3.0 Compliance Monitoring

The MTCA requires three types of compliance monitoring to be performed in order to confirm the adequacy of the remedial action (WAC 173-340-410). These include protection monitoring, performance monitoring, and confirmational monitoring. The compliance monitoring performed during the Duwamish/Diagonal Sediment Remediation project is discussed in this section. The KCDNRP produced two sampling and analysis plans in October 2003 which describe the water quality monitoring activities and the sediment monitoring activities. These two plans (KCDNRP 2003a and 2003b) are included in Appendices F and G and should be consulted for the details of the sampling design and procedures used to collect the compliance monitoring samples. Ecology approved the cleanup project in 2001 under MTCA, but when the lower Duwamish was listed as a Superfund site in September 2001, EPA began reviewing project plans and monitoring for consistency with Superfund requirements.

3.1 PROTECTION MONITORING

Protection monitoring is performed to confirm that human health and the environment are adequately protected during construction of the cleanup action as described in the project's specific safety and health plan (WAC 173-340-410(a)). No deviations from the contractor's health and safety plan were reported or observed.

Water quality monitoring of the Duwamish River was required in several permits, including the Hydraulic Project Approval permit, issued by the Washington Department of Fish and Wildlife to protect the environment. Details of the water quality monitoring were included in both EPA and Ecology comments on the Nationwide 38 permit issued by the U.S. Army Corps of Engineers. Additionally, water quality monitoring was required as part of the Biological Opinion issued jointly by NMFS and the USFWS.

3.1.1 Water Quality Monitoring During Dredging

Water quality monitoring was performed in accordance with the approved *Water Quality Monitoring Sampling and Analysis Plan* (KCDNRP 2003a). Sampling occurred twice daily when dredging operations occurred during both tidal events. One sampling event was during the flood tide and one during the ebb tide. If dredging operations only occurred during one tidal event, only one sample was collected. Three stations were monitored during each event. During the ebb tide, one station was located at the edge of the mixing zone, 300 feet downstream of the dredging operation; the second station was at the mid-point, 150 feet from the dredging operation; and the third station was the background or reference station located about 1600 feet upstream of the dredging operations so as to be outside of the influence of the operations. During the flood tide, the stations were reversed. An echo sounder (fish finder) was used to locate the center of the turbidity plume at the given sampling radius of 150 feet and 300 feet to ensure that the plume, if present, was sampled. Once the plume was located with the fish finder, a field instrument was lowered to identify the depth with the highest turbidity so that the grab sample would collect the water with the highest turbidity.

Field measurements taken at each sampling location either just prior to or just after grab samples were collected for chemical analysis. A Hydrolab MiniSonde® was used to collect field data, including surface water temperature, pH, turbidity, specific conductance, salinity, and dissolved oxygen. Water grab samples were collected using two 10 liter Niskin bottles hung on a hydro wire. The samples were collected 90 centimeters (cm) above the bottom and 60 cm below the surface at each location. The water samples were transferred from the Niskin bottles to sample bottles and stored in coolers until transferred to the laboratory for analysis. All water samples collected during the entire period of dredging were tested in the laboratory for turbidity.

As defined in the monitoring plan, the chemical testing of water samples focused on the first week of dredging and was stopped after 8 days of testing because all samples measured at the edge of the mixing zone (300 feet downstream) were well below the water quality standards (less than 1 to 2 percent of standard). The water samples selected for chemical analysis each day were the ones that were collected when the highest turbidity conditions were observed based on field turbidity measurements. These water samples were analyzed for total suspended solids (TSS), salinity, turbidity, mercury, PAHs, phthalates, and PCBs in accordance with the monitoring plan. A complete listing of all results of the field data and analytical data are provided in Appendix D, including water chemistry.

A summary of the field and laboratory turbidity data measured at the edge of the mixing zone (300 feet downstream) during dredging are listed in Table 1. These two different turbidity values did not agree for several reasons. Even though the field turbidity sensor was suspended below the Niskin bottle, the turbidity plumes are highly variable and even a small distance can result in a large variation of the data. Also, when water from the Niskin bottle was tested with the field turbidity instrument, the numeric value provided by the field instrument was different than the turbidity value determined in the lab for water in the Niskin bottle. Only the laboratory turbidity values were used for official comparison to water quality standards.

Table 1 provides a comparison to the water quality standard for the turbidity values measured at the edge of the mixing zone in nephelometric turbidity units (NTUs) to the maximum calculated turbidity standard (MCTS), which is the reference station turbidity background plus 10 NTUs. The MCTS is different for each measurement, because of the variation of the background measurement. For ease of evaluation, Table 1 contains a row of values that shows the total exceedance amount (in NTUs), if applicable. Approximately 20 percent (22 of 119) of all measurements were out of compliance and a significant number of these occurred in the first 2 weeks of operations and are primarily located at the bottom sampling location. All the turbidity data are presented in Appendix D. Samples with the greatest exceedance occurred in the first few days, on November 14 and 17, 2003 with exceedances of 22, 28.3, 18.7, and 15.7 NTUs, respectively. Also, when the trial bucket was used on November 25, 2003, the exceedance was 25.3 NTU above the MCTS value of 11.1 NTU.

Table 1
Water Sample Turbidity Results During Dredging

Date	Parameter	Flood Tide						Ebb Tide			
		Surface		Bottom		Surface 2		Surface		Bottom	
Friday, November 14, 2003	Lab/Field	6.5	15.1	9.6	3.1			11.6	38.3	32.6	29.5
	MCTS	16.4		10.9				15.6		10.6	
	Exceedance	None		None				None		22	
Monday, November 17, 2003	Lab/Field	3.7	12.1	39.1	35.6			31.3	66.7	27	72.5
	MCTS	12.5		10.8				12.6		11.3	
	Exceedance	None		28.3				18.7		15.7	
Thursday, November 20, 2003	Lab/Field	18	34.1	3.6	4.7						
	MCTS	28.3		11.5							
	Exceedance	None		None							
Friday, November 21, 2003	Lab/Field	9.7	17.5	5.2	27	9.2	15.6				
	MCTS	14.7		11.4		14.7					
	Exceedance	None		None		None					
Tuesday, November 25, 2003	Lab/Field	3.4	4	36.4	54.5	12.3	21.7	7.5	12.8	15.8	23.1
	MCTS	13.3		11.1		13.3		11.9		11.1	
	Exceedance	None		25.3		None		None		4.7	
Wednesday, November 26, 2003	Lab/Field	2.6	4.1	1	1.5	3.2	4.8				
	MCTS	12.5		10.8		12.5					
	Exceedance	None		None		None					
Tuesday, December 02, 2003	Lab/Field	12	24.4	14	12.5	12	25.6	9.2	17.3	10.4	20.5
	MCTS	21.5		11.6		21.5		18.5		12.7	
	Exceedance	None		2.4		None		None		None	
Wednesday, December 03, 2003	Lab/Field	6.6	15.6	4.5	6.1	7.8	17.1	5.5	11.7	2.4	5
	MCTS	17.2		12.9		17.2		15.1		12.4	
	Exceedance	None		None		None		None		None	
Thursday, December 04, 2003	Lab/Field	4.4	7.6	15.3	26.6						
	MCTS	14.9		11.3							
	Exceedance	None		4							
Friday, December 05, 2003	Lab/Field	4.2	7.7	9.1	14.5	16.8	26.1				
	MCTS	14.7		11.4		14.7					
	Exceedance	None		None		2.1					
Monday, December 08, 2003	Lab/Field	11.4	5.2	3.1	20.6	4.3	7.5	4.1	6.1	1.3	2.1
	MCTS	14.2		11.3		14.2		13.7		24.7	
	Exceedance	None		None		None		None		None	
Tuesday, December 09, 2003	Lab/Field							2.4	4	4.1	7.3
	MCTS							12.2		11.4	
	Exceedance							None		None	
Wednesday, December 10, 2003	Lab/Field							2.7	4	2.6	10.4
	MCTS							12.7		11.2	
	Exceedance							None		None	

