn 79%, Cu 86% — L_A Discharged (lbs/yr)

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	-	0.0	0.0
RB-S	0%	0	-	0.0	0.0
RB-N	0%	0	-	0.0	0.0
WA	0%	0	-	0.0	0.0
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	0%	0	-	0.0	0.0
S3	0%	0	-	0.0	0.0
S4	0%	0	-	0.0	0.0
S5	0%	0	-	0.0	0.0
PN	0%	0	-	0.0	0.0
SC	0%	0	-	0.0	0.0
UN	0%	0	-	0.0	0.0
MD	0%	0	-	0.0	0.0
KS	54.0%	3	544	0.8	0.1
PK	0%	0	-	0.0	0.0
V	0%	0	-	0.0	0.0
D	0%	0	-	0.0	0.0
B	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	0%	0	-	0.0	0.0

WEST POINT TP — Treatment Efficiency: TSS 75%, Zn 63%, Cu 77% — L_A Discharged (lbs/yr)

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	1	304	0.7	0.1
RB-S	10%	2	370	0.8	0.1
RB-N	10%	1	212	0.5	0.1
WA	0%	0	-	0.0	0.0
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	0%	0	-	0.0	0.0
S3	0%	0	-	0.0	0.0
S4	0%	0	-	0.0	0.0
S5	0%	0	-	0.0	0.0
PN	0%	0	-	0.0	0.0
SC	0%	0	-	0.0	0.0
UN	0%	0	-	0.0	0.0
MD	0%	0	-	0.0	0.0
KS	44%	2	548	1.2	0.2
PK	44%	1	228	0.5	0.1
V	44%	2	522	1.2	0.1
D	44%	2	453	1.0	0.1
B	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	44%	2	463	1.0	0.1

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Exhibit B-8

REBUILD ALT. PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	0.7	685	1.0	0.2	6.6	1,233	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	7.7	7,133	10.6	2.1	49.1	9,145	23.7	5.7	2.6	492	0.8	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	7.0	1,625	3.6	0.4
LAKE UNION	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

REBUILD ALT. NON-PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	4.4	4,081	6.1	1.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	17.5	16,315	24.2	4.8	0.0	0	0.0	0.0	0.3	52	0.1	0.0	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	6.3	1,475	3.3	0.4
LAKE UNION	3.9	3,617	5.4	1.1	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

BMP-REBUILD ALT. TOTAL	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	5.1	4,800	7.1	1.4	6.6	1,200	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	25.2	23,400	34.8	7.0	49.1	9,100	23.7	5.7	2.9	500	0.8	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	13.3	3,100	6.9	0.9
LAKE UNION	3.9	3,600	5.4	1.1	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

PROJECT AREA - RETROFITTED

Annual Pollutant Load (lbs/yr)

Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	7614	11.3	2.3	8.2
RB-S	13115	19.5	3.9	14.1
RB-N	6738	10.0	2.0	7.2
WA	3926	5.8	1.2	4.2
T46	11224	16.7	3.3	12.0
S1	1668	2.5	0.5	1.8
S2	4241	6.3	1.3	4.6
S3	2143	3.2	0.6	2.3
S4	794	1.2	0.2	0.9
S5	798	1.2	0.2	0.9
PN	2470	3.7	0.7	2.7
SC	313	0.5	0.1	0.3
UN	1672	2.5	0.5	1.8
MD	3331	4.9	1.0	3.6
KS	4555	6.8	1.4	4.9
PK	653	1.0	0.2	0.7
V	3419	5.1	1.0	3.7
D	0	0.0	0.0	0.0
B	0	0.0	0.0	0.0
0	0	0.0	0.0	0.0
0	0	0.0	0.0	0.0
LUW	0	0.0	0.0	0.0

PROJECT - NO TREATMENT

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			0%	0%	0%
			L_A Discharged (lbs/yr)		
LN	9%	0.7	685	1.0	0.2
RB-S	9%	1.3	1,180	1.8	0.4
RB-N	9%	0.7	606	0.9	0.2
WA	9%	0.4	353	0.5	0.1
T46	9%	1.1	1,010	1.5	0.3
S1	9%	0.2	150	0.2	0.0
S2	9%	0.4	382	0.6	0.1
S3	9%	0.2	193	0.3	0.1
S4	9%	0.1	71	0.1	0.0
S5	9%	0.1	72	0.1	0.0
PN	9%	0.2	222	0.3	0.1
SC	9%	0.0	28	0.0	0.0
UN	9%	0.2	150	0.2	0.0
MD	9%	0.3	300	0.4	0.1
KS	3%	0.1	114	0.2	0.0
PK	57%	0.4	369	0.5	0.1
V	57%	2.1	1,932	2.9	0.6
D	57%	0.0	0	0.0	0.0
B	57%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	0.0	0	0.0	0.0

PROJECT - STORMWATER BMPS

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			80%	65%	58%
			L_A Discharged (lbs/yr)		
LN	81%	6.6	1,233	3.2	0.8
RB-S	81%	11.4	2,125	5.5	1.3
RB-N	81%	5.9	1,092	2.8	0.7
WA	91%	3.8	714	1.9	0.4
T46	91%	11.0	2,043	5.3	1.3
S1	91%	1.6	303	0.8	0.2
S2	91%	4.1	772	2.0	0.5
S3	91%	2.1	390	1.0	0.2
S4	91%	0.8	145	0.4	0.1
S5	91%	0.8	145	0.4	0.1
PN	91%	2.4	450	1.2	0.3
SC	91%	0.3	57	0.1	0.0
UN	91%	1.6	304	0.8	0.2
MD	91%	3.3	606	1.6	0.4
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

PROJECT - ROYAL BROUGHAM TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			80%	79%	86%
			L_A Discharged (lbs/yr)		
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	3	492	0.8	0.1
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

WEST POINT TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			75%	63%	77%
			L_A Discharged (lbs/yr)		
LN	10%	1	190	0.4	0.1
RB-S	10%	1	328	0.7	0.1
RB-N	10%	1	168	0.4	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	2	495	1.1	0.1
PK	44%	0	71	0.2	0.0
V	44%	2	372	0.8	0.1
D	44%	0	0	0.0	0.0
B	44%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	0	0	0.0	0.0

NON-PROJECT AREA

Annual Pollutant Load (lbs/yr)

Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	4,535	6.7	1.3	4.9
RB-S	1,690	2.5	0.5	1.8
RB-N	1,727	2.6	0.5	1.9
WA	1,170	1.7	0.3	1.3
T46	2,291	3.4	0.7	2.5
S1	254	0.4	0.1	0.3
S2	12	0.0	0.0	0.0
S3	482	0.7	0.1	0.5
S4	13	0.0	0.0	0.0
S5	-	0.0	0.0	0.0
PN	575	0.9	0.2	0.6
SC	241	0.4	0.1	0.3
UN	1,470	2.2	0.4	1.6
MD	2,766	4.1	0.8	3.0
KS	480	0.7	0.1	0.5
PK	1,448	2.1	0.4	1.6
V	1,385	2.1	0.4	1.5
D	4,166	6.2	1.2	4.5
B	1,212	1.8	0.4	1.3
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	4,256	6.3	1.3	4.6

NON-PROJECT - NO TREATMENT

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			0%	0%	0%
			L_A Discharged (lbs/yr)		
LN	90%	4.4	4,081	6.1	1.2
RB-S	90%	1.6	1,521	2.3	0.5
RB-N	90%	1.7	1,554	2.3	0.5
WA	100%	1.3	1,170	1.7	0.3
T46	100%	2.5	2,291	3.4	0.7
S1	100%	0.3	254	0.4	0.1
S2	100%	0.0	12	0.0	0.0
S3	100%	0.5	482	0.7	0.1
S4	100%	0.0	13	0.0	0.0
S5	100%	0.0	0	0.0	0.0
PN	100%	0.6	575	0.9	0.2
SC	100%	0.3	241	0.4	0.1
UN	100%	1.6	1,470	2.2	0.4
MD	100%	3.0	2,766	4.1	0.8
KS	3%	0.0	12	0.0	0.0
PK	57%	0.9	818	1.2	0.2
V	57%	0.8	783	1.2	0.2
D	57%	2.5	2,354	3.5	0.7
B	100%	1.3	1,212	1.8	0.4
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	2.6	2,405	3.6	0.7

NON-PROJECT - STORMWATER BMPS

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			80%	65%	58%
			L_A Discharged (lbs/yr)		
LN	0%	0.0	0	0.0	0.0
RB-S	0%	0.0	0	0.0	0.0
RB-N	0%	0.0	0	0.0	0.0
WA	0%	0.0	0	0.0	0.0
T46	0%	0.0	0	0.0	0.0
S1	0%	0.0	0	0.0	0.0
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

NON-PROJECT ROYAL BROUGHAM TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			80%	79%	86%
			L_A Discharged (lbs/yr)		
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	0	52	0.1	0.0
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

NON-PROJECT WEST POINT TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
Treatment Efficiency			75%	63%	77%
			L_A Discharged (lbs/yr)		
LN	10%	0	113	0.3	0.0
RB-S	10%	0	42	0.1	0.0
RB-N	10%	0	43	0.1	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	0	52	0.1	0.0
PK	44%	1	157	0.4	0.0
V	44%	1	151	0.3	0.0
D	44%	2	453	1.0	0.1
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	2	463	1.0	0.1

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Exhibit B-9

AERIAL ALT. PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	0.4	404	0.6	0.1	3.9	727	1.9	0.5	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	8.4	7,828	11.6	2.3	33.7	6,271	16.3	3.9	2.0	370	0.6	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	9.5	2,211	4.9	0.6
LAKE UNION	2.9	2,698	4.0	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

AERIAL ALT. NON-PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	7.4	6,897	10.2	2.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	32.2	29,995	44.5	8.9	0.0	0	0.0	0.0	0.9	174	0.3	0.0	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	4.1	966	2.1	0.3
LAKE UNION	0.7	614	0.9	0.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

BMP-AERIAL ALT. TOTAL	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	7.8	7,300	10.8	2.2	3.9	700	1.9	0.5	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	40.6	37,800	56.1	11.2	33.7	6,300	16.3	3.9	2.9	500	0.8	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	13.6	3,200	7.1	0.9
LAKE UNION	3.6	3,300	4.9	1.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

PROJECT AREA - RETROFITTED

Basin	Annual Pollutant Load (lbs/yr) TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	4,485	6.7	1.3	4.8
RB-S	7,662	11.4	2.3	8.2
RB-N	5,913	8.8	1.8	6.3
WA	4,182	6.2	1.2	4.5
T46	88	0.1	0.0	0.1
S1	1,498	2.2	0.4	1.6
S2	3,358	5.0	1.0	3.6
S3	2,003	3.0	0.6	2.1
S4	567	0.8	0.2	0.6
S5	676	1.0	0.2	0.7
PN	2,790	4.1	0.8	3.0
SC	554	0.8	0.2	0.6
UN	2,059	3.1	0.6	2.2
MD	4,596	6.8	1.4	4.9
KS	3,424	5.1	1.0	3.7
PK	1,982	2.9	0.6	2.1
V	3,648	5.4	1.1	3.9
D	2,347	3.5	0.7	2.5
B	702	1.0	0.2	0.8
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	4,073	6.0	1.2	4.4

PROJECT - NO TREATMENT (Treatment Efficiency: TSS 0%, Zn 0%, Cu 0%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	9%	0.4	404	0.6	0.1
RB-S	9%	0.7	690	1.0	0.2
RB-N	9%	0.6	532	0.8	0.2
WA	9%	0.4	376	0.6	0.1
T46	9%	0.0	8	0.0	0.0
S1	9%	0.1	135	0.2	0.0
S2	9%	0.3	302	0.4	0.1
S3	9%	0.2	180	0.3	0.1
S4	9%	0.1	51	0.1	0.0
S5	9%	0.1	61	0.1	0.0
PN	9%	0.3	251	0.4	0.1
SC	9%	0.1	50	0.1	0.0
UN	9%	0.2	185	0.3	0.1
MD	9%	0.4	414	0.6	0.1
KS	3%	0.1	86	0.1	0.0
PK	57%	1.2	1,120	1.7	0.3
V	57%	2.2	2,061	3.1	0.6
D	57%	1.4	1,326	2.0	0.4
B	57%	0.4	396	0.6	0.1
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	2.5	2,301	3.4	0.7

PROJECT - STORMWATER BMPS (Treatment Efficiency: TSS 80%, Zn 65%, Cu 58%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	81%	3.9	727	1.9	0.5
RB-S	81%	6.7	1,241	3.2	0.8
RB-N	81%	5.1	958	2.5	0.6
WA	91%	4.1	761	2.0	0.5
T46	91%	0.1	16	0.0	0.0
S1	91%	1.5	273	0.7	0.2
S2	91%	3.3	611	1.6	0.4
S3	91%	2.0	364	0.9	0.2
S4	91%	0.6	103	0.3	0.1
S5	91%	0.7	123	0.3	0.1
PN	91%	2.7	508	1.3	0.3
SC	91%	0.5	101	0.3	0.1
UN	91%	2.0	375	1.0	0.2
MD	91%	4.5	836	2.2	0.5
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

PROJECT - ROYAL BROUGHAM TP (Treatment Efficiency: TSS 80%, Zn 79%, Cu 86%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	2	370	0.6	0.1
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

WEST POINT TP (Treatment Efficiency: TSS 75%, Zn 63%, Cu 77%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	0	112	0.2	0.0
RB-S	10%	1	192	0.4	0.1
RB-N	10%	1	148	0.3	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	2	372	0.8	0.1
PK	44%	1	216	0.5	0.1
V	44%	2	397	0.9	0.1
D	44%	1	255	0.6	0.1
B	44%	0	76	0.2	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	2	443	1.0	0.1

NON-PROJECT AREA

Basin	Annual Pollutant Load (lbs/yr) TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	7,664	11.4	2.3	8.2
RB-S	7,143	10.6	2.1	7.7
RB-N	2,552	3.8	0.8	2.7
WA	913	1.4	0.3	1.0
T46	13,427	19.9	4.0	14.4
S1	423	0.6	0.1	0.5
S2	894	1.3	0.3	1.0
S3	622	0.9	0.2	0.7
S4	240	0.4	0.1	0.3
S5	122	0.2	0.0	0.1
PN	255	0.4	0.1	0.3
SC	-	0.0	0.0	0.0
UN	1,083	1.6	0.3	1.2
MD	1,501	2.2	0.4	1.6
KS	1,612	2.4	0.5	1.7
PK	119	0.2	0.0	0.1
V	1,156	1.7	0.3	1.2
D	1,819	2.7	0.5	2.0
B	511	0.8	0.2	0.5
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	183	0.3	0.1	0.2

NON-PROJECT - NO TREATMENT (Treatment Efficiency: TSS 0%, Zn 0%, Cu 0%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	90%	7.4	6,897	10.2	2.0
RB-S	90%	6.9	6,429	9.5	1.9
RB-N	90%	2.5	2,297	3.4	0.7
WA	100%	1.0	913	1.4	0.3
T46	100%	14.4	13,427	19.9	4.0
S1	100%	0.5	423	0.6	0.1
S2	100%	1.0	894	1.3	0.3
S3	100%	0.7	622	0.9	0.2
S4	100%	0.3	240	0.4	0.1
S5	100%	0.1	122	0.2	0.0
PN	100%	0.3	255	0.4	0.1
SC	100%	0.0	0	0.0	0.0
UN	100%	1.2	1,083	1.6	0.3
MD	100%	1.6	1,501	2.2	0.4
KS	2.5%	0.0	40	0.1	0.0
PK	56.5%	0.1	67	0.1	0.0
V	56.5%	0.7	653	1.0	0.2
D	56.5%	1.1	1,028	1.5	0.3
B	100%	0.5	511	0.8	0.2
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	56.5%	0.1	104	0.2	0.0

NON-PROJECT - STORMWATER BMPS (Treatment Efficiency: TSS 80%, Zn 65%, Cu 58%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0.0	0	0.0	0.0
RB-S	0%	0.0	0	0.0	0.0
RB-N	0%	0.0	0	0.0	0.0
WA	0%	0.0	0	0.0	0.0
T46	0%	0.0	0	0.0	0.0
S1	0%	0.0	0	0.0	0.0
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

NON-PROJECT ROYAL BROUGHAM TP (Treatment Efficiency: TSS 80%, Zn 79%, Cu 86%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	1	174	0.3	0.0
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

NON-PROJECT WEST POINT TP (Treatment Efficiency: TSS 75%, Zn 63%, Cu 77%)

Basin	% Annual Stormwater Vol.	L_A Discharged (lbs/yr) Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	1	192	0.4	0.1
RB-S	10%	1	179	0.4	0.0
RB-N	10%	0	64	0.1	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	1	175	0.4	0.0
PK	44%	0	13	0.0	0.0
V	44%	1	126	0.3	0.0
D	44%	1	198	0.4	0.1
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	0	20	0.0	0.0

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Exhibit B-10

TUNNEL ALT. PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	0.7	685	1.0	0.2	6.6	1,233	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	9.4	8,760	13.0	2.6	47.8	8,912	23.1	5.6	2.6	491	0.8	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	10.6	2,479	5.5	0.7
LAKE UNION	2.9	2,698	4.0	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

TUNNEL ALT. NON-PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	4.4	4,083	6.1	1.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	17.0	15,855	23.5	4.7	0.0	0	0.0	0.0	0.3	53	0.1	0.0	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	3.0	698	1.6	0.2
LAKE UNION	0.7	614	0.9	0.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

TUNNEL ALT. TOTAL	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	5.1	4,800	7.1	1.4	6.6	1,200	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	26.4	24,600	36.5	7.3	47.8	8,900	23.1	5.6	2.9	500	0.8	0.1	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	13.6	3,200	7.1	0.9
LAKE UNION	3.6	3,300	4.9	1.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

PROJECT AREA - RETROFITTED

	Annual Pollutant Load (lbs/yr)			
Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	7,613	11.3	2.3	8.2
RB-S	13,115	19.5	3.9	14.1
RB-N	6,738	10.0	2.0	7.2
WA	4,214	6.3	1.3	4.5
T46	10,942	16.2	3.2	11.7
S1	1,474	2.2	0.4	1.6
S2	3,288	4.9	1.0	3.5
S3	1,889	2.8	0.6	2.0
S4	580	0.9	0.2	0.6
S5	690	1.0	0.2	0.7
PN	2,073	3.1	0.6	2.2
SC	554	0.8	0.2	0.6
UN	1,763	2.6	0.5	1.9
MD	3,830	5.7	1.1	4.1
KS	4,547	6.7	1.3	4.9
PK	630	0.9	0.2	0.7
V	4,178	6.2	1.2	4.5
D	2,347	3.5	0.7	2.5
B	702	1.0	0.2	0.8
0	0	0.0	0.0	0.0
0	0	0.0	0.0	0.0
LUW	4,073	6.0	1.2	4.4

PROJECT - NO TREATMENT

			Treatment Efficiency		
			0%	0%	0%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	9%	0.7	685	1.0	0.2
RB-S	9%	1.3	1,180	1.8	0.4
RB-N	9%	0.7	606	0.9	0.2
WA	9%	0.4	379	0.6	0.1
T46	9%	1.1	985	1.5	0.3
S1	9%	0.1	133	0.2	0.0
S2	9%	0.3	296	0.4	0.1
S3	9%	0.2	170	0.3	0.1
S4	9%	0.1	52	0.1	0.0
S5	9%	0.1	62	0.1	0.0
PN	9%	0.2	187	0.3	0.1
SC	9%	0.1	50	0.1	0.0
UN	9%	0.2	159	0.2	0.0
MD	9%	0.4	345	0.5	0.1
KS	3%	0.1	114	0.2	0.0
PK	57%	0.4	356	0.5	0.1
V	57%	2.5	2,361	3.5	0.7
D	57%	1.4	1,326	2.0	0.4
B	57%	0.4	396	0.6	0.1
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	2.5	2,301	3.4	0.7

PROJECT - STORMWATER BMPS

			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	81%	6.6	1,233	3.2	0.8
RB-S	81%	11.4	2,125	5.5	1.3
RB-N	81%	5.9	1,092	2.8	0.7
WA	91%	4.1	767	2.0	0.5
T46	91%	10.7	1,991	5.2	1.2
S1	91%	1.4	268	0.7	0.2
S2	91%	3.2	598	1.6	0.4
S3	91%	1.8	344	0.9	0.2
S4	91%	0.6	106	0.3	0.1
S5	91%	0.7	126	0.3	0.1
PN	91%	2.0	377	1.0	0.2
SC	91%	0.5	101	0.3	0.1
UN	91%	1.7	321	0.8	0.2
MD	91%	3.7	697	1.8	0.4
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

PROJECT - ROYAL BROUGHAM TP

			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	3	491	0.8	0.1
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

WEST POINT TP

			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	1	190	0.4	0.1
RB-S	10%	1	328	0.7	0.1
RB-N	10%	1	168	0.4	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	2	494	1.1	0.1
PK	44%	0	69	0.2	0.0
V	44%	2	454	1.0	0.1
D	44%	1	255	0.6	0.1
B	44%	0	76	0.2	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	2	443	1.0	0.1

