
SECTION 4

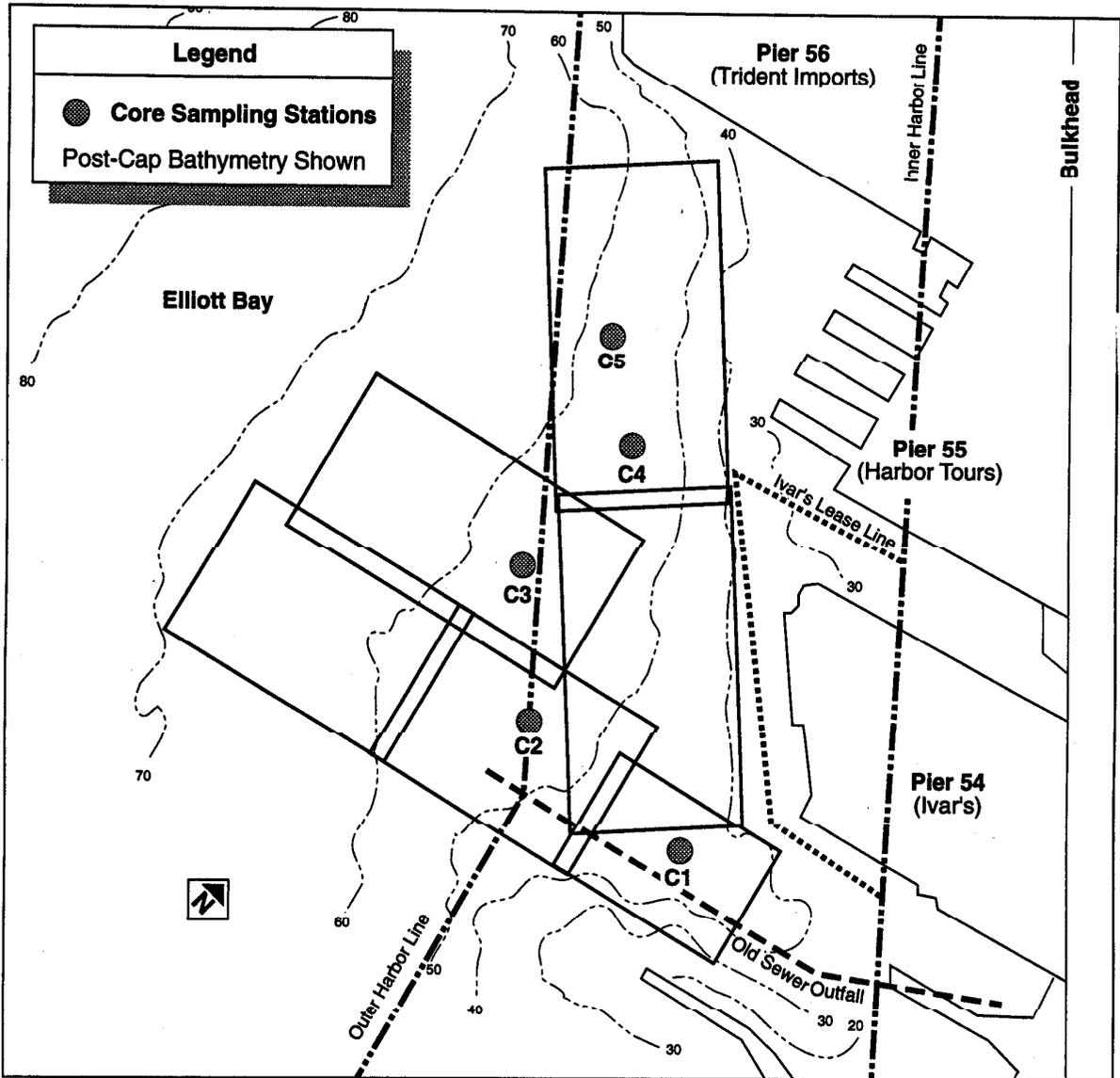
CORE SAMPLE ANALYSIS

On May 20, 1992, the monitoring team collected core samples from the sediment cap and enhanced natural recovery area (ENR). The samples were analyzed for trace metals, pesticides, polychlorinated biphenyls (PCBs), semi-volatile organics, and particle size distribution. The samples were also analyzed for total organic carbon for comparison to the state sediment standards. This section describes the core sampling method and compares the chemistry of the cap to the under-cap sediments and to the state sediment standards. Information from the core samples established baseline data on the distribution of chemicals within the cap and ENR. Samples from subsequent years will be compared to the baseline information to see how well the cap isolates the toxic sediments it covers.