Table 1
Water Sample Turbidity Results During Dredging

Date	Parameter	Flood Tide						Ebb Tide			
		Surface		Bottom		Surface 2		Surface		Bottom	
Thursday, December 11, 2003	Lab/Field	3.8	5.1	2.7	28.5	5.3	5.5	2.8	3.6	6.6	10
	MCTS	13.5		12.9		13.5		12.4		11.1	
	Exceedance	None		None		None		None		None	
Friday, December 12, 2003	Lab/Field	3.4	5.1	10	14.8	4.3	6.7				
	MCTS	14.4		11.5		14.4					
	Exceedance	None		None		None					
Saturday, December 13, 2003	Lab/Field							3.6	5.6	13.1	10.3
	MCTS							12.7		11.6	
	Exceedance							None		1.5	
Monday, December 15, 2003	Lab/Field	3.7	6.1	38	41.9	8	7.7	5.2	7.2	29.4	39
	MCTS	14		11.2		14		13.6		12	
	Exceedance	None		26.8		None		None		17.4	
Tuesday, December 16, 2003	Lab/Field	3.1	5.3	7.3	17	3.8	26.9	3.5	7.6	3.8	12.4
	MCTS	13.3		11.4		13.3		13.5		15.3	
	Exceedance	None		None		None		None		None	
Wednesday, December 17, 2003	Lab/Field	3.5	4.8	2.3	8.6	9.54	12.6	5.5	23.7	5.2	6.4
	MCTS	13.1		11.4		13.1		12.5		13.2	
	Exceedance	None		None		None		None		None	
Thursday, December 18, 2003	Lab/Field	2.3	4	10.8	18.9	8	14.4				
	MCTS	15.9		11.4		15.9					
	Exceedance	None		None		None					
Friday, December 19, 2003	Lab/Field	2	3.8	8.6	14.5	14.3	9.5				
	MCTS	15.5		11.5		15.5					
	Exceedance	None		None		None					
Thursday, January 08, 2004	Reference	5.5	10.9	1.9	2.4	5.5	10.9	6.2	8.4	1.8	6.4
	Lab/Field	6	8.6	29.7	37.6	8.66	13.3	7.6	10.1	6.3	3.4
	MCTS	15.5		11.9		15.5		16.2		11.8	
	Exceedance	None		17.8		None		None		None	
Friday, January 09, 2004	Lab/Field	3.9	7	34.9	46.8	5.3		3.7	6.5	3	7.6
	MCTS	16.9		11.3		16.9		14.2		12.3	
	Exceedance	None		23.6		None		None		None	
Saturday, January 10, 2004	Lab/Field	5.3	8.2	14	26.3	5.7		5.8	11.3	16.1	13.5
	MCTS	17.6		11.4		17.6		11.9		15.9	
	Exceedance	None		2.6		None		None		0.2	
Sunday, January 11, 2004	Lab/Field							3.9	9.6	9.4	15.1
	MCTS							13.7		11.3	
	Exceedance							None		None	
Monday, January 12, 2004	Lab/Field							3.5	8.6	24	20.2
	MCTS							12.5		12	
	Exceedance							None		12	

Table 1
Water Sample Turbidity Results During Dredging

Date	Parameter	Flood Tide						Ebb Tide			
		Surface		Bottom		Surface 2		Surface		Bottom	
Tuesday, January 13, 2004	Lab/Field							3.6	5.3	6.6	16.3
	MCTS							12.9		11.9	
	Exceedance							None		None	
Wednesday, January 14, 2004	Lab/Field	3.5	6.8	25.3	11.5	4.83	10.9	23	11.3	24.2	31.5
	MCTS	14.1		11.2		14.1		13.2		13.2	
	Exceedance	None		14.1		None		9.8		11	
Thursday, January 15, 2004	Lab/Field	12.3	27	2.5	3.1	8.9	29.5	12.8	25	2.6	4.5
	MCTS	16.1		10.8		16.1		14.9		12.5	
	Exceedance	None		None		None		None		None	
Saturday, January 17, 2004	Lab/Field							5.7	12.8	14.4	30.1
	MCTS							15.6		10.8	
	Exceedance							None		3.6	
Sunday, January 18, 2004	Lab/Field	5.1	11.5	10.1	48.7	6.22	18.6	4.6	9.4	2.6	8
	MCTS	16.1		10.7		16.1		14		12.2	
	Exceedance	None		None		None		None		None	
Monday, January 19, 2004	Lab/Field	4.5	7.9	16.2	25.5	4.7	11.4				
	MCTS	15.7		10.5		15.7					
	Exceedance	None		5.7		None					
Tuesday, January 20, 2004	Lab/Field							4.5	10.7	1.9	5.3
	MCTS							13.7		11.7	
	Exceedance							None		None	

Notes: Laboratory and field data reported in NTU.
Surface 2 is a sample collected downstream during the flood tide.
MCTS = Maximum Calculated Turbidity Standard, and is the background concentration plus 10 NTU.
Exceedance = Lab Value - MCTS

The first 5 days of dredge monitoring reports extend over a period of 3 work weeks from Friday, November 14 to Tuesday, November 25, 2003. During this time period, many complaints were logged about the poor dredging practices by various observers including the King County inspector. The most obvious problems were over-filling the dredge bucket and spilling material out of the bucket as it was moved to and from the barge. Initially, the King County inspector was not scheduled to stay permanently at the site, but after King County observed dredging problems on the second day (November 17, 2003), King County determined they needed to use a full time inspector to monitor the contractor. Also, King County directed the contractor to implement the BMPs outlined in their Dredging and Disposal Plan and subsequently specified the dredging rate be reduced to 8 hours to fill one barge instead of the 2.5 to 4 hours that had been the practice to date. Additionally, overfilling the dredge bucket was further discouraged by requiring the contractor to stop dredging for 5 minutes if multiple overfilled buckets occurred. During site visits and meetings with the dredging contractor on November 18 and November 25, 2003, EPA stressed the importance of implementing these BMP in order to address the exceedances of water quality criteria for turbidity. On November 25, 2003, the contractor tried using an 18-cy bucket, without digging teeth, but this produced high turbidity values.