NON-PROJECT AREA

	Annual Pollutant Load (lbs/yr)			
Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	4,536	6.7	1.3	4.9
RB-S	1,690	2.5	0.5	1.8
RB-N	1,727	2.6	0.5	1.9
WA	881	1.3	0.3	0.9
T46	2,573	3.8	0.8	2.8
S1	447	0.7	0.1	0.5
S2	965	1.4	0.3	1.0
S3	736	1.1	0.2	0.8
S4	227	0.3	0.1	0.2
S5	108	0.2	0.0	0.1
PN	972	1.4	0.3	1.0
SC	-	0.0	0.0	0.0
UN	1,378	2.0	0.4	1.5
MD	2,268	3.4	0.7	2.4
KS	488	0.7	0.1	0.5
PK	1,471	2.2	0.4	1.6
V	626	0.9	0.2	0.7
D	1,819	2.7	0.5	2.0
B	511	0.8	0.2	0.5
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	183	0.3	0.1	0.2

NON-PROJECT - NO TREATMENT

			Treatment Efficiency		
			0%	0%	0%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	90%	4.4	4,083	6.1	1.2
RB-S	90%	1.6	1,521	2.3	0.5
RB-N	90%	1.7	1,554	2.3	0.5
WA	100%	0.9	881	1.3	0.3
T46	100%	2.8	2,573	3.8	0.8
S1	100%	0.5	447	0.7	0.1
S2	100%	1.0	965	1.4	0.3
S3	100%	0.8	736	1.1	0.2
S4	100%	0.2	227	0.3	0.1
S5	100%	0.1	108	0.2	0.0
PN	100%	1.0	972	1.4	0.3
SC	100%	0.0	0	0.0	0.0
UN	100%	1.5	1,378	2.0	0.4
MD	100%	2.4	2,268	3.4	0.7
KS	3%	0.0	12	0.0	0.0
PK	57%	0.9	831	1.2	0.2
V	57%	0.4	354	0.5	0.1
D	57%	1.1	1,028	1.5	0.3
B	100%	0.5	511	0.8	0.2
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	0.1	104	0.2	0.0

NON-PROJECT - STORMWATER BMPS

			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0.0	0	0.0	0.0
RB-S	0%	0.0	0	0.0	0.0
RB-N	0%	0.0	0	0.0	0.0
WA	0%	0.0	0	0.0	0.0
T46	0%	0.0	0	0.0	0.0
S1	0%	0.0	0	0.0	0.0
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

NON-PROJECT ROYAL BROUGHAM TP

			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	0	53	0.1	0.0
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

NON-PROJECT WEST POINT TP

			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	0	113	0.3	0.0
RB-S	10%	0	42	0.1	0.0
RB-N	10%	0	43	0.1	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	44%	0	53	0.1	0.0
PK	44%	1	160	0.4	0.0
V	44%	0	68	0.2	0.0
D	44%	1	198	0.4	0.1
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	0	20	0.0	0.0

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Exhibit B-11

BYPASS TUNNEL ALT. PROJECT AREA

	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	0.7	685	1.0	0.2	6.6	1,233	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	17.2	16,051	23.8	4.8	24.7	4,601	11.9	2.9	8.8	1,638	2.6	0.3	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	22.5	5,240	11.7	1.4
LAKE UNION	2.9	2,698	4.0	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

BYPASS TUNNEL ALT. NON-PROJECT AREA

	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	4.4	4,081	6.1	1.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	13.8	12,889	19.1	3.8	0.0	0	0.0	0.0	0.5	100	0.2	0.0	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	3.2	751	1.7	0.2
LAKE UNION	0.7	614	0.9	0.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

BYPASS TUNNEL ALT. TOTAL

	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	5.1	4,800	7.1	1.4	6.6	1,200	3.2	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	31.1	28,900	42.9	8.6	24.7	4,600	11.9	2.9	9.3	1,700	2.7	0.4	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	25.7	6,000	13.3	1.7
LAKE UNION	3.6	3,300	4.9	1.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

PROJECT AREA - RETROFITTED

Annual Pollutant Load (lbs/yr)

Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	7,614	11.3	2.3	8.2
RB-S	13,115	19.5	3.9	14.1
RB-N	7,094	10.5	2.1	7.6
WA	3,963	5.9	1.2	4.3
T46	12,081	17.9	3.6	13.0
S1	1,527	2.3	0.5	1.6
S2	3,367	5.0	1.0	3.6
S3	1,370	2.0	0.4	1.5
S4	567	0.8	0.2	0.6
S5	676	1.0	0.2	0.7
PN	2,820	4.2	0.8	3.0
SC	554	0.8	0.2	0.6
UN	2,880	4.3	0.9	3.1
MD	4,225	6.3	1.3	4.5
KS	4,108	6.1	1.2	4.4
PK	1,340	2.0	0.4	1.4
V	3,336	4.9	1.0	3.6
D	2,347	3.5	0.7	2.5
B	702	1.0	0.2	0.8
0	-	0.0	0.0	-
0	-	0.0	0.0	-
LUW	4,073	6.0	1.2	4.4

PROJECT - NO TREATMENT

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			0%	0%	0%
			L_A Discharged (lbs/yr)		
LN	9%	1	685	1.0	0.2
RB-S	9%	1	1,180	1.8	0.4
RB-N	3%	0	177	0.3	0.1
WA	3%	0	99	0.1	0.0
T46	9%	1	1,087	1.6	0.3
S1	9%	0	137	0.2	0.0
S2	57%	2	1,902	2.8	0.6
S3	57%	1	774	1.1	0.2
S4	57%	0	320	0.5	0.1
S5	57%	0	382	0.6	0.1
PN	57%	2	1,593	2.4	0.5
SC	57%	0	313	0.5	0.1
UN	57%	2	1,627	2.4	0.5
MD	57%	3	2,387	3.5	0.7
KS	3%	0	103	0.2	0.0
PK	57%	1	757	1.1	0.2
V	57%	2	1,885	2.8	0.6
D	57%	1	1,326	2.0	0.4
B	57%	0	396	0.6	0.1
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	57%	2	2,301	3.4	0.7

PROJECT - STORMWATER BMPS

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
LN	81%	6.6	1,233	3.2	0.8
RB-S	81%	11.4	2,125	5.5	1.3
RB-N	0%	0.0	0	0.0	0.0
WA	0%	0.0	0	0.0	0.0
T46	91%	11.8	2,199	5.7	1.4
S1	91%	1.5	278	0.7	0.2
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

PROJECT - ROYAL BROUGHAM TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	54%	4	766	1.2	0.2
WA	54%	2	428	0.7	0.1
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	2	444	0.7	0.1
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

WEST POINT TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
LN	10%	1	190	0.4	0.1
RB-S	10%	1	328	0.7	0.1
RB-N	44%	3	772	1.7	0.2
WA	44%	2	431	1.0	0.1
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	44%	2	366	0.8	0.1
S3	44%	1	149	0.3	0.0
S4	44%	0	62	0.1	0.0
S5	44%	0	73	0.2	0.0
PN	44%	1	307	0.7	0.1
SC	44%	0	60	0.1	0.0
UN	44%	1	313	0.7	0.1
MD	44%	2	459	1.0	0.1
KS	44%	2	447	1.0	0.1
PK	44%	1	146	0.3	0.0
V	44%	2	363	0.8	0.1
D	44%	1	255	0.6	0.1
B	44%	0	76	0.2	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	44%	2	443	1.0	0.1

NON-PROJECT AREA

Annual Pollutant Load (lbs/yr)

Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	4,535	6.7	1.3	4.9
RB-S	1,690	2.5	0.5	1.8
RB-N	1,370	2.0	0.4	1.5
WA	1,133	1.7	0.3	1.2
T46	1,434	2.1	0.4	1.5
S1	394	0.6	0.1	0.4
S2	886	1.3	0.3	1.0
S3	1,255	1.9	0.4	1.3
S4	240	0.4	0.1	0.3
S5	122	0.2	0.0	0.1
PN	226	0.3	0.1	0.2
SC	-	0.0	0.0	0.0
UN	261	0.4	0.1	0.3
MD	1,873	2.8	0.6	2.0
KS	928	1.4	0.3	1.0
PK	761	1.1	0.2	0.8
V	1,469	2.2	0.4	1.6
D	1,819	2.7	0.5	2.0
B	511	0.8	0.2	0.5
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	183	0.3	0.1	0.2

NON-PROJECT - NO TREATMENT

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			0%	0%	0%
			L_A Discharged (lbs/yr)		
LN	90%	4.4	4,081	6.1	1.2
RB-S	90%	1.6	1,521	2.3	0.5
RB-N	90%	1.3	1,233	1.8	0.4
WA	100%	1.2	1,133	1.7	0.3
T46	100%	1.5	1,434	2.1	0.4
S1	100%	0.4	394	0.6	0.1
S2	100%	1.0	886	1.3	0.3
S3	100%	1.3	1,255	1.9	0.4
S4	100%	0.3	240	0.4	0.1
S5	100%	0.1	122	0.2	0.0
PN	100%	0.2	226	0.3	0.1
SC	100%	0.0	0	0.0	0.0
UN	100%	0.3	261	0.4	0.1
MD	100%	2.0	1,873	2.8	0.6
KS	3%	0.0	23	0.0	0.0
PK	57%	0.5	430	0.6	0.1
V	57%	0.9	830	1.2	0.2
D	57%	1.1	1,028	1.5	0.3
B	100%	0.5	511	0.8	0.2
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	57%	0.1	104	0.2	0.0

NON-PROJECT - STORMWATER BMPS

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
LN	0%	0.0	0	0.0	0.0
RB-S	0%	0.0	0	0.0	0.0
RB-N	0%	0.0	0	0.0	0.0
WA	0%	0.0	0	0.0	0.0
T46	0%	0.0	0	0.0	0.0
S1	0%	0.0	0	0.0	0.0
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	0%	0.0	0	0.0	0.0
PK	0%	0.0	0	0.0	0.0
V	0%	0.0	0	0.0	0.0
D	0%	0.0	0	0.0	0.0
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	0%	0.0	0	0.0	0.0

NON-PROJECT ROYAL BROUGHAM TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
LN	0%	0	0	0.0	0.0
RB-S	0%	0	0	0.0	0.0
RB-N	0%	0	0	0.0	0.0
WA	0%	0	0	0.0	0.0
T46	0%	0	0	0.0	0.0
S1	0%	0	0	0.0	0.0
S2	0%	0	0	0.0	0.0
S3	0%	0	0	0.0	0.0
S4	0%	0	0	0.0	0.0
S5	0%	0	0	0.0	0.0
PN	0%	0	0	0.0	0.0
SC	0%	0	0	0.0	0.0
UN	0%	0	0	0.0	0.0
MD	0%	0	0	0.0	0.0
KS	54%	1	100	0.2	0.0
PK	0%	0	0	0.0	0.0
V	0%	0	0	0.0	0.0
D	0%	0	0	0.0	0.0
B	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
0	0%	0	0	0.0	0.0
LUW	0%	0	0	0.0	0.0

NON-PROJECT WEST POINT TP

Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
LN	10%	0.5	113	0.3	0.0
RB-S	10%	0.2	42	0.1	0.0
RB-N	10%	0.1	34	0.1	0.0
WA	0%	0.0	0	0.0	0.0
T46	0%	0.0	0	0.0	0.0
S1	0%	0.0	0	0.0	0.0
S2	0%	0.0	0	0.0	0.0
S3	0%	0.0	0	0.0	0.0
S4	0%	0.0	0	0.0	0.0
S5	0%	0.0	0	0.0	0.0
PN	0%	0.0	0	0.0	0.0
SC	0%	0.0	0	0.0	0.0
UN	0%	0.0	0	0.0	0.0
MD	0%	0.0	0	0.0	0.0
KS	44%	0.4	101	0.2	0.0
PK	44%	0.4	83	0.2	0.0
V	44%	0.7	160	0.4	0.0
D	44%	0.8	198	0.4	0.1
B	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
0	0%	0.0	0	0.0	0.0
LUW	44%	0.1	20	0.0	0.0

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Exhibit B-12

SURFACE ALT. PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	0.7	696	1.0	0.2	6.7	1,252	3.3	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	18.8	17,520	26.0	5.2	22.6	4,203	10.9	2.6	8.3	1,538	2.4	0.3	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	23.6	5,508	12.3	1.5
LAKE UNION	3.1	2,903	4.3	0.9	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

SURFACE ALT. NON-PROJECT AREA	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	4.3	3,976	5.9	1.2	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	14.8	13,807	20.5	4.1	0.0	0	0.0	0.0	0.5	98	0.2	0.0	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	2.4	550	1.2	0.2
LAKE UNION	0.3	251	0.4	0.1	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

SURFACE ALT. TOTAL	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu	Annual Vol. (MG/yr)	TSS	Zn	Cu
DUWAMISH RIVER	5.0	4,700	6.9	1.4	6.7	1,300	3.3	0.8	0.0	0	0.0	0.0	0.0	0	0.0	0.0
ELLIOTT BAY	33.6	31,300	46.5	9.3	22.6	4,200	10.9	2.6	8.8	1,600	2.5	0.3	0.0	0	0.0	0.0
PUGET SOUND	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	26.0	6,100	13.5	1.7
LAKE UNION	3.4	3,200	4.7	0.9	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0	0	0.0	0.0

PROJECT AREA - RETROFITTED

	Annual Pollutant Load (lbs/yr)			
Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	7,731	11.5	2.3	8.3
RB-S	13,115	19.5	3.9	14.1
RB-N	5,637	8.4	1.7	6.1
WA	4,482	6.6	1.3	4.8
T46	9,844	14.6	2.9	10.6
S1	1,577	2.3	0.5	1.7
S2	3,701	5.5	1.1	4.0
S3	1,657	2.5	0.5	1.8
S4	559	0.8	0.2	0.6
S5	676	1.0	0.2	0.7
PN	2,194	3.3	0.7	2.4
SC	554	0.8	0.2	0.6
UN	2,963	4.4	0.9	3.2
MD	5,007	7.4	1.5	5.4
KS	4,126	6.1	1.2	4.4
PK	1,305	1.9	0.4	1.4
V	3,940	5.8	1.2	4.2
D	3,915	5.8	1.2	4.2
B	1,065	1.6	0.3	1.1
0	-	0.0	0.0	-
0	-	0.0	0.0	-
LUW	4,073	6.0	1.2	4.4

PROJECT - NO TREATMENT

		Treatment Efficiency		
		0%	0%	0%
		L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	9%	0.7	696	1.0	0.2
RB-S	9%	1.3	1,180	1.8	0.4
RB-N	3%	0.2	141	0.2	0.0
WA	3%	0.1	112	0.2	0.0
T46	9%	1.0	886	1.3	0.3
S1	9%	0.2	142	0.2	0.0
S2	57%	2.2	2,091	3.1	0.6
S3	57%	1.0	936	1.4	0.3
S4	57%	0.3	316	0.5	0.1
S5	57%	0.4	382	0.6	0.1
PN	57%	1.3	1,239	1.8	0.4
SC	57%	0.3	313	0.5	0.1
UN	57%	1.8	1,674	2.5	0.5
MD	57%	3.0	2,829	4.2	0.8
KS	3%	0.1	103	0.2	0.0
PK	57%	0.8	737	1.1	0.2
V	57%	2.4	2,226	3.3	0.7
D	57%	2.4	2,212	3.3	0.7
B	57%	0.6	602	0.9	0.2
0	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
LUW	57%	2.5	2,301	3.4	0.7

PROJECT - STORMWATER BMPS

			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	81%	6.7	1,252	3.3	0.8
RB-S	81%	11.4	2,125	5.5	1.3
RB-N	0%	0.0	-	0.0	0.0
WA	0%	0.0	-	0.0	0.0
T46	91%	9.6	1,792	4.7	1.1
S1	91%	1.5	287	0.7	0.2
S2	0%	0.0	-	0.0	0.0
S3	0%	0.0	-	0.0	0.0
S4	0%	0.0	-	0.0	0.0
S5	0%	0.0	-	0.0	0.0
PN	0%	0.0	-	0.0	0.0
SC	0%	0.0	-	0.0	0.0
UN	0%	0.0	-	0.0	0.0
MD	0%	0.0	-	0.0	0.0
KS	0%	0.0	-	0.0	0.0
PK	0%	0.0	-	0.0	0.0
V	0%	0.0	-	0.0	0.0
D	0%	0.0	-	0.0	0.0
B	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
LUW	0%	0.0	-	0.0	0.0

PROJECT - ROYAL BROUGHAM TP

			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	-	0.0	0.0
RB-S	0%	0	-	0.0	0.0
RB-N	54%	3	609	0.9	0.1
WA	54%	3	484	0.8	0.1
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	0%	0	-	0.0	0.0
S3	0%	0	-	0.0	0.0
S4	0%	0	-	0.0	0.0
S5	0%	0	-	0.0	0.0
PN	0%	0	-	0.0	0.0
SC	0%	0	-	0.0	0.0
UN	0%	0	-	0.0	0.0
MD	0%	0	-	0.0	0.0
KS	54%	2	446	0.7	0.1
PK	0%	0	-	0.0	0.0
V	0%	0	-	0.0	0.0
D	0%	0	-	0.0	0.0
B	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	0%	0	-	0.0	0.0

WEST POINT TP

			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	1	193	0.4	0.1
RB-S	10%	1	328	0.7	0.1
RB-N	44%	3	613	1.4	0.2
WA	44%	2	487	1.1	0.1
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	44%	2	402	0.9	0.1
S3	44%	1	180	0.4	0.0
S4	44%	0	61	0.1	0.0
S5	44%	0	73	0.2	0.0
PN	44%	1	239	0.5	0.1
SC	44%	0	60	0.1	0.0
UN	44%	1	322	0.7	0.1
MD	44%	2	544	1.2	0.2
KS	44%	2	449	1.0	0.1
PK	44%	1	142	0.3	0.0
V	44%	2	428	1.0	0.1
D	44%	2	426	0.9	0.1
B	44%	0	116	0.3	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	44%	2	443	1.0	0.1

NON-PROJECT AREA

	Annual Pollutant Load (lbs/yr)			
Basin	TSS	Zn	Cu	Annual Vol. (MG/yr)
LN	4,418	6.6	1.3	4.7
RB-S	1,690	2.5	0.5	1.8
RB-N	2,828	4.2	0.8	3.0
WA	613	0.9	0.2	0.7
T46	3,671	5.4	1.1	3.9
S1	344	0.5	0.1	0.4
S2	551	0.8	0.2	0.6
S3	968	1.4	0.3	1.0
S4	248	0.4	0.1	0.3
S5	122	0.2	0.0	0.1
PN	852	1.3	0.3	0.9
SC	-	0.0	0.0	0.0
UN	178	0.3	0.1	0.2
MD	1,091	1.6	0.3	1.2
KS	909	1.3	0.3	1.0
PK	796	1.2	0.2	0.9
V	864	1.3	0.3	0.9
D	251	0.4	0.1	0.3
B	147	0.2	0.0	0.2
0	-	0.0	0.0	0.0
0	-	0.0	0.0	0.0
LUW	183	0.3	0.1	0.2

NON-PROJECT - NO TREATMENT

			Treatment Efficiency		
			0%	0%	0%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	90%	4.3	3,976	5.9	1.2
RB-S	90%	1.6	1,521	2.3	0.5
RB-N	90%	2.7	2,545	3.8	0.8
WA	100%	0.7	613	0.9	0.2
T46	100%	3.9	3,671	5.4	1.1
S1	100%	0.4	344	0.5	0.1
S2	100%	0.6	551	0.8	0.2
S3	100%	1.0	968	1.4	0.3
S4	100%	0.3	248	0.4	0.1
S5	100%	0.1	122	0.2	0.0
PN	100%	0.9	852	1.3	0.3
SC	100%	0.0	-	0.0	0.0
UN	100%	0.2	178	0.3	0.1
MD	100%	1.2	1,091	1.6	0.3
KS	3%	0.0	23	0.0	0.0
PK	57%	0.5	450	0.7	0.1
V	57%	0.5	488	0.7	0.1
D	57%	0.2	142	0.2	0.0
B	100%	0.2	147	0.2	0.0
0	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
LUW	57%	0.1	104	0.2	0.0

NON-PROJECT - STORMWATER BMPS

			Treatment Efficiency		
			80%	65%	58%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0.0	-	0.0	0.0
RB-S	0%	0.0	-	0.0	0.0
RB-N	0%	0.0	-	0.0	0.0
WA	0%	0.0	-	0.0	0.0
T46	0%	0.0	-	0.0	0.0
S1	0%	0.0	-	0.0	0.0
S2	0%	0.0	-	0.0	0.0
S3	0%	0.0	-	0.0	0.0
S4	0%	0.0	-	0.0	0.0
S5	0%	0.0	-	0.0	0.0
PN	0%	0.0	-	0.0	0.0
SC	0%	0.0	-	0.0	0.0
UN	0%	0.0	-	0.0	0.0
MD	0%	0.0	-	0.0	0.0
KS	0%	0.0	-	0.0	0.0
PK	0%	0.0	-	0.0	0.0
V	0%	0.0	-	0.0	0.0
D	0%	0.0	-	0.0	0.0
B	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
0	0%	0.0	-	0.0	0.0
LUW	0%	0.0	-	0.0	0.0

NON-PROJECT ROYAL BROUGHAM TP

			Treatment Efficiency		
			80%	79%	86%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	0%	0	-	0.0	0.0
RB-S	0%	0	-	0.0	0.0
RB-N	0%	0	-	0.0	0.0
WA	0%	0	-	0.0	0.0
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	0%	0	-	0.0	0.0
S3	0%	0	-	0.0	0.0
S4	0%	0	-	0.0	0.0
S5	0%	0	-	0.0	0.0
PN	0%	0	-	0.0	0.0
SC	0%	0	-	0.0	0.0
UN	0%	0	-	0.0	0.0
MD	0%	0	-	0.0	0.0
KS	54%	1	98	0.2	0.0
PK	0%	0	-	0.0	0.0
V	0%	0	-	0.0	0.0
D	0%	0	-	0.0	0.0
B	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	0%	0	-	0.0	0.0

NON-PROJECT WEST POINT TP

			Treatment Efficiency		
			75%	63%	77%
			L_A Discharged (lbs/yr)		
Basin	% Annual Stormwater Vol.	Annual Vol. (MG/yr)	TSS	Zn	Cu
LN	10%	0	110	0.2	0.0
RB-S	10%	0	42	0.1	0.0
RB-N	10%	0	71	0.2	0.0
WA	0%	0	-	0.0	0.0
T46	0%	0	-	0.0	0.0
S1	0%	0	-	0.0	0.0
S2	0%	0	-	0.0	0.0
S3	0%	0	-	0.0	0.0
S4	0%	0	-	0.0	0.0
S5	0%	0	-	0.0	0.0
PN	0%	0	-	0.0	0.0
SC	0%	0	-	0.0	0.0
UN	0%	0	-	0.0	0.0
MD	0%	0	-	0.0	0.0
KS	44%	0	99	0.2	0.0
PK	44%	0	87	0.2	0.0
V	44%	0	94	0.2	0.0
D	44%	0	27	0.1	0.0
B	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
0	0%	0	-	0.0	0.0
LUW	44%	0	20	0.0	0.0

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ATTACHMENT C

Pollutants of Concern

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C. INTRODUCTION

The following steps were taken to identify the pollutants of potential concern and select the pollutants to be included in the loading estimates model used to evaluate the operational impacts of the five alternatives for the Alaskan Way Viaduct Replacement Project.