The monitoring plan for Pier 53 defined five coring stations (C1 through C5) that provide spatial coverage across the site (see Map 4-1). Two stations are in the ENR (C4 and C5) and two are in the 3-foot-thick cap (C2 and C3) to allow comparison between the two areas. All four stations are at similar water depths of 55 to 60 feet. The stations are also in an area where the bottom slope is less steep than it is farther inshore. An additional coring station (C1) is located in the southeast corner of the site, where some of the highest chemical levels were previously observed and where future sampling would be more sensitive to detecting the possible upward migration of toxicants into the cap. All coring stations were situated at least 30 feet away from the surface sampling stations so that any potential release of contaminated sediment from the cores would not affect other surface sediment sampling stations.

METHODS

Two cores were collected from each of the five stations. Each core extended completely through the clean capping sand and into the underlying contaminated sediments by about 1 foot. For each station, the longest core was analyzed first, while the second served as a backup in case there was a problem with the first core such as insufficient sample material from under the cap. Researchers divided the cores into 6-inch-long sections for analysis, as shown in Figure 4-1. For cores in the 3-foot sediment cap, one 6-inch section was taken below the interface of the contaminated sediment and four 6-inch core sections were taken from above



Map 4-1. Core Sampling Stations

the interface for a total of five sections. In the ENR, one 6-inch section was taken from below the interface and two 6-inch sections were taken from above the interface. Because mixing can occur at the interface from the physical process of sediment placement, a space of at least 1 inch was omitted above the interface before taking the first sample.