A complete listing of all chemical results from water grab samples that were submitted for analysis is included in Appendix D. Compliance with water quality standards focused on the same four COCs that were identified in the *Draft Cleanup Study Report* (EBDRP 2001), mercury, PCBs, bis(2-ethylhexyl)phthalate, and butyl benzyl phthalate. Because numerical water quality standards exist only for mercury and PCBs, Table 2 includes a comparison with water quality values for only these two chemicals. For both mercury and PCBs, most of the measurements were less than the respective detection limits (0.005 µg/liter(l) for mercury and 0.47 µg/l for PCBs), and for both chemicals the detection limits were less then 1 percent of the respective water quality standard. In the two samples where mercury was detected, both values (0.007 and 0.0083 µg/l) were below the reliable limit for quantification and were less then 1 percent of the water quality standard value of 1.8 µg/l. The highest PCB value (0.216 µg/l on November 17, 2003) occurred along with one of the higher turbidity values on the second day, but the PCB value was only 2 percent of the water quality standard value of 10 µg/l. The chemistry data show that even when turbidity values were at their highest, the mercury and PCB concentrations in the water column were far below the water quality standard values, and this is also true for the other chemicals measured.

Table 2
Water Sample Chemistry Results During Dredging

Sample Date and Location	Turbidity NTU	Dissolved Mercury µg/l	Mercury % of Standard (1.8 µg/l)	Total PCB µg/l	PCB % of Standard (10 µg/l)
11/14 S	11.6	<.005	<1	<.048	<1
11/14 B	32.6	<.005	<1	.048*	<1
11/17 S	31.3	<.005	<1	.16	2
11/17 B	27.0	<.005	<1	.216	2
11/20 S	18.0	<.005	<1	<.047	<1
11/20 B	3.6	<.005	<1	<.047	<1
11/21 S	9.7	<.005	<1	<.047	<1
11/21 B	5.2	<.005	<1	<.047	<1
11/21 S-2	9.2	<.005	<1	<.047	<1
11/25 S	3.4	<.005	<1	<.048	<1
11/25 B	36.4	<.005	<1	<.047	<1
11/25 S-2	12.3	<.005	<1	.048	<1
11/26 S	2.6	<.005	<1	<.047	<1
11/26 B	1.0	<.005	<1	<.047	<1
11/26 S-2	3.2	<.005	<1	<.047	<1
12/2 S	9.2	<.005	<1	<.047	<1
12/2 B	10.4	.0083*	<1	.052*	<1
12/3 S	5.5	<.005	<1	<.047	<1
12/3 B	2.4	.007*	<1	<.047	<1

* = Value below reliable detection limit for quantification.
S = Surface
B = Bottom

Widespread concern about reported problems at the start of dredging resulted in increased inspection and monitoring throughout the project. NMFS trustees hired Ridolfi as an independent inspector to monitor dredging and provided verbal and written reports. Citizens also monitored activities on a regular basis and reported concerns to regulatory agencies and King County. EPA approved King County's request to conclude water quality monitoring for COCs after 1 week of monitoring, as outlined in the sampling and analysis plan (sampled for the first 8 days of dredging). Data from COC monitoring showed that mercury and PCB values were well below numeric water quality standards even at the highest turbidity values tested. However, King County had to abandon their plans to only monitor turbidity during the first week of dredging because no compliance was demonstrated for turbidity in 1 week. EPA told King County to continue monitoring turbidity on all days of dredging and report the results for timely review. King County tried to use field turbidity measurements to provide the contractor with directions on a real time basis, but found the field turbidity measurements were unreliable because they did not agree or correlate with the laboratory turbidity measurements.

3.1.2 Water Quality Monitoring During Capping

No water sample was collected on January 23 (first day of capping) because work stopped early due to problems with the WINOPS system. Turbidity values taken during the first 7 full days of capping are listed in Table 3 and extend over a period of 2 work weeks. Of the 23 samples collected, two exceeded the turbidity standard, but one value was only slightly above the standard. The one high value occurred the fifth day of capping (January 29) with an exceedance of 63 NTU at the bottom sample. The contractor was notified about the increased turbidity value and was directed to place material with minimum bottom disturbance or King County would need to continue monitoring turbidity during the entire capping process. The contractor and the King County inspector both noted that a large rainstorm occurred on January 29 resulting in a large volume of brown stormwater discharging out the 12-foot-diameter Diagonal CSO/SD outfall. Because this discharge was into the area that had been dredged and not capped, it could have caused some erosion of bottom sediment that partially contributed to the high turbidity value, even at the bottom sample. EPA notified King County that water quality monitoring could be stopped after the planned 7 days of sampling. However, King County inspectors still continued to monitor capping work until completion.

Table 3
Water Sample Turbidity Results During Capping

Date	Parameter	Flood Tide						Ebb Tide			
		Surface		Bottom		Surface 2		Surface		Bottom	
Saturday, January 24, 2004	Lab/Field	5.5	10.3	5.5	10.7	5.47	12.8				
	MCTS	25.0		11.9		25.00					
	Exceedance	None		None		None					
Sunday, January 25, 2004	Lab/Field	4.8		5.9		7.9					
	MCTS	18.0		13.7		18.0					
	Exceedance	None		None		None					
Monday, January 26, 2004	Lab/Field							9.7	21.3	14.3	28.8
	MCTS							15.3		13.6	
	Exceedance							None		0.7	
Wednesday, January 28, 2004	Lab/Field	3.7	12.2	1.6	4.0	8.58	17.5	4.0	14.1	5.6	13.6
	MCTS	16.9		14.5		16.90		12.9		12.7	
	Exceedance	None		None		None		None		None	
Thursday, January 29, 2004	Lab/Field	5.4	9.3	75.5	137.3	18.6	40.9				
	MCTS	19.8		12.5		19.8					
	Exceedance	None		63.0		None					
Tuesday, February 03, 2004	Lab/Field							10.2	20.9	0.9	1.8
	MCTS							18.6		11.4	
	Exceedance							None		None	
Thursday, February 05, 2004	Lab/Field	6.8	6.7	10.6	3.2	9.7		9.31	16.4	1.3	4.1
	MCTS	18.2		12.6		18.2		19.50		11.1	
	Exceedance	None		None		None		None		None	

Notes: Laboratory and Field data reported in NTU.
Surface 2 is a sample collected downstream during the flood tide.
MCTS = Maximum calculated Turbidity Standard, and is the background concentration plus 10 NTU.
Exceedance = Lab value – MCTS

3.2 PERFORMANCE MONITORING

Performance monitoring is conducted to confirm that the cleanup action has attained cleanup standards or other performance standards (WAC 173-340-410 (b)).

3.2.1 Post-Dredge and Post-Cap Surveys

Throughout the dredging and capping operation, bottom surveys performed by the contractor were submitted to King County's project engineer and reviewed for compliance with the Contract Drawings. When all high spots identified by the contractor's surveys had been removed, a post-dredge survey was conducted by Blue Water Engineering to independently confirm the dredging results. The post-dredge survey showed that the contractor removed sediments to the minimum required elevations shown in the Contract Drawings and as described in the Technical Specifications. Similarly, the contractor's surveys were used to determine compliance with the Contract Drawings for each given layer of the cap. Due to the rapid turn-around requirements for each layer and/or part of the site, and because the contractor's surveys were in agreement with the independent surveys, the contractor's surveys were used to confirm that each cap material thickness was sufficient. These surveys showed that the cap layers were placed in accordance with the Contract Drawings and Technical Specifications. When all capping was complete, Blue Water Engineering performed an independent post-cap survey to confirm the final elevations of the area. Surveys are discussed further in Section 4.0 and are included in Appendix E.