1. Identify pollutants that have been documented as causing problems for water and sediment quality in the receiving waters for this project (Duwamish River East Waterway - segment 921; Elliott Bay – Seattle Waterfront; and the south end of Lake Union). The Washington State Department of Ecology (Ecology) 303(d) list of Threatened and Impaired Waterbodies (Ecology, 1998) was used as documentation of pollutants that have caused problems in receiving waters of the study area. In addition the King County Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay (King County and Parametrix, 1999) was referenced as further documentation of pollutants of concern in the affected environment for the AWV project area.
2. Identify pollutants known to be associated with highway runoff for which vehicular traffic and roadway erosion is a potential source. Use local data for the Seattle area where possible.
3. The pollutants from step 2 that match the pollutants from step 1 are considered to be the pollutants of potential concern for the AWV Replacement Project.
4. Concentration data and/or removal efficiency data for stormwater BMPs were determined from the WSDOT water quality impacts guidance document (WSDOT 2002) which used as its' source the National Pollutant Removal Performance Database for Stormwater Treatment Practices (Center for Watershed Protection, 2000). Pollutants of potential concern for which there were either insufficient data to determine the concentration in stormwater runoff or insufficient data to determine BMP removal efficiencies were not included in the loading estimates for the AWV alternative evaluations.

C.1 STEP 1: 303(D) LISTED RECEIVING WATERBODIES AND POLLUTANTS OF POTENTIAL CONCERN IN THE AWV AFFECTED ENVIRONMENT

The East Waterway of the Duwamish River is on the 1998 303(d) list for several metals and organic compounds based on exceedance of the Washington State Sediment Management Standards (SMS) (Ecology, 1995). These parameters include: PAHs, PCBs, 1,2,4-Trichlorobenzene, 1,4-Dichlorobenzene, 2-Methylnaphthalene, phenols, cadmium, copper, lead, mercury, silver, and zinc. Only mercury and cadmium are in excess of the Cleanup Screening Levels in the vicinity of the Hanford and Lander outfalls. The Department of Ecology SEDQUAL database (Version 4.4, February 2003) was used as the source of data for this determination.

The Elliott Bay Seattle Waterfront is on the 1998 303d list for fecal coliforms based on Washington State water quality standards. This same area is on the list for individual PAHs, PCBs, 1,2,4-Trichlorobenzene, 1,4-Dichlorobenzene, 2,4-Dimethylphenol, Benzyl Alcohol, Bis (2-ethylhexyl) phthalate, cadmium, chromium, copper, lead, mercury, and zinc based on exceedance of the Washington State Sediment Management Standards (Ecology, 1995). Of these only mercury, silver, lead, zinc, and PAH are in excess of the Cleanup Screening Levels. (Aura Nova Consultants and Ecology, 1995)

In 1999 King County Department of Natural Resources completed the Combined Sewer Overflow Water Quality Assessment for the Duwamish River and Elliott Bay (King County and Parametrix, 1999). This study determined that there are potential risks to benthic organisms from several chemicals in the sediments of the Duwamish River and Elliott Bay most notably bis(2-ethylhexyl) phthalate, 1,4-dichlorobenzene, mercury, PAHs, PCBs, and TBT (tributyl tin).

Lake Union is on the 1998 303d list only for the pesticide dieldrin taken from a tissue sample and for sediment bioassay test. There are no Washington State Sediment Management Standards for fresh water bodies. If we use the proposed levels in three different freshwater sediment projects (Ingersoll et al. 1996), (Environment Canada, 1995), and (Ontario, 1993), as local benchmarks, lead, mercury, copper, nickel, zinc and PAHs exceed at least one of the three sets of proposed sediment levels for freshwater. Sample sites included in the analysis were in the south end of Lake Union in the vicinity of the Broad Street storm drain outfall (Attachment F).

C.2 STEP 2: HIGHWAY RUNOFF POLLUTANTS

There have been several Seattle –area highway runoff studies conducted since 1980 beginning with A Survey of Trace Organics in Highway Runoff in Seattle Washington (Zawlocki et al, 1980). The Municipality of Metropolitan Seattle (Metro) measured priority pollutants in stormwater runoff from two residential neighborhoods and summarized literature data on stormwater quality and reported the results in, "Toxicants in Urban Runoff" (Galvin and Moore, 1982). Metro also analyzed I-5 highway runoff as part of a CSO planning study from 1986 through 1996. (Personal communication, Karen Huber, 2003). In 1990 the Federal Highway Administration sponsored a national study that analyzed storm events from 31 sites in 11 states (Driscoll et al., 1990). The University of Alabama and the Center for Watershed Protection were awarded an EPA Office of Water 104(b) 3 grant in 2001 to collect and evaluate stormwater data from more than 200 municipalities through out the country. These municipalities are MS4 stormwater permit holders. The first version of this National Stormwater Quality Database (NSQD, version 1.0) is currently being completed and a paper has been prepared for presentation at many national and international stormwater conferences in 2003 and 2004 (Pitt et al., 2003). Additional local data have been collected by Washington State Department of Transportation (WSDOT) as part of SR 405

Vortechs™ Water Quality Monitoring Project and SR 167 Ecology Embankment Water Quality Monitoring Project (Taylor Associates, Inc., 2002a and 2002 b)

Metals consistently present in highway runoff as summarized from the above studies, include arsenic, cadmium, chromium, copper, lead, nickel, and zinc. Of these metals, chromium, copper, lead, nickel and zinc are potentially contributed by gasoline and diesel powered motor vehicles or by weathering and abrasion of vulcanized tires, galvanized iron and steel, asphalt and concrete highway surfaces and highway paint strips.

Organic compounds typically measured in runoff studies include oil and grease and/ or total petroleum hydrocarbons (TPH). TPH are a subset of Oil and Grease constituents derived solely from petroleum products. WSDOT monitors for TPH as part of a commitment to stormwater characterization in WSDOT's Stormwater Management Plan (SWMP). From May 2002 through ay 2003, 24 samples from state highway monitoring stations representing low, medium and high transportation volumes were analyzed for TPH. All samples contained less than the detectable limit of TPH. (WSDOT, 2003)

In some studies individual trace organics have been and are being analyzed. Of the trace organics measured in these studies, the group of compounds known as polycyclic aromatic hydrocarbons (PAHs) can be clearly linked to motor vehicles. PAHs are generated during the combustion of gasoline and diesel fuel, and can be leaked to roadway surfaces. In the ongoing National Stormwater Quality Database analysis (Pitt et al., 2003), a small portion of the municipalities included PAHs in their monitoring program. The percentage of samples that had observable concentrations of PAHs ranged from 15 to 35%. Ecology has promulgated sediment standards for marine waters that include the individual PAH compounds as well as standards for total low molecular weight (LPAH) and total high molecular weight (HPAH). PAHs are a subset of the total petroleum hydrocarbons.

Conventional parameters typically evaluated in highway runoff studies include total suspended solids (TSS), nutrients, and a measure of biochemical or chemical oxygen demand. TSS are generated by abrasive action of motor vehicles and are an essential parameter to analyze when modeling loading to receiving waters.

C.3 Step 3: Pollutants of Potential Concern

The pollutants that are both of concern due to existing conditions in the three receiving water bodies (included on the 303(d) list) and are present in highway runoff and are derived from the operation of motor vehicles include the following:

Metals:	Copper, lead, nickel and zinc
Organics:	Polycyclic Aromatic Hydrocarbons (PAHs)
Conventional:	Total Suspended Solids (TSS)
Nutrients:	None

C.4 STEP 4: REMOVAL EFFICIENCY DATA

The Alaska Way Viaduct water quality impact assessment must be able to estimate loading of pollutants to the receiving waters in order to determine relative impacts from the five alternatives as compared to existing conditions in each of the three receiving water bodies. Loading estimates require data on removal efficiencies of representative stormwater BMPs and other treatment facilities (West Point TP, Royal Brougham TP, and Denny Way TP). The National Pollutant Removal Performance Database (Center for Watershed Protection, 2000) was used as the source of data on removal efficiencies for Stormwater BMPs. Copper and zinc were selected in this report to represent the range in removal efficiencies for metals as a pollutant class. 71 percent of the studies included zinc as a parameter and 46 percent included copper. 94 percent of the studies in the database measured TSS. Very few of the studies included some measurement of hydrocarbons. Based on the limited monitoring data available, the authors suggested that most stormwater BMPs could remove most petroleum hydrocarbons from stormwater runoff. In general, the ability of a (BMP) group to remove hydrocarbons was closely related to its ability to remove suspended sediment." (Center for Watershed Protection, 2000)

Based on available information in this extensive database, removal efficiencies were determined for copper, zinc, and total suspended solids. Loading estimates were therefore not performed specifically for lead and PAHs. It is assumed in this assessment that lead removal will be in the same range as seen for copper and zinc. The removal rate for PAHs is not available at this time.

C.5 REFERENCES

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Attachment D

Potential Pollutant Concentrations

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TECHNICAL MEMORANDUM for WATER QUALITY

For the Alaskan Way Viaduct Preliminary Draft Environmental Impact Statement:

POTENTIAL POLLUTANT CONCENTRATIONS and BMP REMOVAL EFFICIENCIES

20 November 2003

Taylor Associates, Inc.

James Packman, Bruce Rummel, and Curtis Nickerson

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D. INTRODUCTION

The following presents the methodology for determining representative concentrations for potential pollutants of concern for the Alaskan Way Viaduct (AWV) Preliminary Draft Environmental Impact Statement (PDEIS). The methodology is presented step-by-step herein with the final step (6) reporting the results of concentrations of potential pollutants and anticipated removal efficiencies from stormwater best management practices (BMPs).

The report is organized by the steps taken to determine the concentrations and removal efficiencies. The steps are as follows:

METHODS

Step 1

Outline general approach to loading analysis, including pollutant reduction due to BMPs.

Step 2

Review methodologies in agency manuals and guidance documents for determining potential pollutant concentrations, BMP pollutant reduction values.

Step 3

Review water quality impacts sections from recent EISs of regional highway projects.

Step 4

Gather local data of highway runoff and obtain permission to use it.

RESULTS AND RECOMMENDATIONS

Step 5

Present results and recommendations for concentrations of potential pollutants and BMP removal efficiencies.

For purposes of this report, the term "potential pollutants" is defined as substances commonly found in highway stormwater runoff, which, in excessive quantities, are of concern for negatively impacting the aquatic environment. Because stormwater runoff from the AWV would be discharged to the Duwamish River, Elliott Bay, Puget Sound, and Lake Union, negative impacts imply degradation of surface waters, especially water quality, nearshore habitat, and biotic health of fishes, shellfish, and other aquatic organisms.

METHODS

Step 1

The approach is to calculate potential pollutant loading in runoff from the Viaduct using representative concentrations of potential pollutants, estimated discharge volumes from modeled runoff, and percentages of reduction in concentrations due to BMPs.

Step 2

Step 2 was the review of existing methodologies for estimating potential pollutant concentrations and removal efficiencies by stormwater BMPs. The Washington State Department of Transportation (WSDOT) Highway Runoff Manual (WSDOT 1995a), Environmental Procedures Manual (WSDOT 1992), and the Highway Water Quality Manual (WSDOT 1988) were referenced for methods to estimate potential pollutant concentrations. Of these, only the Highway Water Quality Manual had a method for estimating concentrations, which was based on ratios of various parameters to total suspended solids (TSS) concentrations.

The TSS ratios in the Highway Water Quality Manual were derived prior to 1988 and have not been updated, even in the more recent editions of that document. Upon further investigation, an unpublished supplement to the Environmental Procedures Manual was obtained, which is specifically intended to provide guidance for assessing water quality impacts from WSDOT highway projects. The supplement, Quantitative Procedures for Water Quality Impact Assessments (WSDOT 2002), suggests using concentrations in published studies from across the United States, which are given in a Table D-1. Instructions accompanying the transmittal of the supplement (R. Tveten, personal communication) were to verify the (nationally derived) concentrations in the document with those of recent local studies.

The Department of Ecology (Ecology) Stormwater Management Manual for Western Washington (Ecology Manual [Ecology 2001]) was referenced to obtain removal efficiencies of potential pollutants by BMPs designed to treat stormwater runoff. Of the parameters proposed for the loading analysis, only TSS had a published performance goal in the Ecology Manual, which is expressed as a removal rate using options in the basic treatment menu (includes wetvaults and media filters). The performance goal for oil control in the Stormwater Management Manual is expressed for TPH, which is a relatively narrow measurement of automobile-based compounds including oils, greases, and lighter fuels. The performance goal for TPH, like metals, is expressed as a target range of concentrations for effluent discharge. No BMP removal efficiency was given for TPH in the Ecology Manual.

Step 3

The third step was to review recent EISs from regional highway projects to see what methods were used in the water quality impacts sections and for what parameters loadings were estimated. The EISs for the SR 16/Tacoma Narrows Bridge replacement (WSDOT 1998) and the SR 509 extension (WSDOT 1995b) were referenced. The methods used in the water quality impacts sections of these two EISs followed the methods in the WSDOT manuals (Highway Water Quality Manual and Highway Runoff Manual). We felt the SR 16 methods were highly relevant to the AWV PDEIS project since runoff from the Tacoma Narrows bridge will discharge mostly to marine waters as will runoff from the AWV.

Step 4

During Step 4 we sought data of constituent concentrations in highway stormwater runoff from local projects. We contacted several agencies to request data, including Ecology, the Environmental Protection Agency (EPA), King County, Seattle Public Utilities (SPU), and WSDOT. Contact was successfully made at each agency; however, we turned up only a few useable data sets. Ecology (L. Rozmyn, personal communication) and the EPA (M. Vakoc, personal communication) did not have data in a finished form (e.g. reports) that they could send us. King County (K. Huber, personal communication) sent a data set from the baseline study of the University Regulator Combined Sewer Overflow (CSO) Control project (no published report). SPU did not have a data set of pure highway runoff. WSDOT gave us permission to use two data sets from recent highway runoff studies (R. Tveten, personal communication). The WSDOT data are from the *SR 405 Vortechs™ Water Quality Monitoring Project* (Taylor Associates, Inc., 2002a) and *SR 167 Ecology Embankment Water Quality Monitoring Project* (Taylor Associates, Inc., 2002b).

The King County data are event mean concentrations (EMC) in highway runoff from Interstate 5 (I-5) and were collected during storm events from 1986 to 1996. In order to use the most recent data from the King County project, only data collected from 1991 to 1996 (n=7) were used for this report. The relevant parameters measured in the King County project are TSS, total and dissolved copper (Cu), total and dissolved zinc (Zn), total phosphorus (TP), dissolved phosphorus (as orthophosphate-P), total Kjeldahl nitrogen (TKN), and nitrite plus nitrate (NO2+NO3).

The WSDOT data are from highway runoff studies that spanned one year and measured highway runoff water quality in samples collected during storm events (n=20) to measure the effectiveness of experimental stormwater BMPs. Pretreatment data only (from influent stations) were used for this analysis. The relevant parameters measured in the WSDOT studies are TSS, total and dissolved Zn, TP, and dissolved P (as orthophosphate-P).

RESULTS AND RECOMMENDATIONS

Step 5

Step 5 summarizes the concentrations from the WSDOT and King County data sets and compares them to the recommended concentrations in the WSDOT guidance document (WSDOT 2002). In addition, removal efficiencies for stormwater BMPs are summarized.

Concentrations

Averages and five-number summaries (minimum, 25th percentile, 50th percentile (median), 75th percentile, and maximum) of the parameter concentrations were calculated for the WSDOT and King County data sets. Concentrations for each sample (storm event) were expressed as event mean concentrations in the data sets we received, and the summaries presented here were done on the grouped data from the WSDOT and King County data sets (Table D-1). Further information on the derivation of water quality concentrations may be found in Exhibit D.1-1 of Attachment D.1.

Exhibit D-1. Averages and Five-Number Summary of Combined Data Sets (n=27 Except as Noted)

	Precip. mm 1	TSS mg/l	Cu mg/l	Diss. Cu mg/l	Zn mg/l	Diss. Zn mg/l	TP mg/l	Diss. P mg/l 2	TKN mg/l 3	NO2+NO3 mg/l 3
Mean	19.2	129	0.028	0.0072	0.151	0.075	0.26	0.021	1.28	0.58
Min.	5.3	21	0.015	0.0055	0.015	0.012	0.04	0.002	1.00	0.34
25th	10.9	54	0.020	0.0062	0.103	0.029	0.11	0.006	1.10	0.40
50th	12.8	91	0.027	0.0070	0.135	0.042	0.22	0.014	1.30	0.50
75th	26.2	138	0.034	0.0082	0.183	0.091	0.39	0.026	1.50	0.64
Max.	43.7	580	0.044	0.0090	0.587	0.493	0.92	0.119	1.50	1.00
Driscoll median	11.7 (mean)	142	0.054	N/A	0.329	N/A	N/A	0.40	1.83	0.76

WSDOT data from Taylor Associates, Inc. 2002a and Taylor Associates, Inc. 2002b. N=20
King County data transmitted by email from an unpublished report (K. Huber, personal communication). N=7
Driscoll data from Driscoll et al. 1990. N=1000
[1] Precipitation data available only for WSDOT data.
[2] Dissolved phosphorus was reported as orthophosphate-phosphorus.
[3] Sample size for nitrogen is five.

The data in Exhibit D-1 were compared to the mean concentrations reported in the WSDOT guidance document for assessing water quality impacts (WSDOT 2002). A site median concentration (SMC) is the median of all event mean concentrations (EMC) collected at a single site. Values in Table 1 can be considered SMCs. The SMC concentrations of TSS and TKN from the WSDOT and King County data sets fell in the range of the 20th to the 50th percentile of all sites in the Driscoll study (for urban sites with greater than 30,000 ADT). The SMC for Cu from the WSDOT and King County data sets fell in the range of the 10th to the 20th percentile of all sites in the Driscoll study. The SMC for Zn and dissolved P from the WSDOT and King County data sets fell in the range of less than the 10th percentile of all sites in the Driscoll study. The Driscoll study did not include dissolved Cu, dissolved Zn, or TP. Exhibit D-2 summarizes the median concentrations and coefficient of variations recommended for use in the loading analysis for the AWV PDEIS.