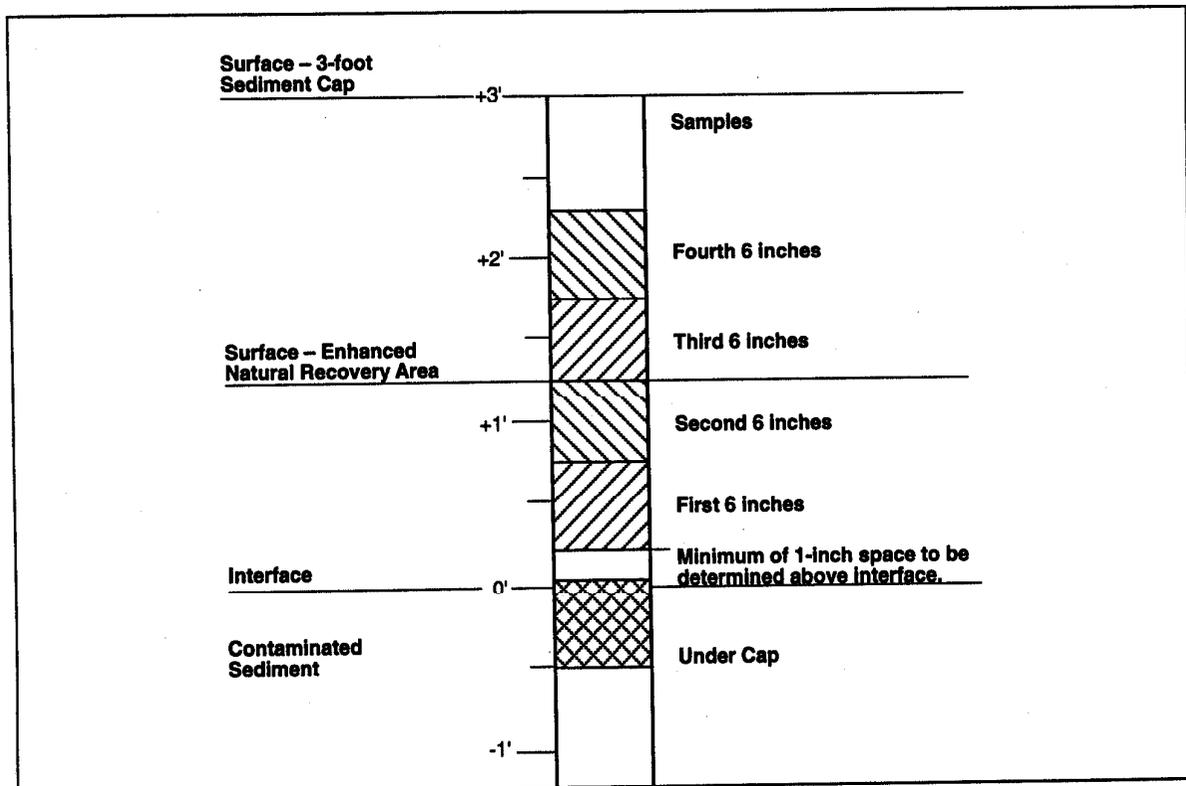


Figure 4-1. Cross Section of Core Sample

The monitoring team collected baseline core samples 2 months after the sediment cap was placed. The team consisted of a diver, diving support crew and boat, Metro's *RV Liberty* and crew, and a shore-based survey crew. The *Liberty* crew started by setting marker buoys at each coring station. The shore-based survey crew guided the *Liberty* to the stations using a range azimuth laser positioning system.

After the buoys were set, the *Liberty* crew anchored at a coring station and tied the diver support boat alongside. While in the water, the diver was in constant contact with the support boats via closed circuit radio. The diver carried a 6-foot long, 4-inch-diameter, thin-walled aluminum coring tube to the core station and inserted it into the bottom, keeping it vertical. A half-inch nylon rope was attached from a boat winch to the coring tube for later retrieval. The crew, using another winch, lowered a pneumatic jack hammer to the diver. The diver then drove the core tube through the cap and into the sediments below. The diver required about 10 minutes to jack hammer the core tube 5 feet into the bottom, leaving about 1 foot of the core tube extending above the bottom. Once the core

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tube was deep enough, the diver removed the hammer and inserted a rubber screw plug into the top of the tube. The winch operator, using the nylon rope attached to the coring tube, slowly pulled the core out of the bottom sediments. Once the core was free of the bottom, the diver inserted a second rubber screw plug into the bottom of the tube to completely encapsulate the sample.

The core samples were then brought onboard where the top plug was removed and excess water was siphoned off. Each core tube was labeled with a permanent mark to show station number and the amount of sediment present. The cores were transported to Metro's laboratory and stored in a walk-in freezer.

Shortly before the cores were processed, they were removed from the freezer and the aluminum tubes were cut down the sides lengthwise. Half of the tube was removed, leaving the other half to be used as a trough holding the core. It was then placed under a heat lamp to thaw. When it was thawed, the core was divided into 6-inch sections. The outsides of the 6-inch sections were scraped away and the interior of the core scooped out and placed into a beaker. The material in each beaker was stirred before a sample was taken. The samples were analyzed for trace metals, pesticides, polychlorinated biphenyls (PCBs) and semi-volatile organics. Total organic carbon was tested to compare the results to the state sediment standards.

RESULTS AND COMPARISONS

The Monitoring Plan for Pier 53 (Appendix A) required the comparison of chemical concentrations in the sediment cap with both the Duwamish River sediments, from which the capping material was dredged (Section 2), and with the under-cap sediments.

Tables 4-1 through 4-5 present the detected chemicals in the under-cap samples and compare them to the samples taken from within the cap. Results in these tables are in dry-weight concentrations. Cores do not provide enough volume of surface sediment for chemical analysis; therefore, the core samples are compared to the nearest surface-grab sample.