3.2.2 Sampling and Analysis of Water From Dewatering Process

Water collected during the sediment dewatering process at the offloading facility was collected and stored in three 100,000 gallon tanks on site. Prior to the discharge of the accumulated water to the sanitary sewer system, it was treated by filtration through multiple granulated activated carbon filters and then tested. Samples were collected and analyzed for chemical and physical constituents required by the King County Industrial Waste Discharge Authorization issued to the off loading facility (see document for details).

The samples were analyzed for TSS, total PCBs, bis (2-ethylhexyl) phthalate, benzo(a)pyrene, and the following metals: arsenic, cadmium, chromium, copper, lead, nickel, silver, and zinc. Results from these analyses are provided in Table 4. No exceedances of discharge permit standards were identified in any of the samples, so the water was allowed to be discharged to the sewer. A total of about 2 million gallons of water was treated, tested, and discharged from mid-November 2003 to the end of January 2004, which also included the first week of the East Waterway Project. During the entire Duwamish/Diagonal project, a batch treatment and discharge approach was used, but during this period the offload facility was performing testing of their continuous discharge treatment system. Approval for continuous discharge was issued by King County Industrial Waste on January 21, 2004.

Table 4
Treated Water Sample Results From Dewatered Sediments (gallons per day)

Sample Date	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	PCB's* (µg/L)	Benz(a)pyrene (µg/L)	Bis-2-ethylhexylpthalate (µg/L)	Flow (GPD)
November											
24	0.14	0.002	0.005	0.003	0.02	0.01	0.006	ND	ND	ND	
25	0.17	0.002	0.005	0.003	0.02	0.01	0.006	ND	ND	ND	
26											40,000
28	0.05	0.002	0.05	0.005	0.02	0.01	0.025	ND	ND	ND	
December											
1	0.05	0.002	0.005	0.017	0.02	0.01	0.017	ND	1.0	11.6	
1	0.05	0.002	0.005	0.012	0.02	0.01	0.022	ND	1.0	2.8	
1	0.004	0.005	0.005	0.044	0.01	0.01	0.05	ND	1.0	1.0	
2								ND			76,900
3								ND			69,100
4								ND			150,000
5								ND	1.0	1.0	38,400
8	0.05	0.002	0.005	0.004	0.02	0.01	0.006	ND	ND	ND	95,200
9								ND	1.0	1.8	95,200
11								ND			85,400
12								ND	1.0	1.0	130,000
13											3,800
14											80,400
15											96800
16	0.05	0.002	0.005	0.002	0.02	0.01	0.006	ND			91,900
19								ND	ND	ND	
22	0.05	0.002	0.005	0.013	0.002	0.01	0.068	ND			
January											
2								ND			100,700
8								ND	ND	3	
9											109,800
10	0.05	0.002	0.005	0.007	0.02	0.01	0.014	ND			
12								ND	ND	ND	
13								ND			89,800
14								ND			129,400
15								ND			109,020
16											87,500
17											99,400

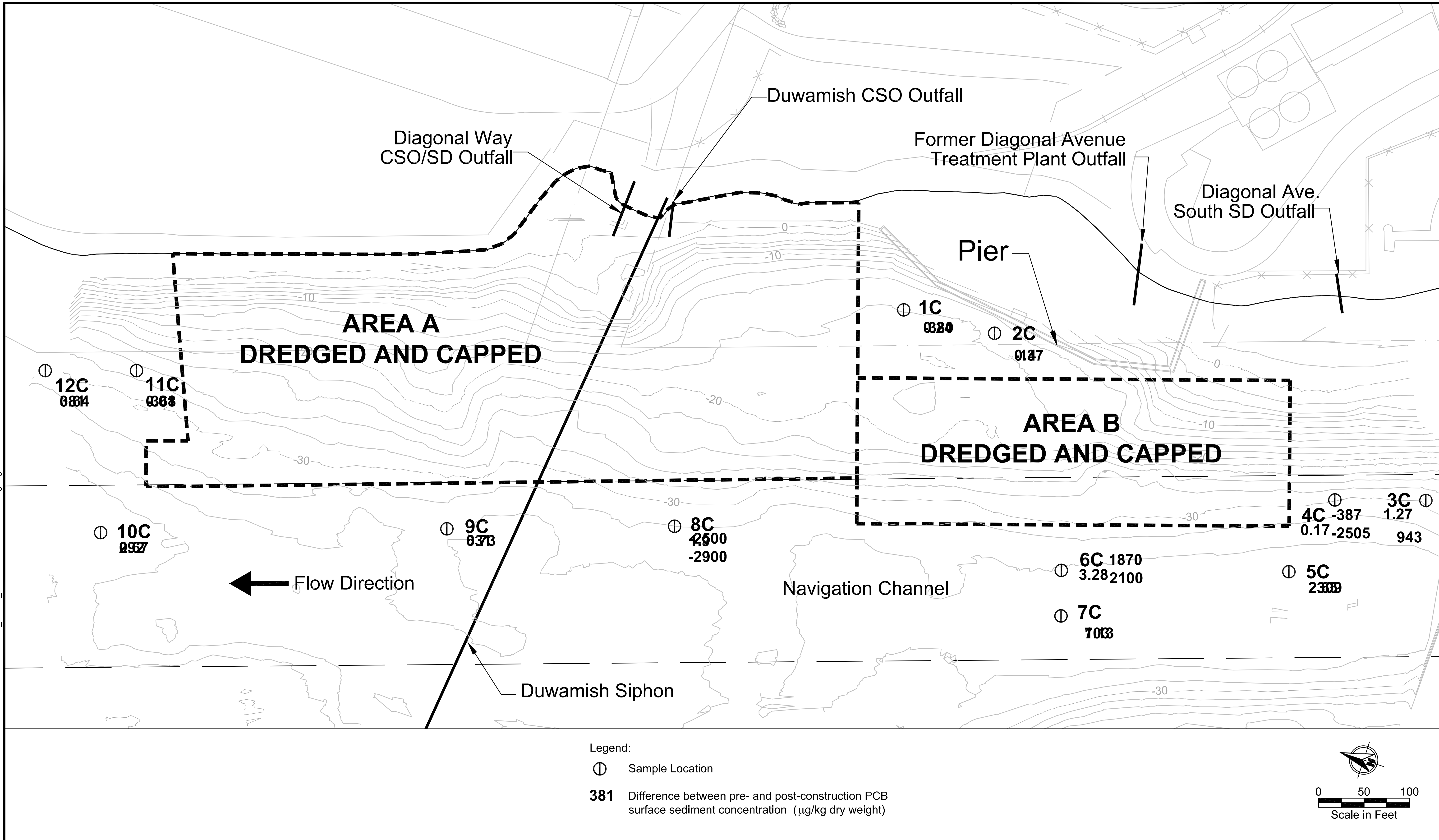
Table 4
Treated Water Sample Results From Dewatered Sediments (gallons per day)

Sample Date	Arsenic (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Lead (mg/L)	Nickel (mg/L)	Zinc (mg/L)	PCB's* (µg/L)	Benz(a)pyrene (µg/L)	Bis-2-ethylhexylpthalate (µg/L)	Flow (GPD)
18	0.05	0.002	0.005	0.007	0.02	0.01	0.0337	ND	ND	ND	93,200
23								ND			82,300
28								ND			95,800
29	0.05	0.002	0.009	0.019	0.02	0.0001	0.087	ND	ND	1.5	
29	0.05	0.002	0.006	0.004	0.02	0.0001	0.035	ND	ND	0.42	
30								0.094**			

ND = not detected
* Water Samples were analyzed for Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260.
**Aroclor 1254 was the only Aroclor detected.
See Appendix D for complete chemical results.