Exhibit D-2. Summary of Concentrations Recommended for use in the AWV PDEIS Loading Analysis

	TSS mg/l	Cu mg/l	Diss. Cu mg/l	Zn mg/l	Diss Zn mg/l	TP mg/l	Diss. P mg/l	TKN mg/l	NO2+NO3 mg/l
Median	91	0.027	0.0070	0.135	0.042	0.22	0.014	1.30	0.50
COV[1]	122%	40%	45%	68%	195%	80%	154%	18%	53%

[1] Coefficient of variation (COV) calculated as standard deviation divided by the median.

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Appendix D.1

Exhibit D.1-1 presents water quality data summaries for selected parameters from the three data sources used in this investigation. Where data were not reported in the table, data were not available from one or two sources for the water quality parameter analyzed. The 10, 20, 80, and 90percentile values for the King County (Huber, personal communication) and the Washington State Department of Transportation (Taylor Associates, Inc., 2002a and 2002b) were calculated to match the percentile values from Driscoll et al. (1990); raw data from Driscoll et al. (1990) was not available for this analysis. Owing to potential differences in antecedent conditions, storm size, traffic conditions, and watershed characteristics between the KC and WSDOT data sets, as well as the large temporal and geographic differences between the local data sets and Driscoll (the Driscoll data set was national in scope and all collected before 1990), no evaluation of potential differences in the water quality characteristics of the data sets was attempted. Owing to their recency and geographic specificity, the local data sets were used preferentially.

Exhibit D.1-1. Water Quality Data Summaries for Selected Parameters from Three Sources

	Total Suspended Solids (mg/liter)			Total Recoverable Copper (mg/liter)		Dissolved Copper (mg/liter)	
	KC I-5	WSDOT	Driscoll	KC I-5	Driscoll	KC I-5	
mean	65	149		0.028		0.0072	
min	29	21		0.015		0.0055	
10%ile	36	47	*68*	0.018	*0.025*	0.0058	
20%ile	42	55	*88*	0.020	*0.032*	0.0061	
median	**58**	**106**	***142***	**0.027**	***0.054***	**0.0070**	
80%ile	81	201	*230*	0.035	*0.091*	0.0084	
90%ile	103	250	*295*	0.039	*0.119*	0.0087	
max	125	580		0.044		0.0090	
n	6	20		7		7	
st dev	34.8	138		0.010		0.0013	
COV	**0.61**	**1.30**	***0.62***	**0.38**	***0.68***	**0.19**	

Table D.1-1. Water Quality Data Summaries for Selected Parameters from Three Sources (continued)

	Total Recoverable Zinc (mg/liter)			Dissolved Zinc (mg/liter)		Total Phosphorus (mg/liter)	
	KC I-5	WSDOT	Driscoll	KC I-5	WSDOT	KC I-5	WSDOT
mean	0.17	0.14		0.044	0.09	0.17	0.28
min	0.10	0.02		0.020	0.01	0.11	0.04
10%ile	0.12	0.07	*0.19*	0.027	0.02	0.12	0.07
20%ile	0.13	0.08	*0.23*	0.033	0.02	0.12	0.09
median	**0.18**	**0.13**	***0.33***	**0.044**	**0.04**	**0.18**	**0.23**
80%ile	0.20	0.16	*0.47*	0.058	0.12	0.22	0.44
90%ile	0.22	0.19	*0.56*	0.061	0.16	0.23	0.51
max	0.26	0.59		0.063	0.49	0.23	0.92
n	7	20		7	19	4	20
st dev	0.053	0.1		0.016	0.1	0.061	0.2
COV	**0.30**	**0.92**	***0.44***	**0.35**	**2.80**	**0.35**	**0.95**
	Dissolved Phosphorus* (mg/liter)			Total Kjeldahl Nitrogen (mg/liter)		Nitrite plus Nitrate (mg/liter)	
	KC I-5	WSDOT	Driscoll	KC I-5	Driscoll	KC I-5	Driscoll
mean	0.017	0.022		1.3		0.58	
min	0.010	0.002		1.0		0.34	
10%ile	0.012	0.004	*0.15*	1.0	*1.1*	0.36	*0.39*
20%ile	0.014	0.004	*0.21*	1.1	*1.3*	0.39	*0.49*
median	**0.018**	**0.012**	***0.40***	**1.3**	***1.8***	**0.50**	***0.76***
80%ile	0.019	0.028	*0.76*	1.5	*2.6*	0.71	*1.18*
90%ile	0.020	0.045	*1.06*	1.5	*3.2*	0.86	*1.48*
max	0.021	0.119		1.5		1.00	
n	5	19		5		5	
st dev	0.0043	0.0		0.23		0.26	
COV	**0.24**	**2.33**	***0.89***	**0.18**	***0.45***	**0.53**	

Notes: %ile = percentile; n = number of observations; st dev = standard deviation of raw data set;
COV = coefficient of variation defined as standard deviation/median for raw data set;
KC I-5 = King County data set (Huber, personal communication, 2003);
WSDOT = Washington State Department of Transportation data sets (Taylor Associates, Inc., 2002a and 2002b);
Driscoll = data transcribed from Driscoll et al. 1990;
* Driscoll data for phosphorus reported as PO4-P

ATTACHMENT E

Treatment Method Removal Efficiencies and Annual Runoff Volumes

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E. TREATMENT METHOD REMOVAL EFFICIENCIES AND ANNUAL RUNOFF VOLUMES

The Alaskan Way Viaduct (AWV) Replacement Project proposes to treat stormwater from the project area stormwater using one or more of the following methods:

- Stormwater Best Management Practices (BMPs);
- West Point wastewater treatment plant (TP); or
- Royal Brougham Combined Sewer Overflow (CSO) TP.

The assumptions used to determine the treatment efficiency and the percentage of annual runoff volume treated for each of these treatment methods are discussed in the following sections.

E.1 TREATMENT METHOD REMOVAL EFFICIENCY

Each of the three treatment methods relies on different technology to remove pollutants. Therefore, they each have different removal efficiencies for the pollutants of concern (Exhibit E-1).

Exhibit E-1. Summary of Removal Efficiencies by Treatment Method

Treatment Method	Removal Efficiency (%)		
	TSS	Zn[1]	Cu[1]
Stormwater BMPs	80	65	58
West Point TP	75	63	77
Royal Brougham TP	80	79	86

Source: Ecology (2001), Center for Watershed Protection (CWP) (2000) as reported in WSDOT (2002).
[1]Removal efficiencies shown are for total zinc and total copper.

E.1.1 Stormwater BMPs[1]

Stormwater BMPs are structures that are specifically designed to remove pollutants from stormwater runoff. Because of the way stormwater BMPs are designed, they have different removal efficiencies for different pollutants. Both the Washington State Department of Ecology (Ecology) and the Washington State Department of Transportation (WSDOT) provide recommendations for the removal efficiency of stormwater BMPs. The Ecology Stormwater Management Manual for Western Washington reports a removal efficiency of 80 percent for TSS (Ecology 2001); therefore, the removal efficiency for TSS was assumed to be 80 percent. However, because the

[1] Section E1.1 was prepared by Taylor Associates Inc. November 2003

Ecology Manual does not have removal efficiencies for Zn or Cu, these removal efficiencies were taken from the WSDOT guidance document.

The WSDOT water quality impacts guidance document (WSDOT 2002) reports removal efficiencies for stormwater BMPs based on a national study by the Center for Watershed Protection (CWP 2000). The CWP reports removal efficiencies for all of the parameters of interest for the AWV study; however, relatively few data have been compiled and published for the majority of BMPs considered. The values selected for Exhibit E-2 reflect the range of removal efficiencies for two categories of treatment technologies available in the WSDOT guidance document, wet ponds and filtering practices. The removal efficiencies of wet ponds are comparable to those of wet vaults (Ecology 2001). BMP technologies considered for determining ranges of removal efficiencies in Exhibit E-2 are wet vaults, organic filters, perimeter sand filters, surface sand filters (non-open channel applications), and vertical sand filters. Treatment technologies such as those considered for removal efficiency values may or may not be applied in this project.

Exhibit E-2. Percent Median Removal Efficiencies for Stormwater BMP

	Removal Efficiency (%)								
Range	**TSS**	**Cu**	**Dis. Cu**	**Zn**	**Dis. Zn**	**TP**	**Dis. P**	**TKN**	**NO2+NO3**
Low	58*	25*	N/A	56*	N/A	41*	21*	N/A	-87*
High	88	66*	N/A	87*	N/A	61*	68*	N/A	36

Data sources: CWP 2000 as reported in WSDOT 2002
N/A indicates data not available for those BMPs.*--based on fewer than five data points.

Exhibit E-2 represents a range of removal efficiencies for stormwater BMPs that are feasible for the site. For the purposes of this analysis, the low end of the median values for BMPs for which there was more than 5 data points was used to provide a conservative estimate of zinc and copper removal efficiency (Exhibit E-1).

E.1.2 Royal Brougham TP

The Royal Brougham TP would be a CSO treatment facility; however, it is currently in a conceptual design phase. The purpose of this facility is to provide treatment for CSO events to reduce the frequency and volume of untreated CSO discharges to Elliott Bay. The pollutant removal of the Royal Brougham TP is dependant on both the influent concentration and the flocculation agent used. Performance of this system was estimated using information from the Bremerton Wastewater Treatment Plant (Poppe, personal communication 2003), which uses this technology and the Actiflow Pilot Study (King County 2001). Assuming that the combined sewer influent concentrations of TSS would be approximately 106 mg/l, the ballasted flocculation treatment system would be capable of removing 80 percent of TSS at the design flow (Exhibit E-3) (Poppe 2003 personal communication).

Exhibit E-3. Ballasted Flocculation Performance

	Pollutant Removal Efficiencies (%)
Total Suspended Solids (TSS)	80
Copper	86 to 89
Zinc	79 to 84

Typical removal efficiencies for metals are also presented in Exhibit E-3. Removal efficiencies for metals were based on grab samples collected during the Actiflow Pilot Study; the Bremerton WWTP did not sample for metals. A value of 86 percent metals removal for copper, and 79 percent removal for zinc was used in this analysis as a conservative estimate of pollutant removal efficiency.

E.1.3 West Point TP

The West Point TP is a secondary municipal treatment facility whose primary purpose is to treat municipal sewage; however, some stormwater is received via the combined sewer system. In general, stormwater runoff dilutes the sewage and reduces the efficiency of the treatment plant to remove pollutants from the wastewater.

Removal efficiencies for TSS and metals for the West Point WTP documented during storm events were used in the mass balance model to compare the BMP Approach and the Convey and Treat Approach to existing conditions. King County provided removal efficiencies for TSS based on influent and effluent data for 2002. The minimum removal efficiency for TSS in 2002 was 52 percent, which was based on a very high flow day followed by additional high flow days (Dick Finger, personal communication, 2003). Occasionally, removal efficiencies of TSS at the West Point WTP can be as low as 9 percent; however, an average of 75 percent removal efficiency for TSS is achieved during most storm events (Exhibit E-4; Karen Huber, personal communication, 2003). King County also provided removal efficiencies for metals. The range of median removal efficiency for copper and zinc was calculated using data collected during wet weather events in 2001 and 2002 (Exhibit E-4).

Exhibit E-4. West Point TP Removal Efficiency

	Pollutant Removal Efficiencies (%)
Total Suspended Solids (TSS)	75
Copper	60 to 92
Zinc	39 to 78

For the purposes of this analysis the average median removal efficiencies of 77 for copper and 63 for zinc were used in this analysis (Exhibit E-1).

E.2 Annual Treatment Volume

Runoff from the project area is collected and conveyed in a complex system of pipes, which includes diversion structures in many sub-basins. This system dictates where runoff from the project area is treated and discharged. The assumptions used to determine the percentage of annual runoff treatment treated by each treatment method is summarized in the following sections.

E.2.1 Stormwater BMPs

Stormwater BMPs were conceptually designed using the WSDOT Instructional Letter (IL) 4020.2, which recommends the use of the Ecology 2001 Manual for designing basic treatment BMPs. These BMPs were designed to treat the volume of precipitation generated during the 6-month storm event. This volume is approximately 91 percent of the average annual stormwater runoff volume from the site. Stormwater runoff volumes that are greater than the 6-month storm event would discharge directly to the receiving water without passing through the treatment BMP.

E.2.2 Royal Brougham TP

The Royal Brougham TP was conceptually designed with enough capacity to treat a volume equivalent to the new volume of runoff from the project area that will be combined with the combined sewer system (approximately 11 percent larger than the facility currently proposed under King County Plan). The methods and assumptions used to design this facility are documented in the Detention and/or Treatment Facility at Royal Brougham Technical Memorandum (WSDOT 2003).

The Royal Brougham TP was designed meet the state requirement of no more than one CSO event per year. Because there is a probability that a storm event greater than a 1-year return frequency will occur in any given year, it was assumed that approximately 2.5 percent of the annual project volume in any given year could be discharged as a CSO (Exhibit E-5). This assumption was made using the 2-yr event probability of occurrence in any given year (0.50) multiplied by the 5 percent annual volume associated with the 2-yr event.

Exhibit E-5. Return Frequency Analysis

Return Frequency	24-hr Rainfall (inches)	% Annual Volume	Probability of Occurrence per Year
2-year	2.0	5	50%

Therefore, it was assumed that 2.5 percent would overflow as a CSO and 54 percent of the annual runoff would be routed to the Royal Brougham TP. The remaining 43.5 percent of the annual volume would go to the West Point TP as discussed in Section E.2.3.

E.2.3 West Point TP

Based on the analysis performed using rainfall data for the Denny Way Project, King County determined that 41 percent of the annual stormwater runoff in the Denny Way project area flows to the West Point WTP, 56 percent discharges as a CSO (prior to construction of the Denny Way project), and 3 percent evaporates (Karen Huber, personal communication).

Due to its proximity to the AWV project area, the Denny Way Project information was used in the AWV analysis. Reapportioning the portion of runoff that would evaporate, it was assumed that 43.5 percent of the stormwater runoff from the AWV Project would go to the West Point TP and 56.5 percent of the stormwater runoff from combined sewer sub-basins would overflow as part of a CSO. Evaporation was not accounted for in this analysis and the 3 percent volume was evenly distributed between the West Point TP and CSO.

E.3 References

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ATTACHMENT F

Summary of Sediment Survey Findings

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F.1 SEDIMENTS

F.1.1 Duwamish River East Waterway

The Lander combined storm drain and CSO and the Hanford CSO discharge to the East Waterway of the Duwamish River (segment 921). Sediment samples in this segment of the river have exceeded the sediment quality standards for the following parameters and are the basis for inclusion of segment 921 on the Washington State 1998 303(d) list.

- 1,2,4-Trichlorobenzene
- 1,4-Dichlorobenzene
- 2-Methlynaphthalene
- Acenaphthene, LPAH
- Anthracene, LPAH
- Naphthalene, LPAH
- Phenanthrene, LPAH
- Benz(a)anthracene, HPAH
- Benzo(a)pyrene, HPAH
- Benzo(g,h,i)perylene, HPAH
- Dibenz(a,h)anthracene, HPAH
- Chrysene, HPAH
- Fluoranthene, HPAH
- Indeno(1,2,3-cd)pyrene, HPAH
- Benzoic Acid
- Phenol
- Bis(2-ethylhexyl)phthalate
- Butylbenzyl phthalate
- Dibenzofuran
- Total PCBs
- Cadmium
- Copper
- Arsenic
- Silver
- Zinc
- Lead
- Mercury

Sediment samples from the East Waterway included in the Washington State Department of Ecology's SEDQUAL Data base (release 4.4, February 2003) were screened for metals and PAHs that exceed the Washington State Sediment Management Standard's Cleanup Screening Levels (CSL). Mercury and cadmium were the only metals from sample sites in the vicinity of the Lander CSO and storm drain (Exhibits F-1 and F-2 and the Hanford CSO (Exhibits F-3 and F-4) that exceeded the CSLs. None of the individual PAHs nor total LPAH or HPAH exceeded the CSLs in this area of the East Waterway.

F.1.2 Elliott Bay

Both surface and subsurface sediments in Elliott Bay have been analyzed for contaminants of concern in previous studies. The results of these studies are summarized here.

F.1.3 Surface Sediments

The Seattle Waterfront from Pier 46 to Pier 59 has been the focus of several studies and remediation projects sponsored by the Elliott Bay Action Team, the Environmental Protection Agency, the Washington State Department of Ecology, the Municipality of Metropolitan Seattle, the City of Seattle, and the Elliott Bay/Duwamish Restoration Program. These projects have identified mercury, silver, lead, zinc, HPAHs, LPAHs, benzyl alcohol, butyl benzyl phthalate, phenol, and benzoic acid as contaminants of concern (Romberg et al. 1984; EPA 1988; Metro 1988; Tetra Tech, Inc. 1988; Metro 1989; Metro 1993; Hart Crowser 1994; KCDMS 1994). The Elliott Bay Waterfront Recontamination Study sponsored by the Elliott Bay/Duwamish Restoration Program Panel used data from the above sources to describe surficial sediment chemistry for the waterfront study area. Surface sediment sampling locations (top 2 cm and top 10 cm samples) and data sources used for describing the surficial sediment chemistry are shown in Exhibit F-5 (Ecology, 1995a)

Contours for selected metals (mercury, silver, lead, and zinc) and organic contaminants (HPAH and LPAH) show values exceeding the SQS and CSL within the study area Exhibits F-6 through F-11 (Ecology, 1995a). These maps show CSL exceedances for silver, zinc, and lead in the slips between Piers 46 and 48, and for lead and silver between Piers 48 and 52. Mercury is above the CSL throughout the study area except for the capped areas, seaward of Pier 48, and a relatively small area south of the Pier 53-55 cap. HPAHs were above the CSL off of Pier 53 and offshore of the aquarium. LPAHs were above the CSL between the Seattle Ferry Terminal and the Pier 53-55 cap.

Figure F-12 shows the location of the Denny Way sediment remediation areas.

Elliott Bay is listed on the 303d list (1998) for the following chemicals which have exceeded the sediment quality standards.

• Bis(2-ethylhexyl) phthalate	• 2,4 Dimethylphenol
• Copper	• Acenaphthene
• Mercury	• Benzo(a)pyrene
• Silver	• Benzo(b,k)fluoranthene
• Chromium	• Hexachlorobenzene
• Lead	• Dibenz(a,h)anthracene
• Zinc	• Dibenzofuran

• Cadmium	• 1,4-Dichlorobenzene
• Arsenic	• Diethyl phthalate
• Anthracene	• Di-n-octyl phthalate
• Acenaphthylene	• Fluoranthene
• Benz(a)anthracene	• Indeno(1,2,3-cd)pyrene
• Benzo(b,k)fluoranthene	• Pentachlorophenol
• Benzo(g,h,i)perylene	• Phenanthrene
• Benzoic Acid	• Total PCBs
• Benzyl alcohol	• Pyrene
• Benzo(g,h,i)perylene	• 1,2,4-Trichlorobenzene
• Butylbenzyl phthalate	• Naphthalene
• Chrysene	• 2-Methylnaphthalene
• Fluorene	• HPAH and LPAH

F.1.4 Subsurface Sediments

Five hollow stem auger cores from a Hart Crowser study were analyzed for PAHs and metals (Hart Crowser 1994) (core locations shown on Exhibit F-14 (Ecology 1995a). These cores had up to 6 meters penetration. Analyses showed HPAH, LPAH, and mercury exceeding the CSL down to approximately 3 meters (10 feet). Exhibit F-14 shows example locations for deep cores to help fill existing data gaps (designated Areas A, B, and C on the figure) (Ecology, 1995a).

To supplement existing subsurface sediment data on the area, the Elliott Bay Waterfront Recontamination Study (Ecology, 1995a) collected three 4-inch gravity cores for selected chemical analysis: core C1, between Piers 54 and 56 (approximately 200-ft west of the shoreline); core C2, between Piers 56 and 57 (approximately 300-ft west of the shoreline); and core C3, approximately 100-ft north of Pier 48 (and 600-ft west of the shoreline) Exhibit F-15 (Ecology, 1995). Sediment recoveries ranged in length from 84 to 155 cm (compacted).

The cores were analyzed for selected metals (aluminum, copper, iron, lead, magnesium, mercury, and zinc), PCBs, grain size, TOC, percent solids, and $^{137}Cs/^{210}Pb$ In summary, concentration peaks for copper, lead, mercury, and zinc between Piers 56 and 57 (core C2), and lead and mercury between Piers 54 and 55 (core C1) and north of Pier 48 (core C3) exceeded the applicable cleanup screening level (CSL). Relatively high concentrations of mercury were present in all cores, ranging from 2.2 to 5.5 mg/kg in C1, 5.3 to 16 mg/kg in C2, and 0.036j to 1.8 mg/kg in C3 (all values dry weight) (mercury CSL = 0.58 mg/kg). The lead concentration in the upper 7 cm of core north of Pier 48 (core C3) was extremely high at 2,100 mg/kg (CSL = 530 mg/kg). The highest total PCB level (8,800 μg/kg = 130 mg PCB/Kg OC) was measured in between Piers 56 and 57 (core C2) in the 21 – 42 cm layer (CSL = 65 mg PCB/Kg OC).

Vertical profiles in bottom cores indicate that between Piers 52 and 57 (northern portion of the study area) concentrations of most contaminants typically peak at depths ranging from 16 to 42 cm, with some contaminants peaking at deeper depths. This was especially true for mercury between Piers 56 and 57, where concentrations as high as 16 mg/kg (dry weight) occurred at a depth of 105 – 168 cm. In contrast, between Piers 48 and 52 (southern portion of the study area), the highest concentrations were typically present in the top 7 cm. The contaminant profile for this area is consistent with the ^{137}Cs results that suggested the upper portion of the sediment record may have been removed.

These data indicate that sediment cleanup(s) in the northern portion of the study area that only involved sediment removal (i.e., dredging) would potentially expose more highly contaminated material then currently exists at the surface.

F.1.5 Lake Union

The Broad Street storm drain discharges to the south end of Lake Union. Lake Union is on the 1998 303d list for failing the freshwater sediment bioassay test. Washington State has not promulgated freshwater sediment chemical standards. In order to determine chemicals of potential concern in the south end of Lake Union in the vicinity of the Broad Street storm drain outfall, data collected from that area were compared to proposed freshwater sediment toxicity levels derived in three separate studies (Ingersoll et al. 1996), (Environment Canada, 1995), and (Ontario, 1993). If we use these proposed levels as local benchmarks, lead, mercury, copper, nickel, zinc and PAHs exceed at least one of the three sets of proposed sediment levels for freshwater Exhibits F-16 and F-17.

F.2 REFERENCES

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Prepared by Parametrix 11/03/03.
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● CSO and City of Seattle Stormdrain Outfall

● Sediment Sampling Sites

Exhibit F-1.
Lander street CSO and storm drain outfall and sediment sample locations taken from SEDQUAL database (Ecology, Release 4.4, February 2003)

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Exhibit F-2. Sediment concentrations for metals and PAHs from sample sites in the vicinity of the Lander CSO and storm drain

	EBCHEM[a]				PST18_P1[b]																			
SEDQUAL Station ID #	EW-08 (10/14/1985)		EW-09 (10/14/1985)		21 (3/26/1996)	22 (3/11/1996)		25 (3/26/1996)	26 - C10/4 (3/15/1996)	26 - S22/3 (3/15/1996)		26 - C10/12 (3/15/1996)		27 (3/15/1996)		62 (3/20/1996)	63 (3/15/1996)		64 (3/15/1996)		65 (3/15/1996)			
Parameter	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg dw	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	SIZM / SCSL[c] Criteria	
Arsenic	15.3	--	13.5	--	12	12	--	17	5.3	6.9	--	--	--	19	--	12	14	--	9.6	--	5.7	--	93	mg/Kg dw
Cadmium	1.63	--	2.84	--	1.3	1.6	--	3.5	0.32	0.65	--	--	--	3.6	--	2.7	6	--	1.5	--	0.57	--	6.7	mg/Kg dw
Chromium	125	--	84	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	270	mg/Kg dw
Copper	143	--	160	--	71	85	--	140	29	42	--	--	--	140	--	100	140	--	69	--	33	--	390	mg/Kg dw
Lead	166	--	137	--	110	140	--	220	18	39	--	--	--	230	--	170	260	--	110	--	40	--	530	mg/Kg dw
Mercury	0.667	-- Y	0.569	--	0.56	0.48	--	0.89 Y	0.22	0.33	--	--	--	0.89	-- Y	0.59	0.81	-- Y	0.44	--	0.57	--	0.59	mg/Kg dw
Silver	2.11	--	1.01	--	--	1.2	--	1.4	--	--	--	--	--	3.8	--	2.3	3	--	2.1	--	0.58	--	6.1	mg/Kg dw
Zinc	267	--	13.5	--	2.84	84	--	160	137	0.569	--	--	--	1.01	--	277	150	--	12	--	1.3	--	960	mg/Kg dw
Naphthalene	--	--	--	--	--	0.025	1.25	--	--	--	--	0.026	2.26	0.1	3.57	--	0.28	7.73	0.035	1.84	0.035	1.87	170	mg/Kg organic carbon
Acenaphthylene	--	--	--	--	--			--	--	--	--	--	--	--	--	--	0.057	1.57	--	--	--	--	66	mg/Kg organic carbon
Acenaphthene	--	--	--	--	--	0.037	1.85	--	--	--	--	0.021	1.83	0.2	7.14	--	0.48	13.26	0.043	2.26	0.022	1.18	57	mg/Kg organic carbon
Fluorene	--	--	--	--	--	0.047	2.35	--	--	0.023	1.92	0.033	2.87	0.28	10.00	--	0.59	16.30	0.076	4.00	0.044	2.35	79	mg/Kg organic carbon
Phenanthrene	0.4	16.39	0.67	29.52	--	0.15	7.50	--	--	0.1	8.33	0.13	11.30	0.76	27.14	--	--	--	0.29	15.26	0.21	11.23	480	mg/Kg organic carbon
Anthracene	--	--	0.24	10.57	--	0.069	3.45	--	--	0.044	3.67	0.051	4.43	0.22	7.86	--	0.6	16.57	0.13	6.84	0.061	3.26	1200	mg/Kg organic carbon
Total LPAH	0.4	16.39	0.91	40.09	--	0.328	16.40	--	--	0.167	13.92	0.261	22.70	1.56	55.71	--	2.007	55.44	0.574	30.21	0.372	19.89	780	mg/Kg organic carbon
Fluoranthene	1	40.98	2.2	96.92	--	0.4	20.00	--	--	0.21	17.50	0.2	17.39	1.1	39.29	--	--	--	0.71	37.37	0.34	18.18	1200	mg/Kg organic carbon
Pyrene	1.2	49.18	2.4	105.73	--	0.58	29.00	--	--	0.27	22.50	0.24	20.87	1.2	42.86	--	--	--	0.95	50.00	0.38	20.32	1400	mg/Kg organic carbon
Benzo(a)anthracene	0.58	23.77	0.97	42.73	--	0.2	10.00	--	--	0.094	7.83	0.087	7.57	0.39	13.93	--	0.75	20.72	0.26	13.68	0.14	7.49	270	mg/Kg organic carbon
Chrysene	1.2	49.18	1.6	70.48	--	0.26	13.00	--	--	0.13	10.83	0.12	10.43	0.58	20.71	--	1	27.62	0.36	18.95	0.2	10.70	460	mg/Kg organic carbon
Benzofluoranthenes	1.51	61.89	1.5	66.08	--	0.39	19.50	--	--	0.194	16.17	0.12	10.43	0.68	24.29	--	1.22	33.70	0.55	28.95	0.27	14.44	450	mg/Kg organic carbon
Benzo(a)pyrene	0.58	23.77	0.9	39.65	--	0.2	10.00	--	--	0.094	7.83	0.071	6.17	0.31	11.07	--	0.57	15.75	0.26	13.68	0.14	7.49	210	mg/Kg organic carbon
Indeno(1,2,3-cd)pyrene	--	--	0.25	11.01	--	0.1	5.00	--	--	0.059	4.92	0.044	3.83	--	--	--	0.22	6.08	0.14	7.37	0.082	4.39	88	mg/Kg organic carbon
Dibenzo(a,h)anthracene	--	--	--	--	--			--	--	--	--	--	--	0.032	1.14	--	--	--	0.027	1.42	--	--	33	mg/Kg organic carbon
Benzo(g,h,i)perylene	--	--	0.18	7.93	--	0.11	5.50	--	--	0.041	3.42	0.055	4.78	0.13	4.64	--	0.22	6.08	0.12	6.32	0.076	4.06	78	mg/Kg organic carbon
Total HPAH	6.07	248.77	9.82	432.60	--	2.24	112.00	--	--	1.092	91.00	0.937	81.48	4.422	157.93	--	3.98	109.94	3.377	177.74	1.628	87.06	5300	mg/Kg organic carbon
TOC (%)	2.44	--	2.27	--	--	2	--	--	--	1.2	--	1.15	--	2.8	--	--	3.62	--	1.9	--	1.87	--	--	--

[a] King County. 1995.
[b] USEPA Region 10. 1991. SEDQUAL Reference ID: EPA0025
[c] USACE. 1997. SEDQUAL Reference ID: USACE0026

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CSO and City of Seattle Stormdrain Outfall

Sediment Sampling Sites

Exhibit F-3.
Hanford CSO outfall and sediment sample locations taken from SEDQUAL (Ecology, Release 4.4, Feb. 2003)

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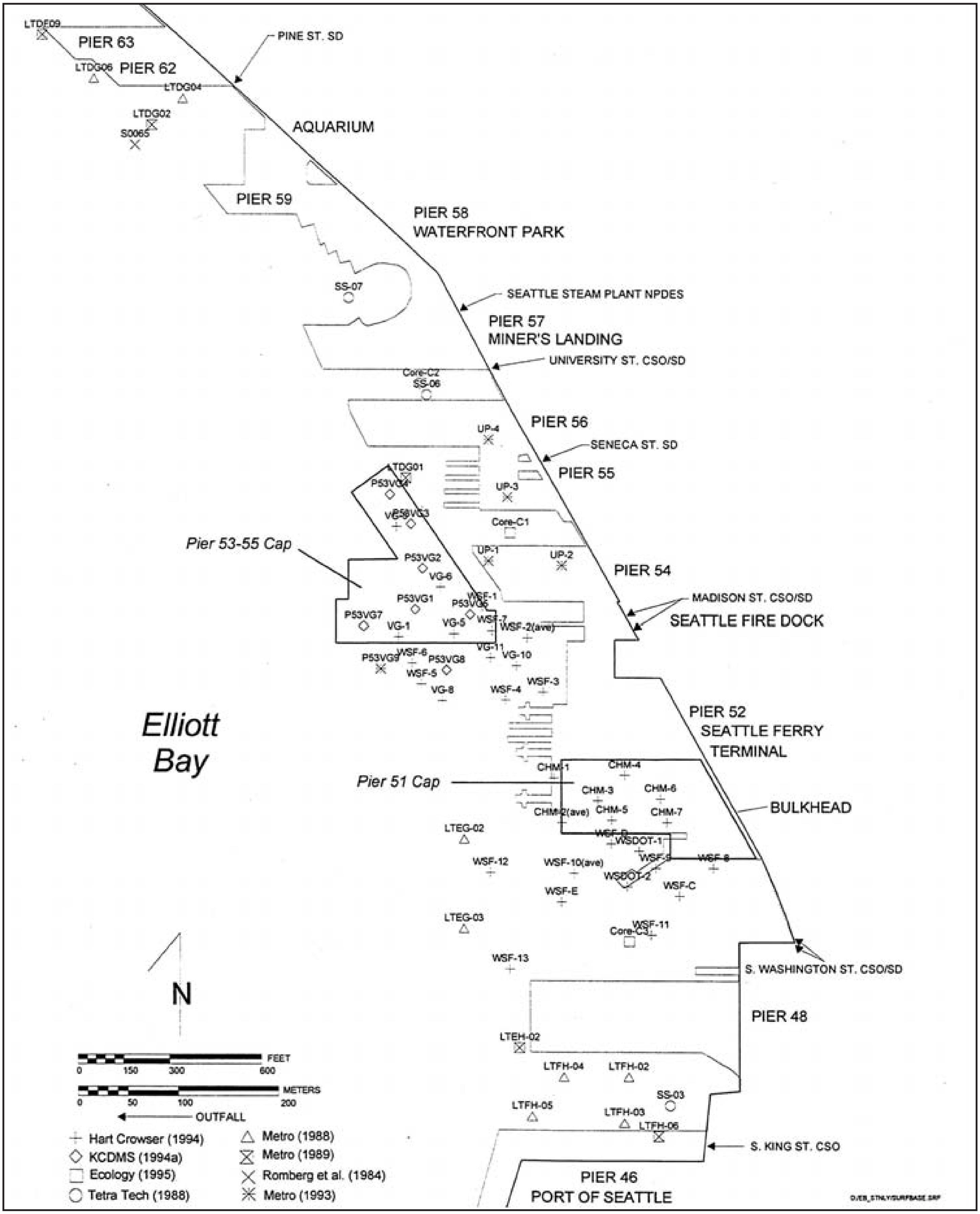
Exhibit F-4. Sediment concentrations for metals and PAHs from sample sites in the vicinity of the Hanford CSO

	HANCSO95[a]												HIRIPH2[b]					PST18_P1[c]								
	HN00 (6/27/1995)		HN10N (6/27/1995)		HN10S (6/29/1995)		HN10W (6/29/1995)		HN20N (6/27/1995)		HN20S (6/29/1995)		E-02 (10/1/1991)		E-06 (10/1/1991)		E-06 (10/31/1991)	50 (3/26/1996)		51 (3/27/1996)		71 (3/14/1996)		72 (3/14/1996)		
Parameter	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	mg/kg dw	mg/kg-oc	SIZM / SCSL Criteria
Arsenic	14.9						14.3		12.6		16.4		9.4		14.6		8.3	8.1		14		7.9		9.6		93 mg/Kg dw
Cadmium	2.4		1.8		2.1		2.7		2.3		2.1		7.4 Y		7.4 Y		8.3 Y	0.78		3.6		0.44		1.6		6.7 mg/Kg dw
Chromium	48.8		48.6		48.3		54.5		50.4		52.0				43		50									270 mg/Kg dw
Copper	126.1		121.4		133.3		115.4		134.6		130.2		114		105		123	59		140		42		36		390 mg/Kg dw
Lead	129.1		122.0		116.8		178.1		134.1		118.0		76.8		74.1		93.5	48		310		27		130		530 mg/Kg dw
Mercury	0.54		0.56		0.62 Y		0.79 Y		0.60 Y		0.48		0.49		1.50 Y		4.20 Y	0.39		1.66 Y		0.22		0.67 Y		0.59 mg/Kg dw
Silver	2.2		2.2		2.1		3.1		2.3		2.2				0.85					2.3		0.33		1.4		6.1 mg/Kg dw
Zinc	296.2		215.2		214.8		245.9		233.4		212.4		168		164		193	120		390		74		160		960 mg/Kg dw
Naphthalene							2.25	66.2					0.074	4.2	0.072	5.1						0.023	1.8	0.041	2.05	170 mg/Kg organic carbon
Acenaphthylene					0.065	1.90	0.061	1.8	0.039	1.1	0.059	1.8	0.013	0.7	0.021	1.5										66 mg/Kg organic carbon
Acenaphthene			0.032	1.0	0.061	1.78	0.715	21.0	0.041	1.2	0.222	6.8	0.046	2.6	0.04	2.8								0.068	3.4	57 mg/Kg organic carbon
Fluorene			0.045	1.4	0.097	2.83	0.91	26.8	0.061	1.7	0.253	7.8	0.059	3.3	0.051	3.6						0.038	2.9	0.094	4.7	79 mg/Kg organic carbon
Phenanthrene	0.188	4.5	0.295	9.1	0.6	17.49	3.61	106.2	0.329	9.3	0.965	29.6	0.36	20.2	0.44	31.2		0.1	6.7			0.14	10.8	0.43	21.5	480 mg/Kg organic carbon
Anthracene	0.095	2.3	0.145	4.5	0.263	7.67	0.639	18.8	0.181	5.1	0.274	8.4	0.16	9.0	0.19	13.5		0.032	2.1			0.04	3.1	0.17	8.5	1200 mg/Kg organic carbon
Total LPAH	0.283	6.8	0.517	15.9	1.086	31.66	8.185	240.7	0.651	18.4	1.773	54.4	0.712	40.0	0.814	57.7		0.132	8.8			0.241	18.5	0.803	40.15	780 mg/Kg organic carbon
Fluoranthene	0.412	9.9	0.657	20.2	1.125	32.80	2.172	63.9	0.76	21.5	1.361	41.7	0.7	39.3	1.1	78.0		0.18	12.0			0.17	13.1	0.73	36.5	1200 mg/Kg organic carbon
Pyrene	0.441	10.6	0.616	19.0	0.793	23.12	1.811	53.3	0.654	18.5	1.237	37.9	0.67	37.6	0.87	61.7		0.31	20.7			0.23	17.7	0.95	47.5	1400 mg/Kg organic carbon
Benzo(a)anthracene	0.249	6.0	0.395	12.2	0.608	17.73	1.826	53.7	0.462	13.1	0.738	22.6	0.38	21.3	0.43	30.5		0.086	5.7			0.081	6.2	0.3	15	270 mg/Kg organic carbon
Chrysene	0.377	9.0	0.595	18.3	1.003	29.24	2.09	61.5	0.741	20.9	1.307	40.1	0.7	39.3	0.66	46.8		0.13	8.7			0.09	6.9	0.56	28	460 mg/Kg organic carbon
Benzofluoranthenes	0.63	15.1	1.08	33.2	1.58	46.06	3.39	99.7	1.21	34.2	1.64	50.3	0.84	47.2	1.2	85.1		0.235	15.7			0.154	11.8	0.57	28.5	450 mg/Kg organic carbon
Benzo(a)pyrene	0.275	6.6	0.489	15.0	0.69	20.12	1.951	57.4	0.535	15.1	0.728	22.3	0.4	22.5	0.4	28.4		0.091	6.1			0.082	6.3	0.29	14.5	210 mg/Kg organic carbon
Indeno(1,2,3-cd)pyrene	0.299	7.2	0.389	12.0	0.378	11.02	0.924	27.2	0.412	11.6	0.663	20.3	0.24	13.5				0.036	2.4			0.035	2.7	0.13	6.5	88 mg/Kg organic carbon
Dibenzo(a,h)anthracene			0.105	3.2			0.27	7.9	0.133	3.8	0.15	4.6												0.025	1.25	33 mg/Kg organic carbon
Benzo(g,h,i)perylene	0.254	6.1	0.369	11.0	0.288	8.40	0.58	17.1	0.368	10.4	0.438	13.4	0.29	16.3								0.046	3.5	0.17	8.5	78 mg/Kg organic carbon
Total HPAH	2.937	70.4	4.685	144.2	6.465	188.48	15.014	441.6	5.275	149.0	8.262	253.4	4.22	237.1	4.66	330.5		1.068	71.2			0.888	68.3	3.725	186.25	5300 mg/Kg organic carbon
TOC (%)	4.17		3.25		3.43		3.4		3.54		3.26		1.78		1.41			1.5				1.3		2		-- --

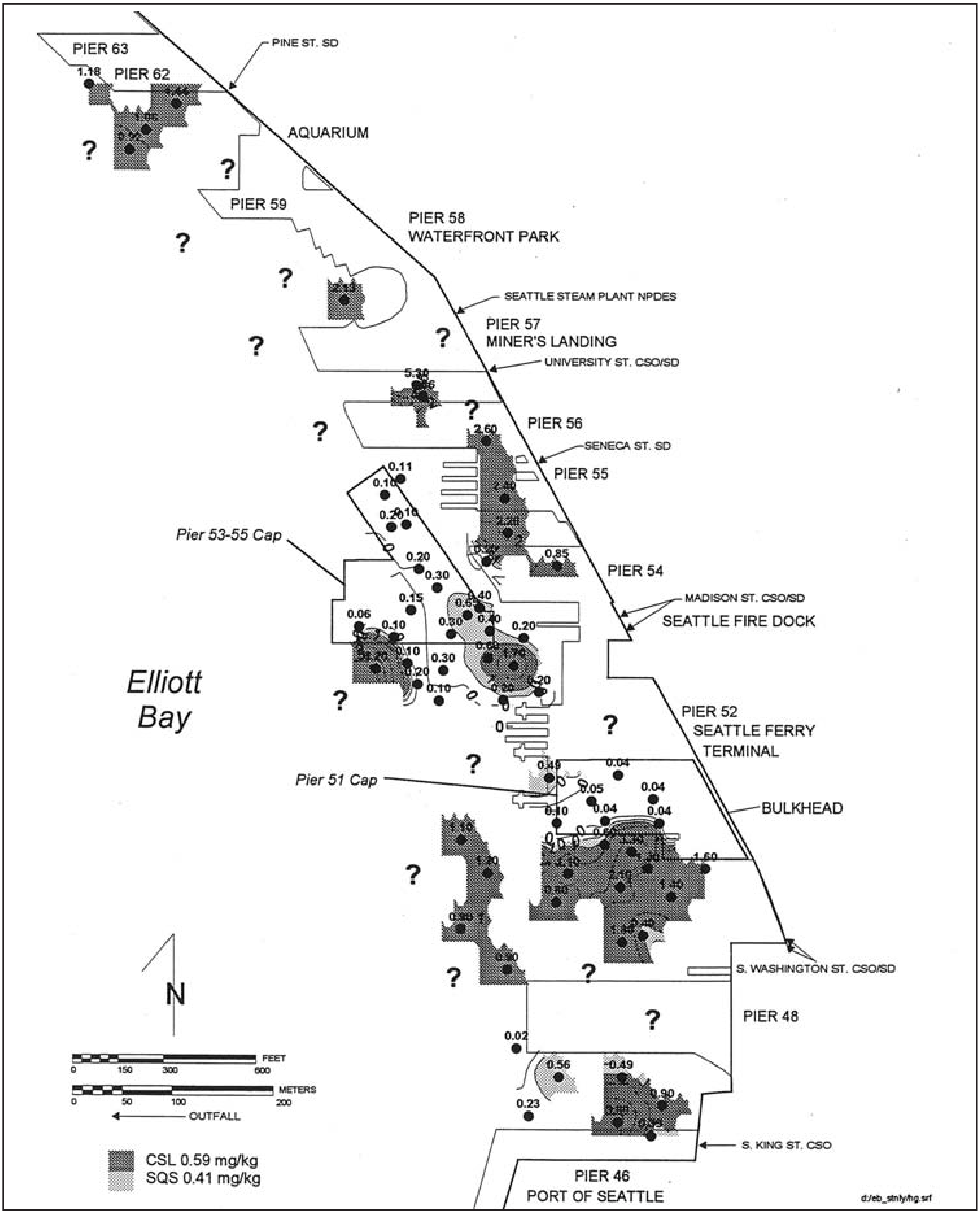
[a] King County. 1995.
[b] USEPA Region 10. 1991. SEDQUAL Reference ID: EPA0025
[c] USACE. 1997. SEDQUAL Reference ID: USACE0026