3.2.3 Sediment Sampling

When the *Sediment Monitoring Sampling and Analysis Plan* (KCDNRP 2003b; Appendix G) was prepared for the project, the regulatory agencies overseeing the monitoring activities (Ecology and EPA) required sediment sampling beyond the site boundary to document any changes in chemical concentrations of surface sediments due to dredge material moving beyond the site boundary. A total of 12 monitoring stations were established beyond the site boundary and sampled both before and after the project was implemented to document potential changes over time. Figure 8 shows that stations C1 through C12 were spaced upstream, downstream, inshore, and offshore of the dredge site and were generally either 50 feet or 150 feet from the boundary of the dredge prism, as requested by EPA. A discussion of the rationale for locating the 12 monitoring stations was included in the *Sediment Monitoring Sampling and Analysis Plan* (KCDNRP 2003b). In order to improve the reproducibility of chemical measurements at each monitoring station, 10 individual grab samples were collected at each monitoring station (instead of the usual 3). All 10 grabs were then combined into a single composite sediment sample for the station. To verify reproducibility of the 10 grab composite samples, field replicates were obtained at two stations before construction (4C and 8C) and three stations after construction (4C, 6C, and 8C).



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Duwamish/Diagonal Sediment Remediation Project

Post-Construction Changes in PCB Dry Weight Concentrations At Twelve Stations Beyond Site Boundary

Figure 8

3.2.3.1 Sediment Analyses

All sediment samples collected beyond the site boundary for before and after comparisons were submitted to the King County Environmental Laboratory for analysis of standard sediment characterization parameters (PCBs, base/neutral/acid extractable semi-volatiles (BNAs), chlorinated pesticides, mercury, metals, and the sediment conventional parameters of total organic carbon (TOC), total solids, and particle size distribution (PSD). The analytical methods used for various parameters are listed in Appendix D. All analyses were performed under QA1 guidance (Ecology 1989) per the methods described in the *Sediment Monitoring Sampling and Analysis Plan* (KCDNRP 2003b), and the resulting data underwent QA1 review. Based on this review, it was determined that for the before samples a third PCB aroclor (1260) could be quantified so revisions were made that resulted in final PCB values that were 12 to 44 percent larger then PCB values initially reported in draft documents (see QA reports for discussion). During QA review of the after samples, it was determined that quantification should be based on second column results, which had a higher standards recovery, so the PCB values were revised, but only a few stations had minor reductions compared to values reported in draft documents (maximum of 4 percent at station 10C; see QA reports for discussion). Results of the analyses are presented in Tables 5 and 6, and are discussed in the next section.

Table 5
Chemicals That Exceed SMS At 12 Stations Beyond Site Boundary
Before and After Construction

Stations	PCBs		BEHP		BBP		Mercury		Cadmium		Silver		1,4 DCB	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
DUD_1C	SQS	SQS	CSL	CSL		SQS								
DUD_2C	SQS	SQS	CSL	CSL		SQS								
DUD_3C	SQS	CSL	SQS	CSL		SQS								
DUD_4C	SQS	SQS												
DUD_4C Rep	CSL	CSL	SQS	CSL										
DUD_5C	SQS	CSL		CSL										
DUD_6C	CSL	CSL		CSL		SQS	SQS						CSL	
DUD_6C Rep		CSL		CSL		SQS								
DUD_7C	SQS	CSL	SQS	SQS		SQS								
DUD_8C	CSL	CSL	CSL	CSL		SQS	CSL							
DUD_8C Rep	CSL	CSL	CSL	CSL		SQS	CSL		SQS					
DUD_9C	SQS	CSL	SQS	CSL		SQS								
DUD_10C	SQS	CSL		SQS				CSL						
DUD_11C	SQS		CSL		SQS									
DUD_12C	SQS	CSL	SQS	CSL		SQS	SQS				CSL			
Stations>SQS	9>SQS	2>SQS	5>SQS	2>SQS	1>SQS	8>SQS	2>SQS		1>SQS					
Stations>CSL	3>CSL	9>CSL	4>CSL	9>CSL			1>CSL	1>CSL			1>CSL		1>CSL	

Table 6
Changes in PCB Dry Weight and SMS Values at 12 Stations
Beyond Site Boundary After Construction

Stations	PCB Concentration (µg/kg dry weight) #				PCB Concentration (mg/kg OC)			
	Before	After	Increase	Decrease	Before	After	Increase	Decrease
DUD_5C	341	2,650	2310 ##		27 *	153 **	126	
DUD_6C Rep	1,290***	3,390	2100 ##			213 **	123	
DUD_6C	1,290	3,160	1870 ##		90 **	208 **	118	
DUD_3C	327	1270	943 ##		15 *	107 **	91	
DUD_7C	427	1,130	703 ##		28 *	75 **	47	
DUD_9C	103	733	631		13 *	95 **	82	
DUD_12C	263	644	381		20 *	80 **	60	
DUD_10C	373	666	292		37 *	65 **	28	
DUD_2C	382	368		14. ##	16 *	47 *	31	
DUD_11C	378	9.21		368	28 *	low TOC		
DUD_1C	621	240		380	18 *	35 *	17	
DUD_4C	492	105		387 ##	21 *	42 *	21	
DUD_4C Rep	2,740	235		2510 ##	129 **	101 **		28
DUD_8C	4,180	1,680		2,500	245 **	162 **		83
DUD_8C Rep	5,030	2,130		2,900	254 **	164 **		90

Stations	Total Solids (percent dry weight)				TOC (percent dry weight)			
	Before	After	Increase	Decrease	Before	After	Increase	Decrease
DUD_5C	60	57		3	1.27	1.73	0.46	
DUD_6C Rep	61 ###	59		2	1.43	1.59	0.16	
DUD_6C	61	61	0	0	1.43	1.52	0.09	
DUD_3C	50	63	13		2.16	1.19		0.97
DUD_7C	55	59	4		1.54	1.51		0.03
DUD_9C	69	70	1		0.78	0.77		0.01
DUD_12C	59	69	10		1.32	0.81		0.51
DUD_10C	66	65		1	1.02	1.03	0.01	
DUD_2C	50	67	17		2.36	0.78		1.58
DUD_11C	59	79	20		1.36	<.05		1.31
DUD_1C	46	72	26		3.36	0.68		2.68
DUD_4C	48	76	28		2.38	0.25		2.13
DUD_4C Rep	50	76	26		2.12	0.23		1.89
DUD_8C	56	67	11		1.70	1.04		0.66
DUD_8C Rep	55	65	10		1.98	1.30		0.68

= Values rounded to three significant figures
= Stations near Area B
- Value from DUD_6C used
* = Value Exceeds SQS
** = Value Exceeds CSL
*** = Original value from DUD_6C used

3.2.3.2 Discussion of Sampling Results

The complete listing of analytical results for sediment samples collected before and after construction are included in Appendix D for both dry weight and TOC normalized values. A summary of the SMS comparison for all chemicals is included in Table 5 and individual results for PCBs are included in Table 6. Corresponding TOC and total solids values are also include in Table 6.