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Exhibit F-5
Surface Sediment Sample Locations, Data Sources, Sediment Remediation Sites and CSD and Storm Drain Locations

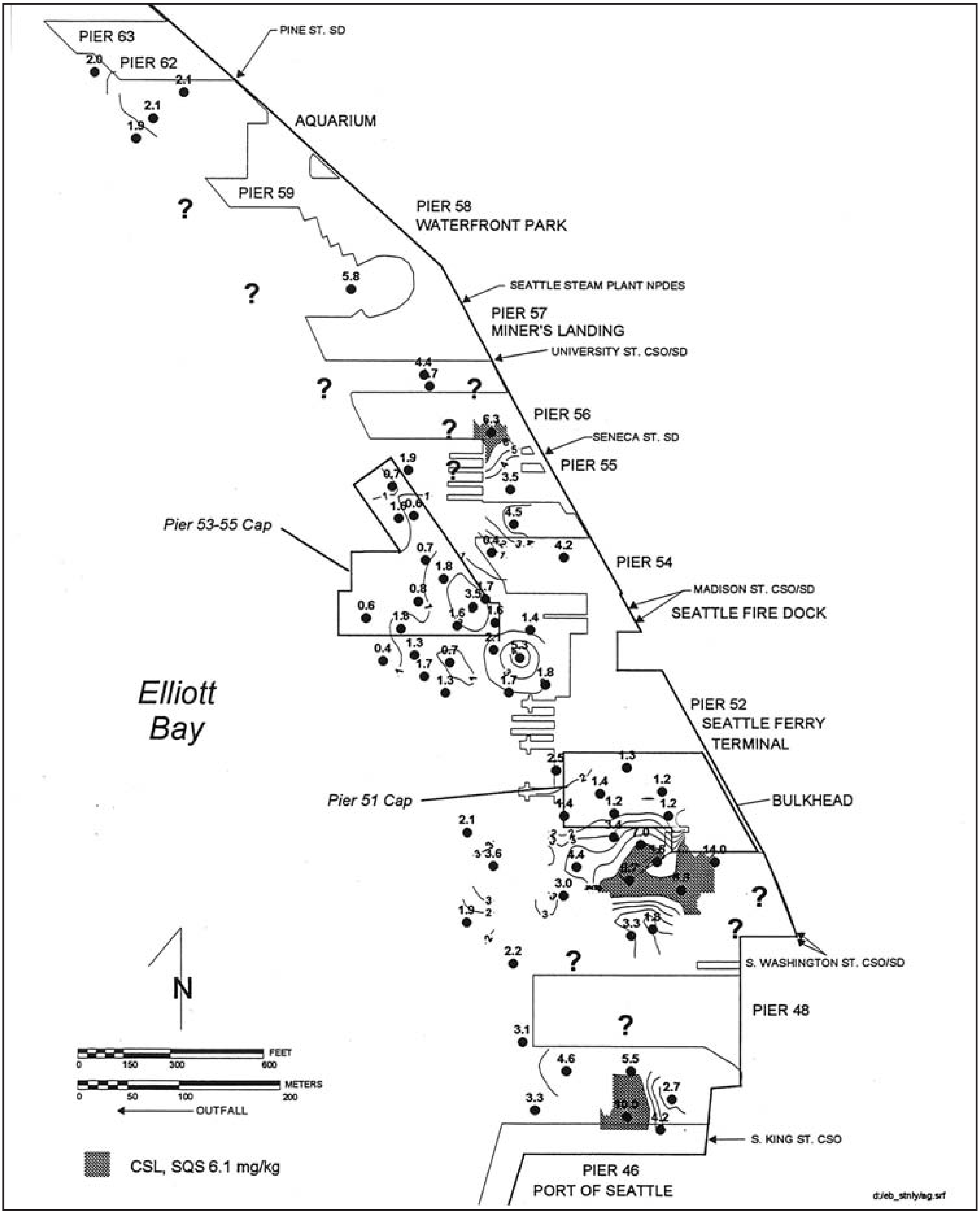
Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

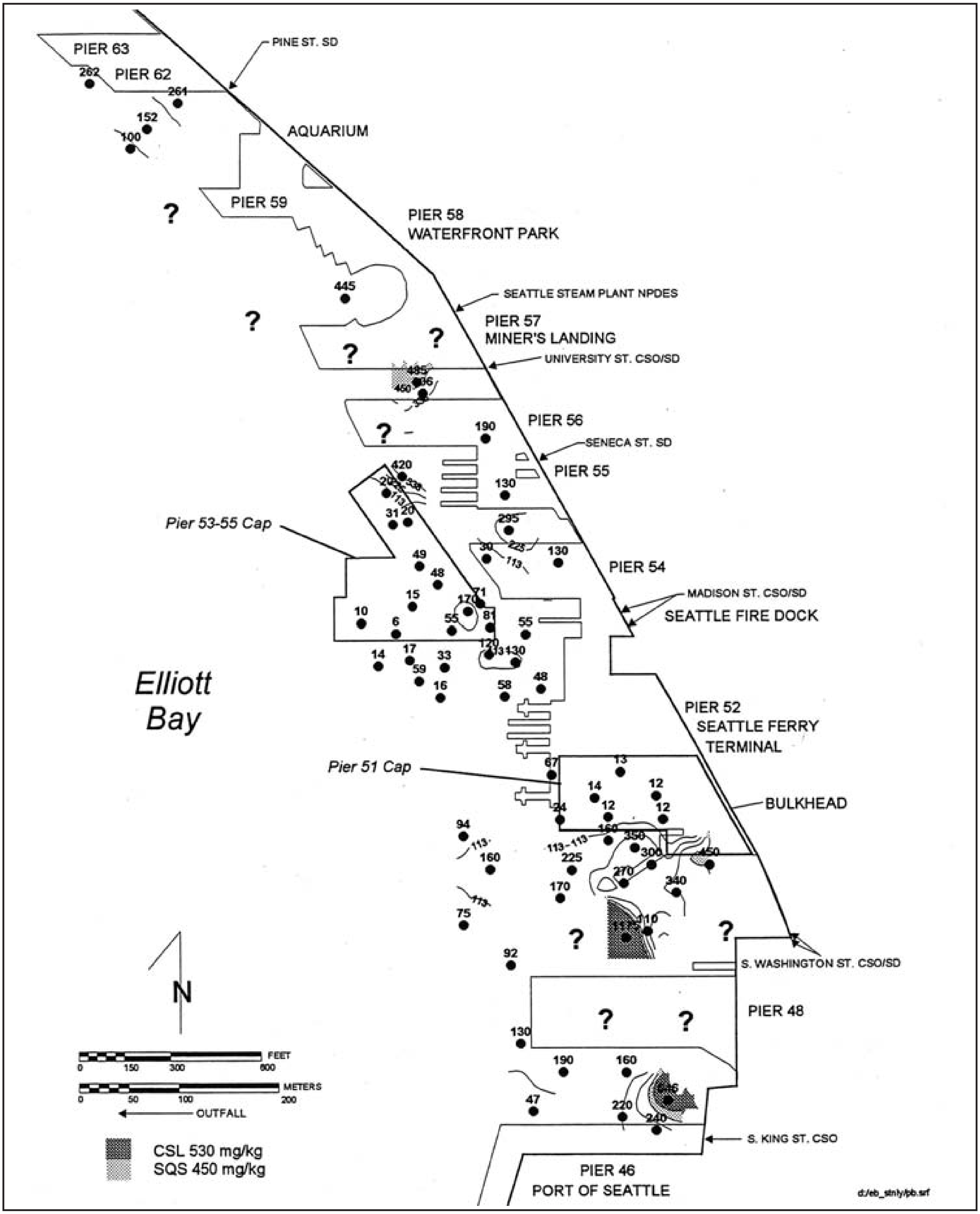
Exhibit F-6
Surface Mercury Contours (mg/kg)



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

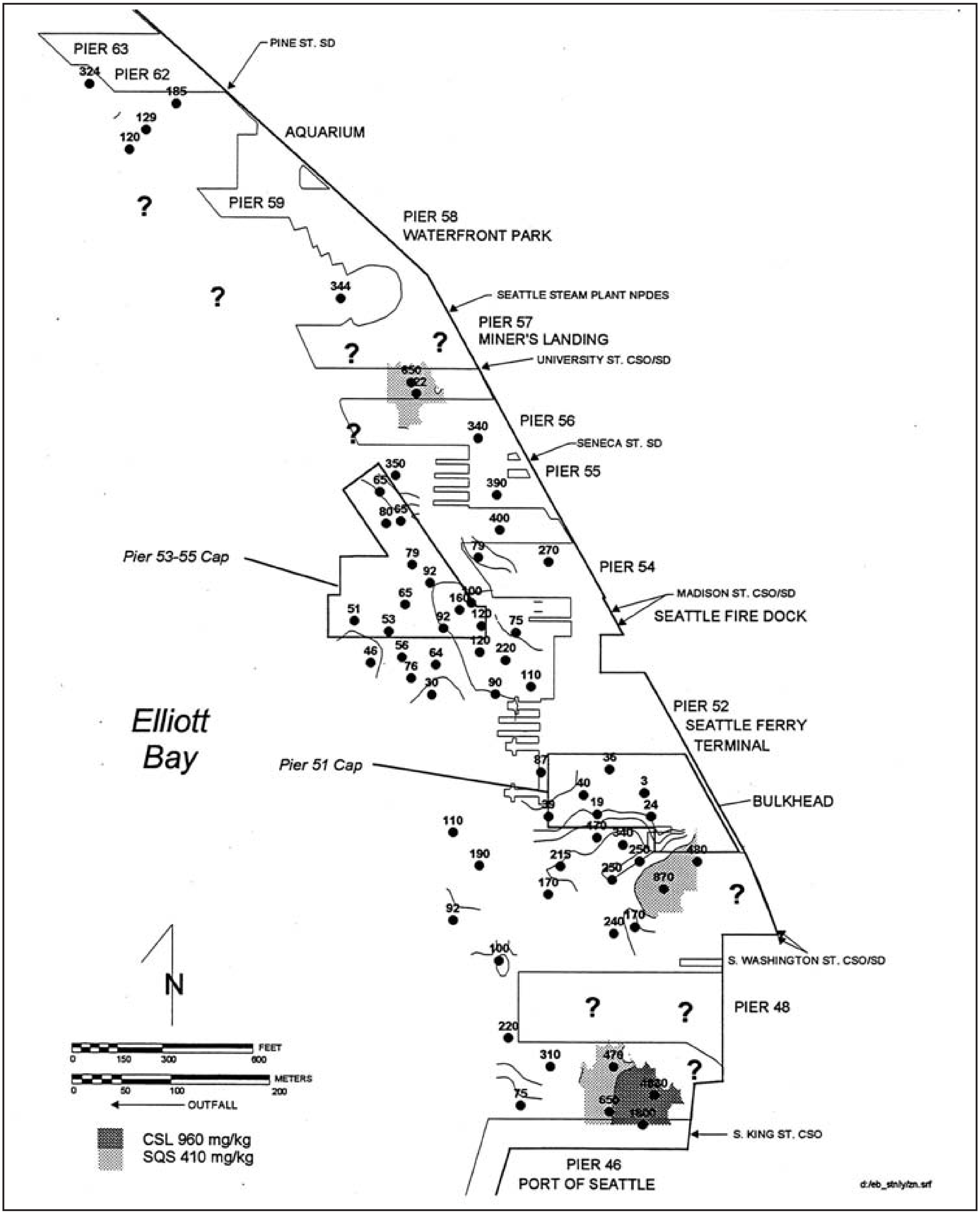
Exhibit F-7
Surface Silver Contours (mg/kg)



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

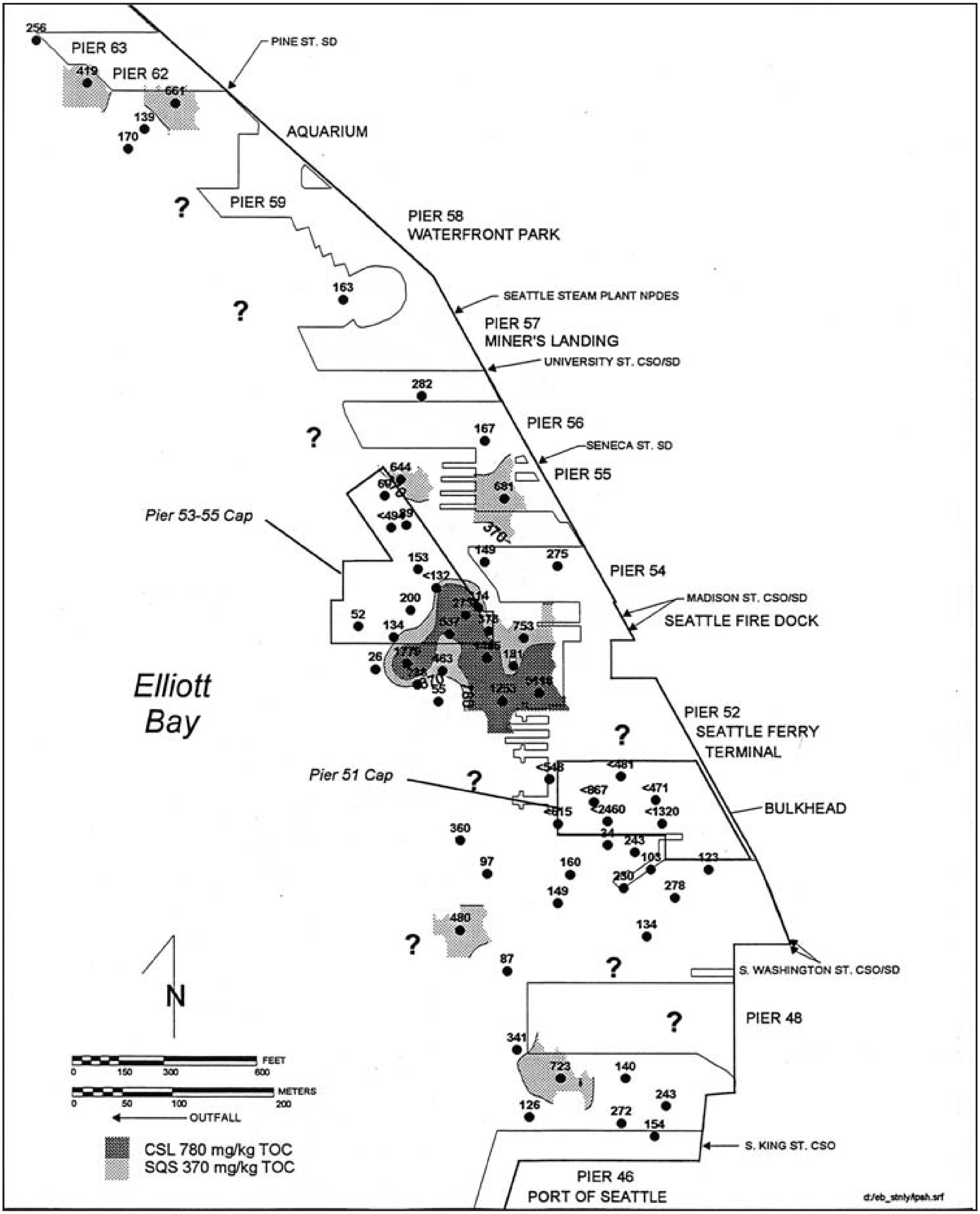
Exhibit F-8
Surface Lead Contours (mg/kg)



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

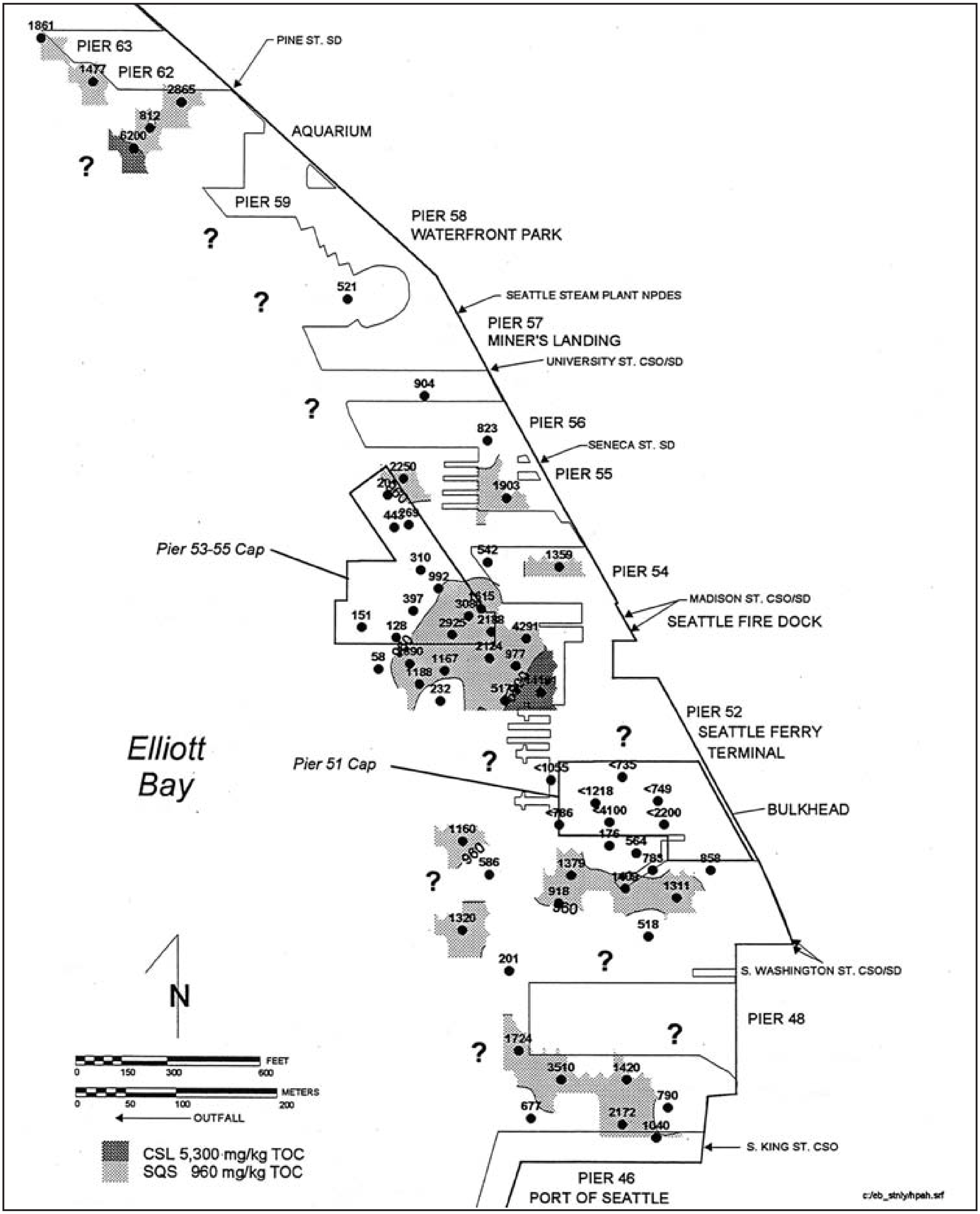
Exhibit F-9
Surface Zinc Contours (mg/kg)



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

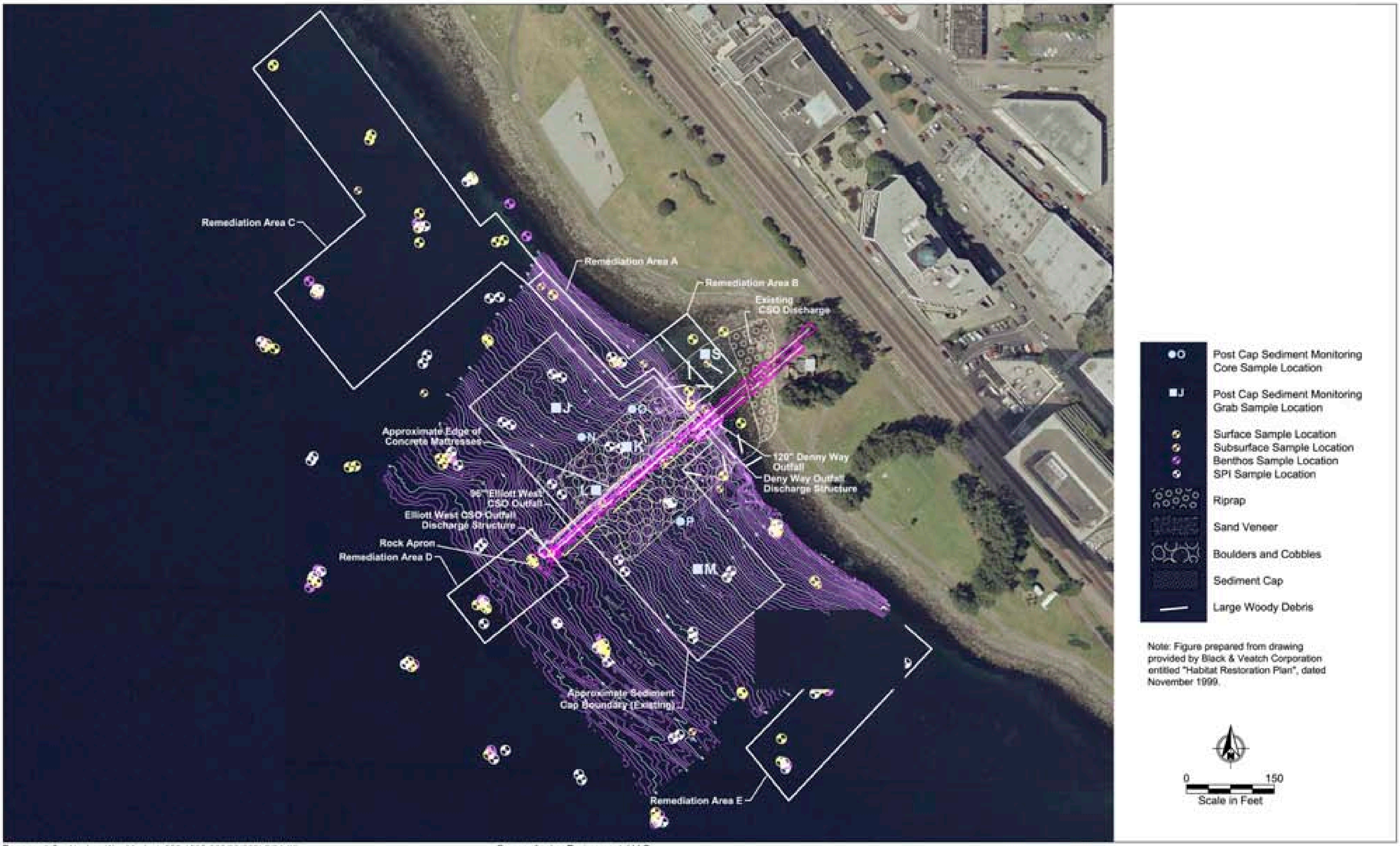
Exhibit F-10
Surface LPAH Contours (mg/kg)



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995

Exhibit F-11
Surface HPAH Contours (mg/kg)



Parametrix Alaskan Way Viaduct 553-1585-002/06(063) 2/04 (K)

Source: Anchor Environmental LLC

Figure F-12
Denny Way Sediment Remediation Project Map

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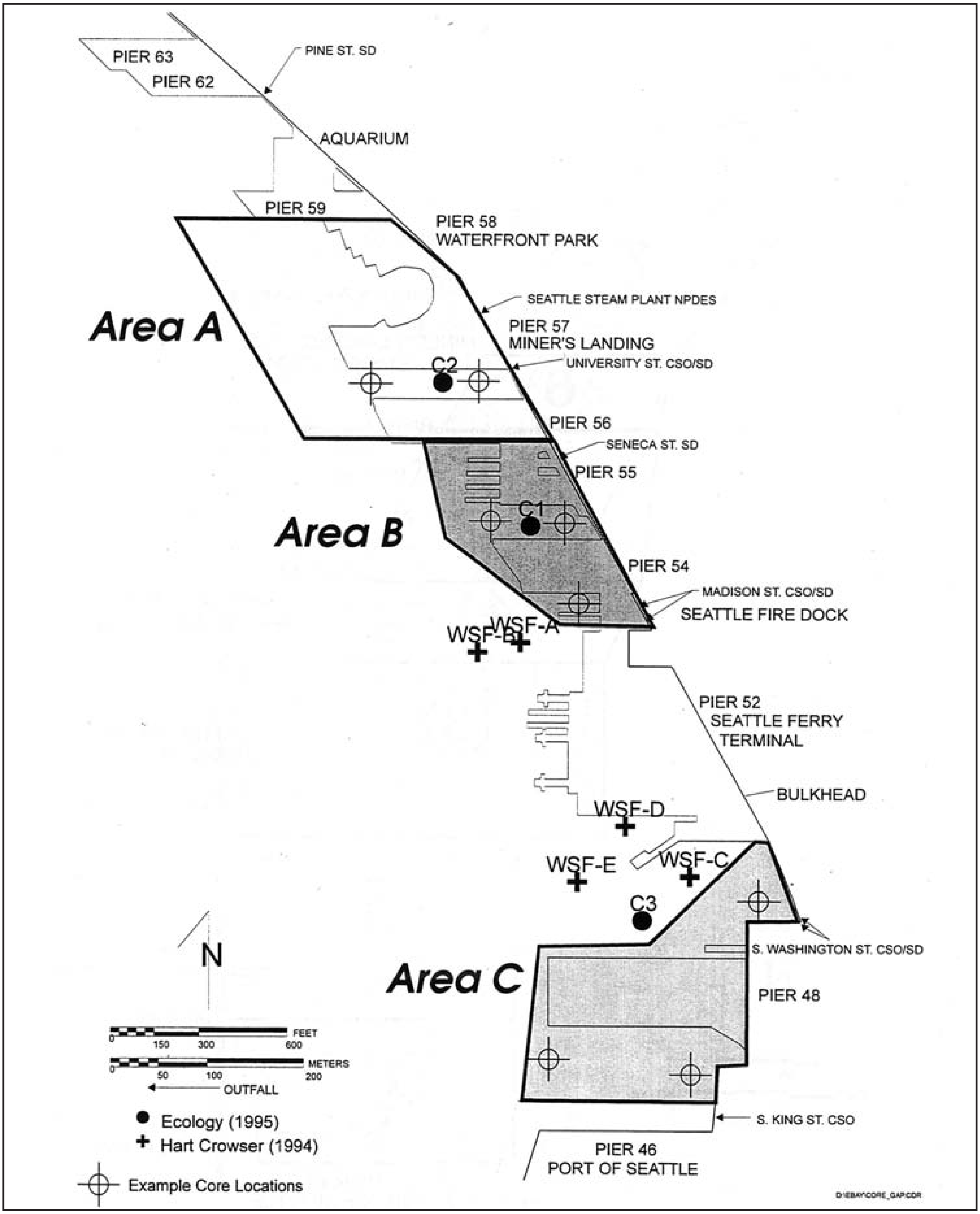
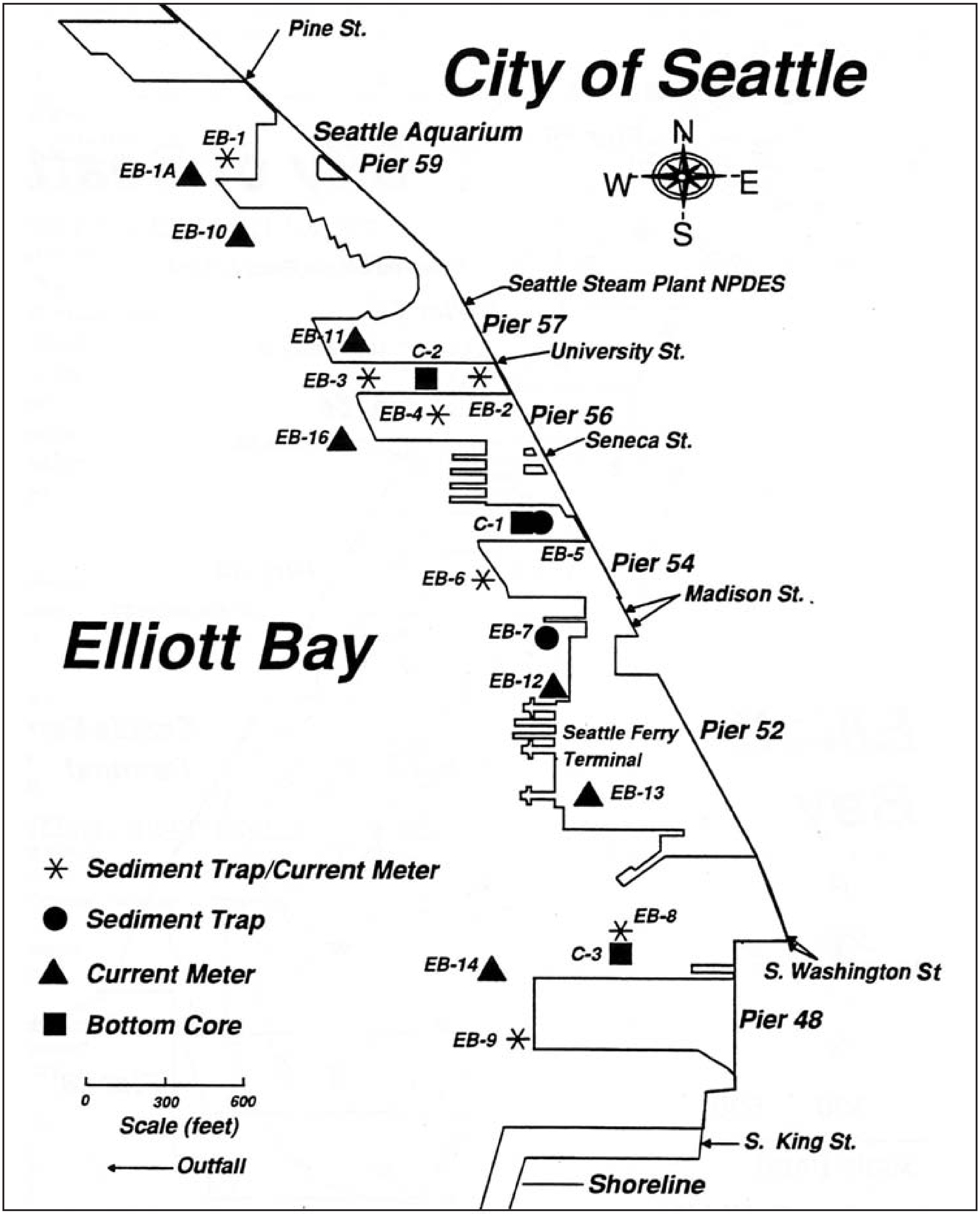


Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Exhibit F-13
Subsurface Sediment
Sample Locations

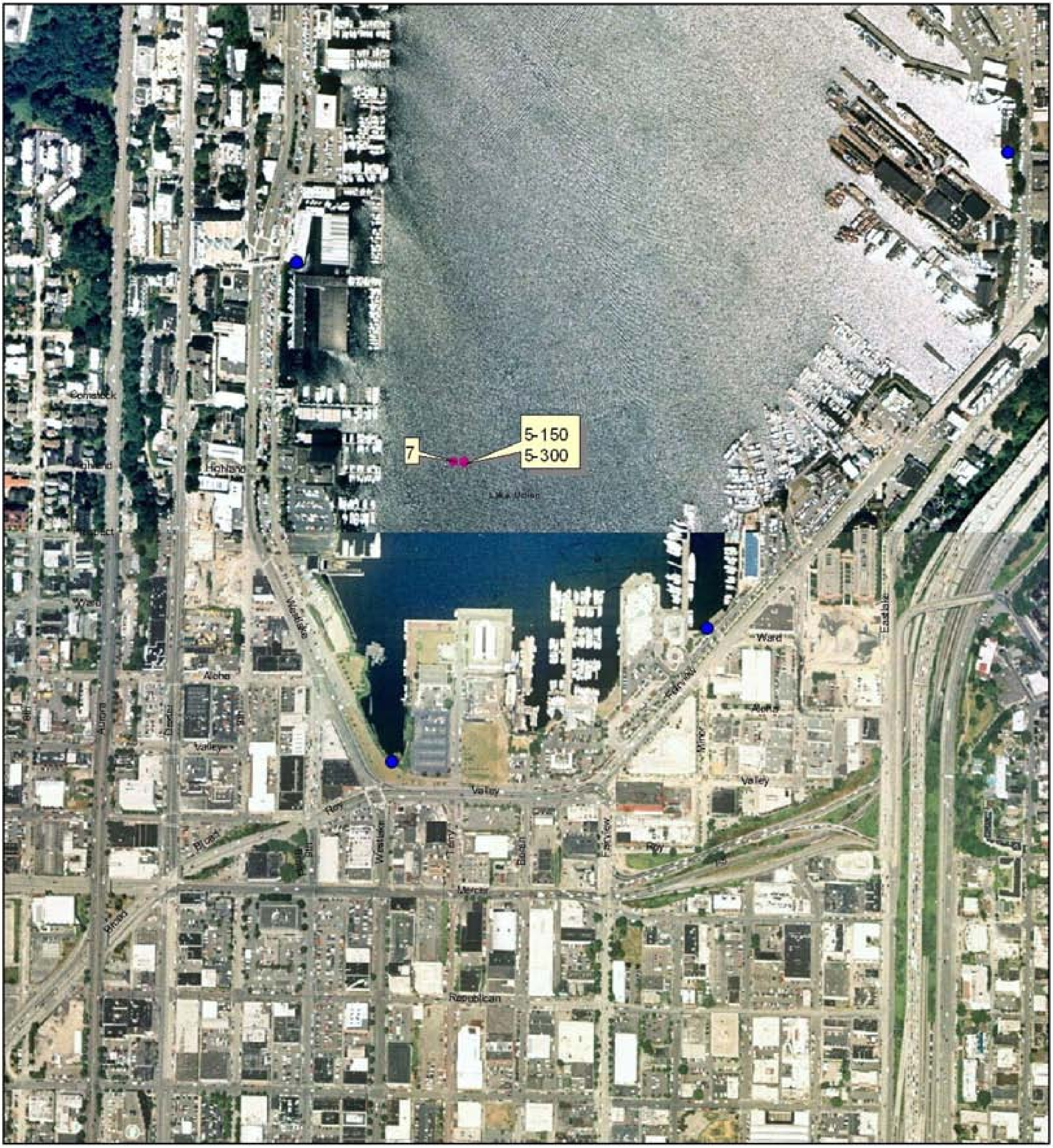
Figure taken from:
Aura Nova Consultants Inc. and Ecology, 1995



Alaskan Way Viaduct 554-1585-025/06(063) 11/03 (K)

Exhibit F-14
Sediment Sample Locations for the Elliott Bay Waterfront Recontamination Study

Ref: Ecology. 1995. Elliott Bay Waterfront Recontamination Study. Volume I: Field Investigation Report.



Prepared by Parametrix 11/03/03.
C:\Projects\AWV\AWV_CSO.apr [Lake Union]

- Storm Drain Outfall
- Sediment Sampling Sites

Exhibit F-15
Broad Street storm drain outfall and sediment sample locations taken from SEDQUAL (Ecology, Release 4.4, Feb. 2003)

N

100 0 100 Feet

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Exhibit F-16. Sediment Concentrations for metals and PAHs from sample sites in the vicinity of the Broad Street storm drain

Broad St. (Lake Union)

	SLUPLT86, 5-50 (12/1/1986)					SLUPLT86, 5-150 (12/1/1986)					SLUPLT86, 5-300 (12/1/1986)					LKUNION, 7 (6/20/1990)					A	B	C
			Exceed?					Exceed?					Exceed?					Exceed?			Ingersoll et al (1996)	Environment Canada (1995)	Ontario (1993)
Parameter	mg/kg dw	mg/kg-oc	A	B	C	mg/kg dw	mg/kg-oc	A	B	C	mg/kg dw	mg/kg-oc	A	B	C	mg/kg dw	mg/kg-oc	A	B	C	ERM (ug/g dry)	PEL (ug/g dry)	SEL (ug/g dry)
Arsenic	2.96					7.3					6.45										50	17	33
Cadmium	0.942					0.667					0.751					1.1					3.9	3.53	10
Chromium	9.43					6.8					7.94										270	90	110
Copper	45.9					31.8					39.3					189				Y	190	197	110
Lead	234		Y	Y		118		Y	Y		144		Y	Y		497		Y	Y	Y	99	91.3	250
Mercury	7.78			Y	Y	3.85			Y	Y	8.94			Y	Y	0.87			Y		---	0.486	2
Nickel	13.6					10.6					11					47.3		Y	Y		45	35.9	75
Zinc	196					133					140					531			Y		550	315	820
																							(ug/g oc-norm)
Naphthalene	0.91	16.73	Y			0.54	9.33	Y			0.67	12.55	Y			0.33	6.47	Y			0.098	---	---
Fluorene	0.32	5.88	Y			0.16	2.76	Y			0.24	4.49	Y								0.14	---	160
Phenanthrene																1.5	29.41	Y	Y		0.35	0.515	950
Anthracene	0.56	10.29	Y			0.26	4.49	Y			0.28	5.24	Y			0.28	5.49	Y			0.14	---	370
Fluoranthene	4.95	90.99	Y	Y		2.07	35.75	Y			2.75	51.50	Y	Y		2.2	43.14	Y			0.18	2.355	1020
Pyrene	5.03	92.46	Y	Y		2.33	40.24	Y	Y		2.89	54.12	Y	Y		3.1	60.78	Y	Y		0.35	0.875	850
Benzo(a)anthracene	1.33	24.45	Y	Y		0.68	11.74	Y	Y		0.96	17.98	Y	Y		1.2	23.53	Y	Y		0.3	0.385	1480
Chrysene	2.34	43.01	Y	Y		0.81	13.99	Y			1.2	22.47	Y	Y		1.3	25.49	Y	Y		0.5	0.862	460
Benzo(a)pyrene	2.89	53.13	Y	Y		0.64	11.05	Y			0.97	18.16	Y	Y		1	19.61	Y	Y		0.47	0.782	1440
Indeno(1,2,3-c,d)pyrene	1.66	30.51	Y			0.49	8.46	Y			0.53	9.93	Y			1.2	23.53	Y			0.25	---	320
Dibenzo(a,h)anthracene	0.5	9.19																			---	---	130
Benzo(g,h,i)perylene	1.83	33.64	Y			0.67	11.57	Y			0.74	13.86	Y			1.5	29.41	Y			0.28	---	0.32
TOC (%)	5.44					5.79					5.34					5.1							

A = Freshwater sediment levels suggested in Ingersoll st al. (1996)
B = Freshwater sediment levels suggested in Environment Canada (1995)
C = Freshwater sediment levels suggested in Ontario (1993)

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ATTACHMENT G

Technical Memorandum: Potential Need for an AFFF Treatment Facility and Supporting Costs

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SR 99: Alaskan Way Viaduct Project

Technical Memorandum: Potential Need for an AFFF Treatment Facility and Supporting Costs

Agreement No. Y-7888

Task 17.6

The SR 99: Alaskan Way Viaduct Project is a joint effort between the Washington State Department of Transportation (WSDOT), the City of Seattle, and the Federal Highway Administration (FHWA). To conduct this project, WSDOT contracted with:

Parsons Brinckerhoff Quade & Douglas, Inc.
999 Third Avenue, Ste 2200
Seattle, WA 98104

In association with:

BERGER / ABAM Engineers Inc.
BJT Associates
David Evans and Associates, Inc.
Entech Northwest
EnviroIssues, Inc.
Harvey Parker & Associates, Inc.
Jacobs Civil Inc.
Larson Anthropological Archaeological Services Limited
Mimi Sheridan, AICP
PanGEO INCORPORATED
Parametrix, Inc.
Preston, Gates, Ellis, LLP
ROMA Design Group
RoseWater Engineering, Inc.
Shannon & Wilson, Inc.
Steven L. Kramer, Ph.D., Consulting Engineer
Taylor Associates, Inc.
Tom Warne and Associates, LLC
William P. Ott

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LIST OF TABLES

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Technical Memorandum

Potential Need for an AFFF Treatment Facility and Supporting Costs

BACKGROUND

As part of the proposed Alaskan Way Viaduct (AWV) improvements, it has been proposed that the portion of the Alaskan Way Viaduct running along the waterfront be routed through an underground tunnel. Routing traffic through a tunnel presents a special hazard if a vehicle or truck transporting flammable hydrocarbons should be involved in an incident resulting in a fire. To address this possibility, the proposed tunnel will be constructed with a fire suppression system that has heat sensors located throughout its length. If a heat sensor is triggered it will initiate a tunnel closure and the release of a fire suppression agent. The most common fire suppression agent used in such commuter tunnels is a 3% aqueous film forming foam (AFFF). The AFFF is purchased as a concentrate that is held in airtight storage tanks until needed. If the fire suppression system is triggered, the concentrate will be mixed with water to achieve a mixture containing 3% of the AFFF concentrate before its release.