Previous results from stations sampled beyond the site boundary by King County (1994 to 1996), NOAA (1997) and EPA (1998) showed SMS values were exceeded at most stations, which is why both Ecology and EPA considered the Duwamish/Diagonal project to be a partial cleanup action. The new sediment samples collected at the 12 stations in October 2003, before the Duwamish/Diagonal project, reflect these conditions and showed that all 12 stations beyond the site boundary exceeded the SQS or CSL values for one or more of 5 chemicals (PCBs, BEHP, benzyl butyl phthalate (BBP), 1,4 dichlorobenzene, mercury, cadmium and silver). The results listed in Table 5 show that the main focus for increases in SMS was limited to PCBs, BEHP, and BBP.

For PCBs, Table 5 shows that all 12 stations exceeded SMS before construction with 9 greater then SQS and 3 greater then CSL. After construction, 11 stations exceeded SMS with 2 greater then SQS and 9 greater then CSL, which is a net increase of 6 stations exceeding the CSL. The maximum increase occurred at stations 5C and 6C, which increased to over 2 times the CSL and 3 times the CSL, respectively.

For BEHP, Table 5 shows that 9 stations exceeded SMS before construction with 5 greater than SQS and 4 greater than CSL. After construction, 11 stations exceeded SMS with 2 greater than the SQS and 9 greater than the CSL for a net increase of 5 in stations greater than the CSL and 2 stations greater than the SMS. For BBP, one station exceeded the SQS before construction and this increased to 8 stations after construction, but no stations exceeded the CSL. For mercury, 4 stations initially exceeded SMS (2 greater than the SQS and 2 greater than the CSL), but in the after samples these all dropped below SMS and one different station exceeded the CSL. For cadmium, silver, and 1,4 dichlorobenzene, only one station initially exceeded SMS for each chemical (1 greater than the SQS for first compound and 1 greater than the CSL for the last two compounds), but in the after samples this dropped to no stations above the SMS.

To accurately evaluate changes in chemical concentration over time and space, it is important to use chemical quantification measurements that contain the least variability. Based on comparisons of PCB data in Table 6, TOC normalized values have more variability then dry weight values because the change in TOC does not change uniformly with the change in the chemistry value. A clear example can be seen in one of the replicate samples from stations 4C and 8C (sample 4C rep and 8C) , which both underwent a decrease of 2,500 parts per billion (ppb) in PCB dry weight values, but the corresponding change in TOC normalized values differ by more than a factor of two (minus 28 vs. minus 83 mg/kg TOC, respectively). Another example occurs at stations 7C and 9C, where the increase in dry weight was greater at station 7C (703 ppb vs. 631

ppb), but station 9C showed a much larger increase in the SMS value than station 7C (82 vs. 47 mg/kg TOC respectively). In a few cases the TOC normalized values can show an increase even though the dry weight chemistry values show a decrease, and this occurs with PCBs in three samples (1C, 2C, and 4C). Table 6 shows that SMS values increased at 11 stations (1C, 2C, 3C, 4C rep, 5C, 6C, 7C, 9C, 10C, 11C, 12C), but PCB dry weight values increased at only 7 stations (3C, 5C, 6C, 7C, 9C, 10C, 12C).

The most accurate way to identify changes produced by the two transport processes that effect chemical concentrations beyond the site boundary (i.e., dredge sediment transport and capping sand transport) is to look for spatial differences in the change in dry weight concentrations at each station. To assist in this analysis, the stations in Table 6 were arranged in progressive order starting with the greatest increase and progressing to the largest decrease in PCB dry weight. In Figure 8, the observed changes in PCB dry weight values were plotted next to the station numbers to show the spatial differences. Dry weight concentrations increased at 7 stations, but there was a greater increase in the four stations located near Area B (3C, 5C, 7C, and the replicate samples 6C and 6C rep) compared to the three stations located near Area A (9C, 10C, 12C). The highest increase (2,309 ppb) occurred at station 5C, which is located in the channel 50 feet west of the upstream end of Area B. The second and third highest increases (2,100 ppb and 1,870 ppb) occurred in the two replicate samples at station 6C (samples 6C and 6C rep), which is also located in the channel 50 feet from the edge of Area B, approximately midway along the length of Area B. The next highest increase (943 ppb) occurred at station 3C, which is located 150 feet upstream of Area B, upstream of station 4C, near the edge of the channel. The increase at station 3C shows upriver transport of suspended dredge material with incoming tide. The fourth and lowest level of increase at Area B was 702 ppb at station 7C, which is located in the channel 100 feet from the edge of Area B, offshore from station 6C. The lower increase at station 7C compared to station 6C shows a reducing concentration gradient going away from Area B in the cross-current direction. The four stations with the greatest increase in PCB values all border Area B, which correlates with where the contractor was observed spilling the most material when they started dredging.

For the three stations that increased around Area A, the largest increases (631 ppb) occurred at station 9C, which is located in the channel 50 feet west of Area A, slightly downstream of the middle of Area A. The next level of increase was 381 ppb that occurred at station 12C, which is located 150 feet downstream of Area A, downstream of station 11C, inshore of the east channel line. The lowest amount of increase was 292 ppb at station 10C, which is located in the channel about 65 feet from the downstream corner of Area A.

Five stations showed a reduction in PCB dry weight values (1C, 2C, 4C, 8C, and 11C), but the reduction at station 2C (-14 ppb) is so small that it could be considered as no change. A reduction in PCB values can occur when some of the clean capping sand is transported onto the station, which either buries all the underlying contaminated sediment (station 11C) or partially dilutes the 10 cm deep sample (samples 1C, 2C, 4C, 4C rep, 8C, and 8C rep). The amount of reduction that is produced depends both on the amount of sand added and the size of the beginning PCB value. Stations with the highest starting PCB values can produce the largest reduction values, and this is shown in the results. One of the replicate samples from station 8C (8C rep) had the highest beginning concentration value of 5,030 ppb, which was reduced to 2,130 ppb and yielded the largest reduction value (2,900 ppb). The seconded largest reduction in PCBs was 2,500 ppb for the second replicate sample at station 8C (sample 8C) and one of the replicate samples at station 4C (4C rep). Sample 8C had a much higher beginning total PCB value then sample 4C rep (4,180 ppb vs. 2,740 ppb). The addition of capping sand at the five stations (1C, 2C, 4C, 8C, and 11C) not only reduced the PCB concentration at these five stations, but also produced a corresponding reduction in the TOC values plus an increase in the percent total solids values, as seen in Table 6 for samples from these 5 stations (samples 1C, 2C, 4C, 4Crep, 8C, 8C rep, and 11C).