The AFFF fire suppression foam / water mixture, when triggered, must, under normal circumstances, be disposed of appropriately. All wastes generated from the deployment of AFFF during a training and / or testing event should be appropriately contained by the tunnel drainage design for subsequent disposal, or channeled to a wastewater treatment plant (WWTP) and not directly into ground or surface waters. However, in the event of an emergency, there is the potential for AFFF to enter ground and surface waters without receiving proper treatment. For this reason, AFFF manufactures try to select ingredients that are not toxic to microorganisms.

All formulations of AFFF contain some combination of water, hydrocarbon-based surfactants and fluorinated surfactants (fluorosurfactants) (Robin 2001). While the majority of other chemicals used to manufacture AFFF are biodegradable, fluorosurfactants are only partially biodegradable (Ansul Inc. 1997). However, the remaining fluorine functional group is relatively unreactive and not believed to result in environmental harm (Ansul Inc. 1997; USN 2002).

DISCUSSION

Evaluation of the problem focused on three areas: 1) An evaluation of the treatability of AFFF fluids and / or their toxicity to aquatic organisms in the event of discharge, 2) An evaluation of the regulations that might affect the emergency discharge of AFFF to the environment, and 3) Current practice on the I-90 tunnels that utilize AFFF.

A separate evaluation (Attachment A) discusses the treatability and toxicity of AFFF fluids in the environment. Although all exhibit a significant Biological Oxygen Demand (BOD), the AFFF fluids are biodegradable in conventional wastewater treatment plants. Further, although some toxicity to specific species was noted, none of the compounds evaluated were found to be highly toxic to fresh water or marine species. However, if the fluids were discharged to an aquatic environment in the concentrations applied (3%), localized toxicity impacts could occur.

From a regulatory standpoint, regular process and stormwater discharges are subject to State Water Quality Standards. Emergency discharges however are permitted under WAC 173-201A-110, Short-term modifications (to the Water Quality Standards). Specifically, this section states, *"The criteria and special conditions established in WAC 173-201A-030 through 173-201A-140 may be modified for a specific body of water on a short-term basis when necessary to accommodate essential activities,* ***respond to emergencies, or otherwise protect public interest,*** *even though such activities may result in a temporary reduction of water quality conditions below those criteria and classifications established by the regulation." (Emphasis added).* However, despite the ability to discharge under emergency conditions, a Spill Prevention and Countermeasure Control (SPCC) Plan will likely be required during the permitting process to ensure that all known and reasonable practices are being implemented to contain an emergency flow. This Plan will have design implications that must be considered.

Several WSDOT and AWV team engineers, familiar with the I-90 tunnel designs and operation, were contacted to ascertain their current practice(s) with respect to the potential discharge of AFFF fluids to the environment during an emergency. It appears the systems differ somewhat between the Mt. Baker tunnel (Seattle) and the First Hill Lid (Mercer Island). Both systems utilize a combination sedimentation / oil-water separator tank (vault) to capture tunnel drains (normal stormwater and fire flows). The First Hill vaults discharge to Lake Washington; the Mt Baker vaults discharge to the City of Seattle sewer system. Therefore, during fire training events, the discharge of any AFFF from the Mt. Baker vaults eventually finds its way to a King County wastewater treatment plant, where it is treated and discharged. In the event of an actual fire (and the fire suppression system kicks in), Mt. Baker emergency procedures require that the sedimentation vault outlet valves be manually closed to prohibit the discharge of any spilled fuel in the tunnel from entering the sewer system. In this case, the vaults collect and hold the fire flow for subsequent removal or discharge. If the fire event flows exceeds the holding capacity of the vaults, they overflow to Lake Washington. Although the First Hill Lid vaults normally flow to Lake Washington, it is presumed they can be isolated during an actual fire event similar to the Mt Baker Tunnel vaults, however, this could not be confirmed during this limited investigation.

It should be noted that if a similar concept is adopted for the AWV project, the design of containment for potentially flammable liquids must be done by individuals with qualifications and experience in the field. All appropriate standards and safeguards must be adhered to.

An alternative that should be considered during detail design is the use of a self-extinguishing trench drain similar to those in use at SeaTac airport. The trench could be constructed using a modified trench former system and installed at the gutter line. The trench grade could be run at 0.5%, with spill collector manholes every 200 ft. to limit the spread of fire and facilitate cleanup after a fire. Each manhole would cascade into the next downstream section of the trench drain. Each 425 ft. of trench drain could hold approximately 10,000 gallons of fuel / foam / water mixture. Final connection would be to a storm drain system outside each end of the tunnel.

SUPPORTING COSTS

Based on the conclusions and recommendations below, there are no cost impacts over and above those already planned on for tunnel drainage collection and conveyance. Therefore, there are no supporting costs to be considered.

CONCLUSIONS/RECOMMENDATIONS

1. Based on past practices and the best engineering judgment, it is recommended that the AWV project should NOT consider treating fire flows and any AFFF discharges, but rather install a system similar to that found at the I-90 Mt. Baker Tunnel.

2. As is currently being planned, AWV tunnel drains should be collected in a vault or catch basin that can be routed, or pumped, to the City sewer system. This will provide for the treatment of AFFF flows (at the West Point Treatment Plant) from routine, planned fire training events.

3. In the event of a fire, due to the potential for a discharge of spilled fuel, operational procedures or automatic controls (preferable) must be in place to valve out, or otherwise isolate the AWV tunnel drain collection system from the City sewer system. Flammable fluids must never enter the City sewer system.

4. The drain collection system must have sufficient capacity to hold a nominal fire flow, or spill volume for subsequent disposal or discharge, and provide for an emergency by-pass to Elliott Bay.

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Attachment A

Evaluation of Toxicity of Aqueous Fill Forming Foam (AFFF) Liquid Concentrate Ingredients Towards Aquatic Organisms

BACKGROUND

The Federal Highway Administration (FHWA), the Washington State Department of Transportation (WSDOT), and the City of Seattle (City) have proposed making major improvements to the Alaskan Way Viaduct Corridor and to the Alaskan Way Seawall. Located in the downtown Seattle area of King County, Washington, the Alaskan Way Viaduct Corridor extends from approximately Spokane Street on the south to north of the Battery Street Tunnel. The Alaskan Way Seawall extends from South Washington Street to Bay Street along Elliot bay on Puget Sound. These improvements are required as both the Viaduct and Seawall are at the end of their useful life, and are necessary to protect public safety and maintain the transportation corridor.

As part of these improvements, it has been proposed that the portion of the Alaskan Way Viaduct running along the waterfront be routed through an underground tunnel. Routing traffic through a tunnel presents a special hazard if a vehicle or truck transporting flammable hydrocarbons should be involved in an incident resulting in a fire. To address this possibility, the proposed tunnel will be constructed with a fire suppression system that has heat sensors located throughout its length. If a heat sensor is triggered it will initiate a tunnel closure and the release of a fire suppression agent. The most common fire suppression agent used in such commuter tunnels is a 3% aqueous film forming foam (AFFF). The AFFF is purchased as a concentrate that is held in airtight storage tanks until needed. If the Fire Suppression System is triggered, the concentrate will be mixed with water to achieve a mixture containing 3% of the AFFF concentrate before its release.

PROBLEM STATEMENT

The release of AFFF fire suppression foam generates process waters that must be disposed of appropriately. All waste generated from the deployment of AFFF should be channeled to a wastewater treatment plant (WWTP) and not directly into ground or surface waters. However, there is the potential for AFFF to enter ground and surface waters without receiving proper treatment. Even if properly disposed of there is a potential for AFFF to upset the balance of biodegradation mechanisms in WWTPs (USN 2002). For this reason, AFFF manufactures try to select ingredients that are not toxic to microorganisms that are necessary for biological sewage treatment (Ansul Inc. 1997).

Additionally, the AFFF must not have too high of a BOD because the rapid reduction of oxygen in the aquatic environment can potential harm aquatic organisms and will impair the microorganisms that degrade AFFFs.

All formulations of AFFF contain some combination of water, hydrocarbon-based surfactants and fluorinated surfactants (fluorosurfactants) (Robin 2001). While the majority of other chemicals used to manufacture AFFF are biodegradable, fluorosurfactants are only partially biodegradable (Ansul Inc. 1997). However, the remaining fluorine functional group is relatively unreactive and not believed to result in environmental harm (Ansul Inc. 1997; USN 2002). In spite of this, 3M voluntarily removed its brand of AFFF, Light Water, from the market due to concerns regarding presence of perfluorooctane sulfonate in human blood samples. Differences in the manufacturing process of perfluorooctanesulfonyl derivatives produced by other manufactures has resulted in fluorosurfactans that are not retained in the blood stream but are instead expelled through the tissue walls and out of the lungs during respiration (Weber, 2000). Regardless, the fluorosurfactants are persistent in the environment, and there is uncertainty regarding the potential of these compounds to result in direct or indirect toxicity.

Aqueous film forming foams manufactured by two different companies are being considered for use in the fire suppression system that would be installed in the Alaskan Way Viaduct tunnel. One of the companies is National Foam that manufactures Aer-O-Lite 3% and the other company is AMEREX Corporation that manufactures various brands of AFFF 3% foam concentrate. This memo reports the results of an evaluation of the ingredients in each of these AFFFs made to determine which of these products poses the least risk to the environment if it is released to Puget Sound without receiving proper treatment.

METHODS

The MSDS of each product was consulted to determine the active ingredients in each AFFF product. An AQUIRE (**AQU**atic toxicity **I**nformation **RE**trieval) database search was conducted on each of the listed ingredients. The AQUIRE database was established by the USEPA in 1981, and contains information (e.g., toxicity data) on lethal and sublethal effect concentrations for aquatic organisms, including freshwater and marine plant and animal species. The majority of the toxicity data reported was published between 1970 and the present. Priority is given to data published in peer-reviewed literature, but theses and dissertations, government reports and other “gray” literature were included as well. Lastly, computerized laboratory data files from the public sector and available unpublished reports have also been included and critiqued in the AQUIRE database. Additionally, an internet search was conducted inquiring how other agencies select the AFFF employed in their facilities.

DATA ORGANIZATION

The remainder of this memo describes the characteristics of National Foam and AMEREX Corporation AFFF 3% concentrates. Each section highlights the properties and ingredients used in each of these AFFFs. Information on the reasoning behind the selection of AFFF used by other organizations is grouped as 'General AFFF Requirements' and is discussed in the final section of this report. All of the information described in the following sections is summarized in a chemical toxicity summary table (Table 2).

NATIONAL FOAM

National Foam manufactures the AFFF, Aer-O-Lite 3%, for use in the suppression and extinguishing of hydrocarbon fuel fires. It can be used in fire suppression systems and manually to extinguish fires involving fuels such as crude oil, gasoline, and fuel oils. The Aer-O-Lite 3% AFFF contains in addition to water, 1,2-propanediol, (2-methoxymethylethoxy) propanol, a mixture of synthetic detergents and a fluoroalkyl surfactant. While this product is biodegradable, National Foam states it should not be directly discharged onto the ground or into surface waters or storm drains. Rather, it should be subjected to treatment by a biological sewage treatment system before being discharged. An AQUIRE search was conducted on 1,2 propanediol and (2-methoxymethylethoxy)propanol. As the synthetic detergents are a proprietary mixture and the fluoroaklyl surfactant is a confidential constituent, no specific information could be identified regarding the aquatic toxicity of these compounds.

AMEREX CORPORATION

AMEREX Corporation produces a 3% aqueous fill forming foam product that is used to extinguish fires involving hydrocarbon fuels. AMEREX's 3% AFFF product contains in addition to water, 2-(2-butoxyethoxy) ethanol, triethanolamine, methyl-1 H-benzotriazole, and a mixture of alkyl sulfate salts, amphoteric fluoroalkylamide, and perfluoroalkyl sulfonate salts. AMEREX states this product should not be directly discharged into ground or surface waters or storm drains with out treatment at a permitted facility or as advised by a local hazardous waste regulatory authority. An AQUIRE search was conducted on 2-(2-butoxyethoxy) ethanol, triethanolamine and methyl-1 H-benzotriazole. The mixture alkyl sulfate salts, amphoteric fluoroalkylamide, and perfluoroalkyl sulfonate salts is a proprietary mixture; therefore, no information was available regarding their aquatic toxicity.

GENERAL AFFF REQUIREMENTS

The National Fire Protection Association (NFPA) Code 11 lists the requirements of AFFF used for fire suppression. The Department of Defense (DOD) is one of the world's largest consumers of AFFF for suppressing combustible/flammable liquid fuel fires (USN 2002). The Navy's chemical and physical requirements used to determine if an AFFF meets the combined fire protection and environmental needs are presented in Table 1. When selecting an appropriate AFFF the United States Navy has specific chemical and physical requirements based on NFPA 11 that an AFFF must conform to (Tatem et al., 2001).

Table 1: Chemical and Physical Requirements for Concentrates or Solutions

Requirements	Pass/Fail Criteria
Refractive index, minimum	1.358
Viscosity (Centistoke) Maximum @ 5°C Minimum @ 25°C	 10 2
Hydrogen Ion Concentration (pH)	7.0 to 8.5
Spreading Coefficient, dynes/cm, minimum	3
Film Formation and Sealability	No sustained ignition
Foamability: Foam Expansion Ratio, minimum Fresh Agent Test: Fresh Water / Sea Water Stability Test, concentrate: Fresh Water / Sea Water Compatibility Tests: Fresh Water / Sea Water Foam 25% Drainage Time, minutes, minimum Fresh Agent Test: Fresh Water / Sea Water Stability Test, concentrate: Fresh Water / Sea Water Stability Test, solution: Fresh Water / Sea Water Compatibility Tests: Fresh Water / Sea Water	 5.0 - - - 2.5 - - -

Table 1 (Continued)

Requirements	Pass/Fail Criteria
Corrosion Rate: General Cold rolled. Low carbon steel mili in/yr, maximum Copper-Nickel (90-10) mili in/yr, maximum Bronze, milligrams maximum Localized, corrosion-resistant (CRES) steel	 1.5 1.0 100 No pits
Total Halides, ppm maximum	250
Dry chemical compatibility, burn-back resistance time 360 seconds minimum	360
Environmental impact: Toxicity, LC50, mg/L, minimum COD, mg/L, maximum BOD/COD minimum	 1,000 $5x10^5$ 0.65
Fluorine content, mg/L	No value
Stratification: Stability Test Compatibility Test	None None
Precipitation, % by Volume: Stability Test 1:1 Ratio Mixes All agent Mix	- - -
Container cap opening torque (average)	50 in-lbs max

Taken from Tatem et al. 2001

RESULTS/DISCUSSION

Results of the AQUIRE search are presented in Table 2. Toxicity information was only available for triethanolamine (CAS # 102-71-6), 2-(2-butoxyethoxy) ethanol (CAS # 112-34-5), and propylene glycol (CAS # 57-55-6). No information was available regarding toxicity testing conducted using (2-methoxymethylethoxy) propanol (CAS # 34590-94-8) or methyl-1 H-benzotriazole (CAS # 29385-43-1). Overall, the majority of the toxicity test results were for tests conducted with freshwater species, and very few test results were available for salmonid species.

Table 2: Summary of AQUIRE search results

Constituent	Species Tested	Test Type	Endpoint	Concentration[a] (µg/L)
Triethanolamine	*Daphnia magna*	Chronic	NOEC	16000
	Entosiphon sulcatum	Chronic	EC	56000
	Scenedesmus subspicatus	Chronic	EC50	593717
	Uronema parduczi	Chronic	EC	>10,000,000
	Ceriodaphnia dubia	Acute	EC50	609,980
	Daphnia magna	Acute	EC50	1,683,098
	Carassius auratus	Acute	EC50	>5,000,000
	Pimephales promelas	Acute	LC50	11,800,000
2-(2-Butoxyethoxy)ethanol	*Uronema parduczi*	Chronic	EC	420,000
	Tetrahymena thermophila	Chronic	EC	974,986
	Lepomis macrochirus	Acute	LC50	1,300,000
	Leuciscus idus melanotus	Acute	EC	1,887,701
	Carassius auratus	Acute	LC50	2,700,000
	Daphnia magna	Acute	LC50	2,850,000
1,2-Propanediol	*Pimephales promelas*	Chronic	NOEC	1,369,500
	Artemia salina	Acute	NOEC	>10,000,000
	Oryzias latipes	Acute	LC50	>1,000,000
	Ceriodaphnia dubia	Acute	NOEC	2,931,416
	Ceriodaphnia dubia	Acute	LC50	4,325,136
	Carassius auratus	Acute	LC50	>5,000,000
	Pimephales promelas	Acute	NOEC	5,635,424
	Pimephales promelas	Acute	LC50	6,636,200
	Daphnia magna	Acute	EC50	>10,000,000
	Oncorhynchus mykiss	Acute	EC	47,740,968

Table 2 (Continued)

Constituent	Species Tested	Test Type	Endpoint	Concentration[a] (µg/L)
(2-Methoxymethylethoxy) propanol	No Data			
Methyl-1 H-benzotriazole	No Data			

[a] Geometric mean of the data available in the AQUIRE database.

NOEC = No observed effect concentration

LC50 = Lethal concentration 50 percent (concentration at which 50% of test organisms die)

EC50 = Effect concentration 50 percent (concentration at which 50% of test organisms demonstrate an effect)

EC = Effect concentration (concentration at which a significant effect is observed)

None of the compounds were found to be highly toxic to fresh water or marine species (Table 2). The most toxic compound was triethanolamine having a significant effect on the population of *Entosiphon sulcatum* (a flagellate euglenoid) at 56,000 µg/L and an EC50 of 593,717 µg/L for *Scenedesmus subspicatus* (green algae). The waterflea, *Ceriodaphnia dubia*, were the most sensitive invertebrate species with an LC50 of 609,980 µg/L. *Pimephales promelas* was the only vertebrate species with available toxicity information and had an LC50 of 11,800,000 µg/L. The initial concentration of AFFF in the discharge is 30,000,000 ug/L and these compounds could be present at concentrations 7,500,000 to 300,000 ug/L. Therefore, there is a potential for AFFF to have localized impact on organism in a water body receiving untreated AFFF runoff.

The next most toxic compound was 2-(2-butoxyethoxy) ethanol. Chronic tests conducted using freshwater ciliated protozoans found 2-(2-butoxyethoxy) ethanol had a significant effect on the population growth of *Uronema parduczi* at 420,000 µg/L and on the population growth of *Tetrahymena thermophila* at 974,985 µg/L. The vertebrate *Lepomis macrochirus* was the most sensitive animal species with an LC50 of 1,300,000 µg/L. *Daphnia magna*, with an LC50 of 2,850,000 µg/L, was the least sensitive species tested.

The least toxic of these compounds is 1,2-propanediol. This was the only compound that had test results using a saltwater species. Test results using *Artemia salina* found there was no effect on survival at 10,000,000 µg/L. *Ceriodaphnia dubia* was the most sensitive species tested with a NOEC and LC50 for survival of 2,931,416 µg/L and 4,325,136 µg/L, respectively. *Oncorhynchus mykiss* was the least sensitive species tested with propylene glycol having a significant effect on survival at 47,740,968 µg/L.

The initial concentration of AFFF in the discharge from the fire suppression system is 30,000,000 ug/L and the compounds tested above could be present at concentrations between 300,000 and 7,500,000 ug/L. Therefore, there is a potential for AFFF to have localized impact on organisms in a water body receiving untreated AFFF runoff.

The greatest environmental hazard AFFF presents to the aquatic environment is a high biological oxygen demand (BOD) and chemical oxygen demand (COD). The high oxygen demand is due to the presence of synthetic detergents mixtures, and the various fluoroalkyl surfactant salts in AFFFs. The five-day BODs for Aer-O-Lite 3% concentrate and 3% solution are 239,000 mg/kg and 8,750 mg/kg, respectively, and the COD of the concentrate is 400,000 mg/kg. Though no information was available regarding the BOD and COD of AMEREX AFFF product, as this product contains surfactants it will likely also have a similarly high BOD and COD.

Based on the results of the AQUIRE search Aer-O-Lite 3% is the better choice of AFFF based on environmental concerns. The main ingredients in Aer-O-Lite 3% are 1,2-propanediol and (2-methoxymethylethoxy) propanol. While no information was available on (2-methoxymethylethoxy) propanol toxicity in the AQUIRE database, 1,2-propanediol was the least toxic of the substances with AQUIRE information. While Aer-

O-Lite 3% has a high COD and BOD, the values are still below the criteria established by the US Navy (see Table 1). The LC50 of 1,2-propanediol is below the 1000 mg/L value set by the US Navy. A general internet search did not find any additional information on the toxicity of (2-methoxymethylethoxy) propanol or methyl-1 H-benzotriazole.

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