The transport of capping sand beyond the site boundary appears to have the greatest effect on the area of the river bottom located within 50 feet of the site boundary, because only the stations in this area have lower PCB values after construction. Five of the eight stations located within 50 feet of the site boundary show a reduction in PCB dry weight values. The five stations, which exhibit a decrease in PCB values (1C, 2C, 4C, 8C, and 11C), are fairly evenly distributed around the perimeter of both cleanup Areas A and B (Figure 5), except there are no PCB reductions at stations on the offshore side of Area B. Stations 1C (minus 380 ppb) and 2C (minus 14 ppb) are both located upstream of Area A and inshore of Area B. Station 4C (replicates of minus 387 ppb and minus 2,505 ppb) is located upstream of Area B and near the shore side of the channel. Neither of the two perimeter stations in the channel offshore of Area B shows a reduction; however, one of the two perimeter stations in the channel offshore of Area A is station 8C, which shows the maximum reduction of all stations (replicates of minus 2,500 ppb and minus 2,900 ppb). The fifth station to show a reduction was station 11C (minus 368 ppb) located downstream of Area A and inshore of the channel. It is reasonable to expect some transport of capping sand beyond the site boundary because there are substantial tidal currents in the river and each bucket of capping sand is intentionally spread across the surface of the water to increase dispersion and minimize impact on the bottom.

A second approach was used to help interpret the changes in PCB dry weight values that were observed at stations beyond the site boundary. This approach involved using a simple mathematical model to estimate the amount of dredge material that would accumulate at each of the 12 stations under a given set of conditions. A simple three-dimensional dispersion model had been used during the Cleanup Study (EBDRP 2001) to predict PCB recontamination; this model included conservative assumptions regarding river hydrodynamics, sedimentation/settling rates, contaminant concentrations and potential dredging actions. For consistency, this same model was used to generate an estimated deposition curve for increasing distance from the center of the dredge area. The deposition curve was derived by assuming that 2 percent of the dredge prism was dispersed (Anchor 2003) and that dispersion occurred from the center of the dredge prism. This curve was used to estimate the deposition thickness of dredge material (in centimeters) at each of the 12 stations, as shown in Table 7. The predicted PCB concentration produced by this deposition at each station was calculated by assuming the average PCB concentration for the newly deposited dredge material was equal to the average PCB concentration for the entire dredge prism (4.45 mg/kg dry weight). For simplicity, replicate samples were averages for this analysis.

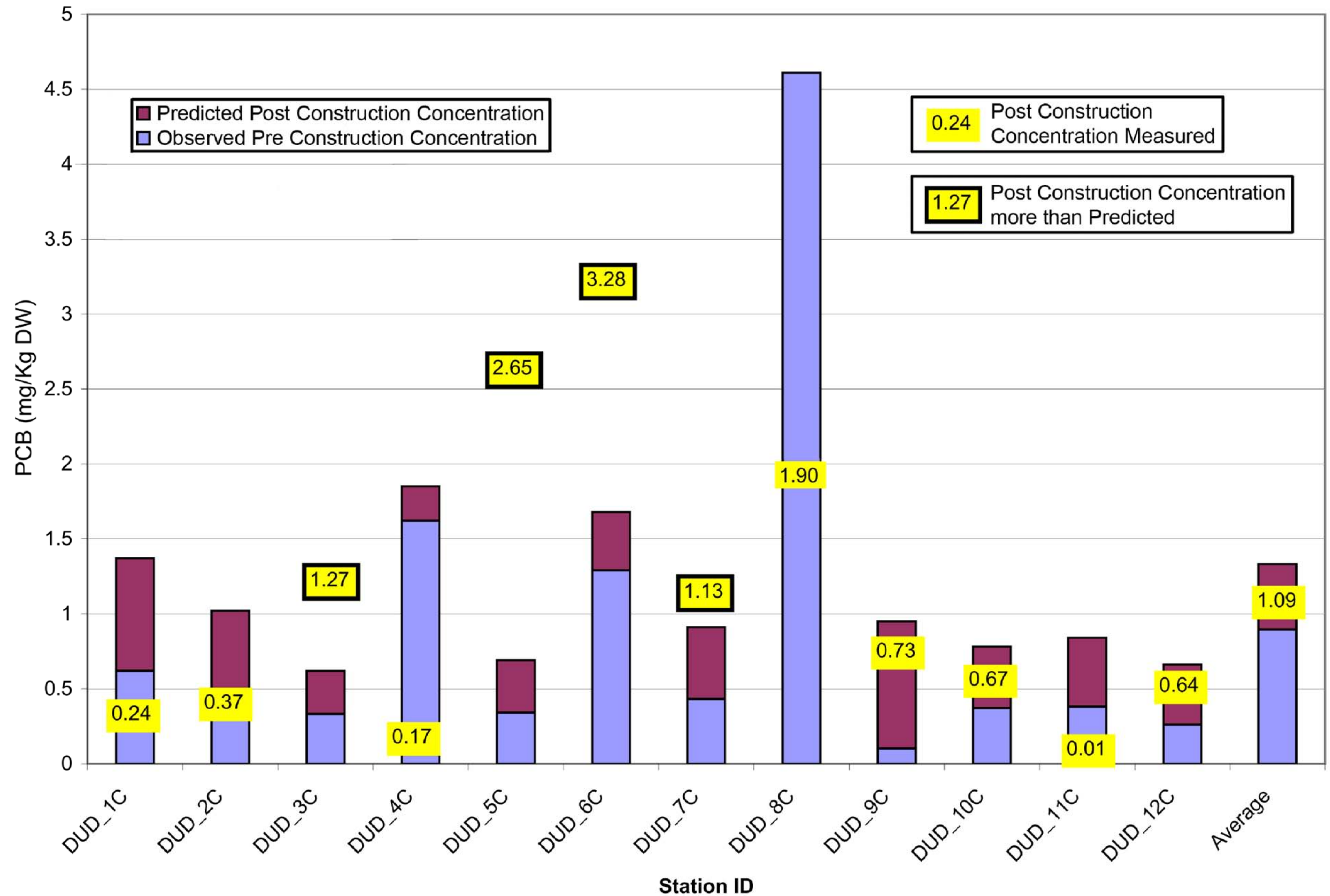
Table 7 lists the comparison between the predicted PCB values that were calculated using a 2 percent release and the actual dry weight PCB values measured after construction. The vertical bars in Figure 9 show the predicted increase in PCB dry weight values at each of the 12 stations and how the measured PCB values after construction compare with the predicted values. Figure 10 shows the spatial distribution of the PCB dry weight values measured after construction and whether the values are lower or higher than the values predicted by the model. Of the seven stations that had higher PCB dry weight values after construction, only the four stations around Area B (stations 3C, 5C, 6C, and 7C) had values that were higher than the predicted values (Figures 9 and 10). These four locations are adjacent to Area B, which is where the contractor started dredging and encountered the greatest problems with spillage. All six stations adjacent to Area A (1C, 8C, 9C, 10C, 11C and 12C) had PCB concentrations that were less than those predicted by the model, which could be interpreted to suggest that loss rates at these sites were less then the 2 percent value used for the model estimates or that the stations were influenced by transport of capping sand beyond the site boundary. The five stations that underwent a reduction in PCB values (stations 1C, 2C, 4C, 8C, and 11C) were significantly different than the model predictions; however, the difference between predicted and observed values can be explained by the transport of capping sand onto the station during cap placement.

Regulatory agencies and environmental groups expressed concern that excess amounts of PCB sediment were released due to sloppy dredging practices at the start of the project when the dredging contractor failed to use best management practices to minimize loss of dredge material. Ecology and EPA stated that they did not approve a 2 percent loss rate for the Duwamish/Diagonal project and that they could not accept the modeling results as an accurate prediction. Ecology ultimately informed King County that the data showed that an excessively high amount of PCBs were released around Area B and that the elevated PCB levels should be addressed by further cleanup actions as soon as possible. A new alternatives evaluation was performed in November 2004 to remediate the highest PCB values, which recommended installing a thin layer of sand to reduce elevated PCB values around Area B. In order to work during the early 2005 dredge window, King County moved quickly to obtain Ecology approval and the required permits to place a minimum 6-inch-thick layer of sand over about 4 acres of river bottom adjacent to Area B. The thin layer placement work was completed in February 2005 and will be described in a separate Closure Report for that cleanup action. Additional monitoring work required specifically for the thin layer placement action will also be described in a future report.

Table 7
PCB Distribution and Model Prediction
(mg PCB/kg dry weight)

Station	Measured Values Before	Model* Predicted Values	After Measured Values Lower than Predicted Values	After Measured Values Higher than Predicted Values	Distance to Station (meters)	Deposition** Thickness at Station (cm)
DUD_1C	0.62	1.37	0.24		92	1.97
DUD_2C	0.38	1.02	0.37		123	1.58
DUD_3C	0.33	0.62		1.27 ***	278	0.72
DUD_4C	1.62	1.85	0.17		245	0.8
DUD_5C	0.34	0.69		2.65 ***	237	0.9
DUD_6C	1.29	1.68		3.28 ***	163	1.23
DUD_7C	0.43	0.91		1.13 ***	169	1.19
DUD_8C	4.61	4.57	1.9		61	2.62
DUD_9C	0.1	0.95	0.73		92	1.97
DUD_10C	0.37	0.78	0.67		204	1.00
DUD_11C	0.38	0.84	0.01		180	1.13
DUD_12C	0.26	0.66	0.64		214	0.95

* = Based on Average PCB concentration of 4.45 ppm dry weight for all dredged sediment that settles onto bottom
** = Based on an assumed loss rate of 2 percent for dredged sediment dispersed from center of dredge area
*** = Stations exceeding predicted PCB increase all boarder cleanup Area B



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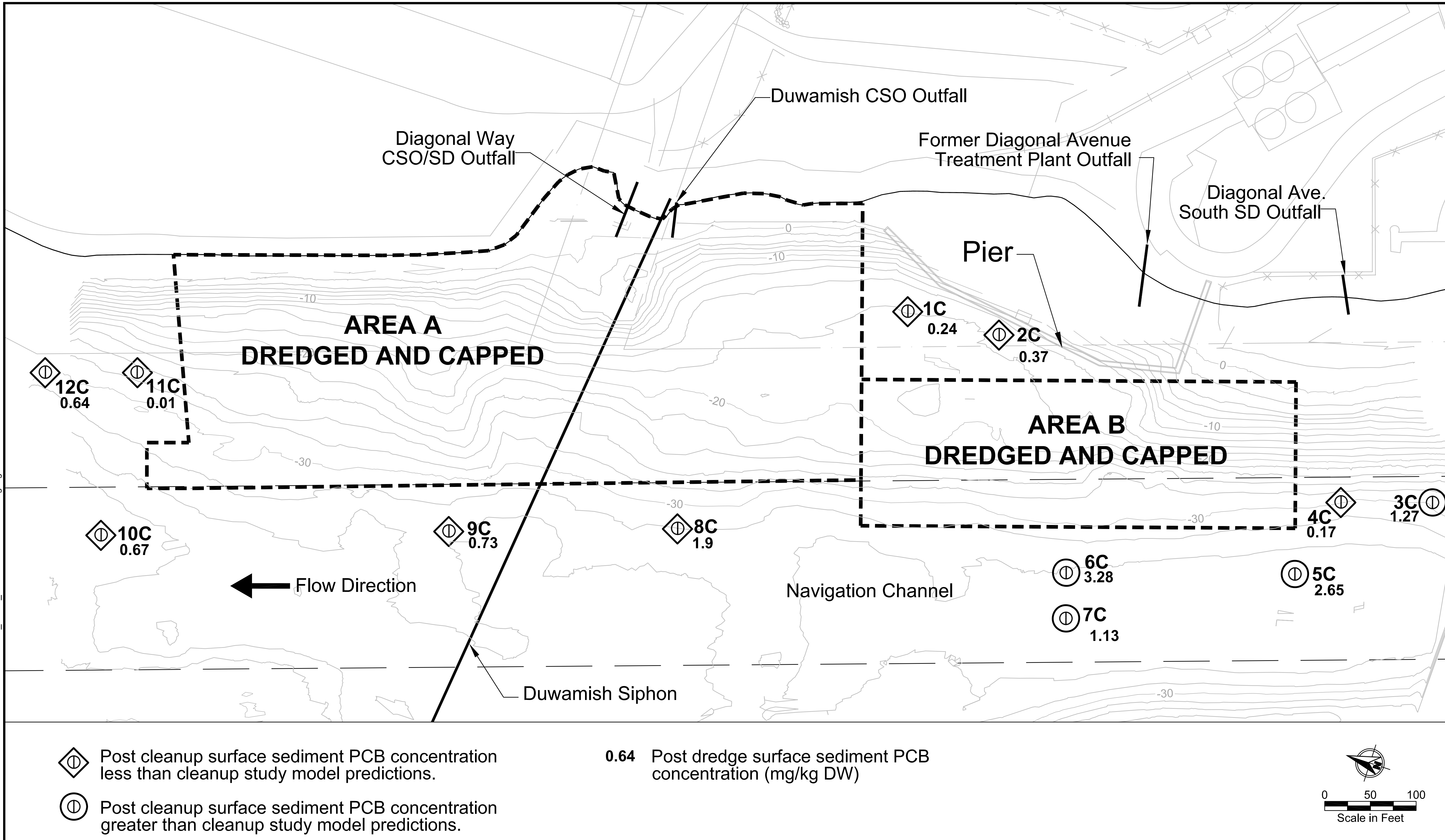
EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Predicted vs. Observed Post Construction PCB Concentrations At Twelve Stations Beyond Site Boundary	Figure 9



K:\Jobs\00008601-Duwamish\CLSR_RPRT_2005\00008601-80CR.dwg Fig 10

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Duwamish/Diagonal Sediment Remediation Project

Post Construction PCB Concentrations in PPM at Stations Beyond Site Boundary Compared to Predicted Values

Figure 10

3.3 CONFIRMATIONAL MONITORING

Cleanup regulations require confirmation monitoring to be performed to confirm the long-term effectiveness of the cleanup action, once cleanup standards and other performance standards have been attained (WAC 173-340-410 (c)). Long term confirmation testing of the chemical levels on surfaces of cleanup up Areas A and B began in the summer of 2004 and will continue for 10 years until 2014. Sampling during the first 5-year period will occur each year, but during the second 5-year period there is the potential that the sampling frequency could be reduced. A separate report will be issued with the sediment chemistry results for each year sampled; however, Section 6 of this report (Post Construction Monitoring) includes results of 2004 baseline chemistry for stations on the cap. Appendix G details the Sediment Monitoring Sampling and Analysis Plan for cleanup Areas A and B.