The metal and organic concentrations were nearly uniform throughout the cap and at the surface. Typically, less than six organic compounds were above detection limits, and these were consistently low throughout the cap. The

Results and Comparisons

TABLE 4-1. Detected Chemicals at Station C1

	Under cap	First 6 inches	Second 6 inches	Third 6 inches	Fourth 6 inches	Surface Grab VGS
Date:	5/19/92	5/19/92	5/19/92	5/19/92	5/19/92	5/26/92
Sample #:	9201215	9201216	9201217	9201218	9201219	9201096
% Solids:	54.00	76.00	73.00	74.00	82.00	70.00
Compound Name (ppb)						
Values in Dry Weight						
Naphthalene <i>LPAH</i>	200	<66	<68	<68	<61	<40
Acenaphthylene	290	<22	<23	<23	<20	<10
Acenaphthene	190	<18	<18	<18	<16	<9
Fluorene	300	<22	<23	<23	<20	T 10
Phenanthrene	2200	42	<23	34	<20	120
Anthracene	1200	<22	<23	<23	<20	46
2-Methylnaphthalene	T 87	<66	<68	<68	<61	<40
Fluoranthene <i>HPAH</i>	490	77	39	65	<24	200
Pyrene	6600	68	44	52	<20	100
Benzo (a) anthracene	2200	30	<23	33	<20	69
Chrysene	3500	44	<23	36	<20	100
Benzo (b) fluoranthene	7300	T 61	<68	T 54	<61	110
Benzo (k) fluoranthene	5000	<66	<68	<68	<61	T 40
Benzo (a) pyrene	4100	T 36	<46	<45	<41	54
Indeno (1,2,3-c,d) pyrene	560	<44	<46	<45	<41	<20
Dibenzo (a,h) anthracene	200	<66	<68	<68	<61	<40
Benzo (g,h,i) perylene	460	46	<46	<45	<41	<20
Benzyl butyl phthalate	140	<22	<23	<23	<20	<10
Dibenzofuran	170	<44	<46	<45	<41	<20
Carbazole	1100	<44	<46	<45	<41	<20
Bis(2-ethylhexyl)phthalate	1800	71	51	75	<20	B <10
Aroclor 1254 <i>PCB</i>	540	<44	<46	<45	<41	<20
Aroclor 1260	700	<44	<46	<45	<41	<20
Metals (ppm)						
Aluminum	18000	9300	9600	8100	8400	9600
Antimony	G 3.7	G 1.3	G 2.7	G 4.1	G 2.4	G 1.4
Arsenic	30	7.9	6.8	8.1	6.1	E 4.3
Beryllium	E 0.37	E 0.13	E 0.14	E 0.14	E 0.12	0.29
Cadmium	E 7.8	E 0.13	E 0.12	E <1	E 0.12	E 0.14
Chromium	G 94	G 13	G 13	G 13	G 10	12
Copper	180	12	13	11	9.9	12
Iron	24000	16000	16000	14000	15000	16000
Lead	330	5.3	10	5.4	3.7	5.7
Manganese	220	210	210	190	180	210
Mercury	E 3.1	E .039	E <0.03	E <0.03	E <0.02	<0.13
Nickel	G 37	G 12	10	G 10	G 10	12
Selenium	<4	<1	<1	<1	<1	<1
Silver	G 12	G 0.26	G 0.27	G 0.27	G 0.24	0.29
Thallium	E 19	E 12	E 11	E 8.1	E 11	7.1
Zinc	G 440	G 42	G 45	G 41	G 40	44

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

Results and Comparisons

TABLE 4-2. Detected Chemicals at Station C2

	Under cap	First 6 inches	Second 6 inches	Third 6 inches	Fourth 6 inches	Surface Grab VG1	
Date:	5/19/92	5/19/92	5/19/92	5/19/92	5/19/92	5/26/92	
Sample #:	9201210	9201211	9201212	9201213	9201214	9201098	
% Solids:	54.00	80.00	80.00	82.00	79.00	74.00	
Compound Name (ppb)		Values in Dry Weight					
Napthalene	LPAH	160	<63	<63	<61	<63	<30
Acenaphthylene		200	<21	<21	<20	<21	<10
Acenaphthene		160	<17	<17	<16	<17	<9
Fluorene		220	<21	<21	<20	<21	<10
Phenanthrene		2300	<21	<21	<20	<21	T 10
Anthracene		740	<21	<21	<20	<21	<10
2-Methylnaphthalene	T	74	<63	<63	<61	<63	<30
Fluoranthene	HPAH	3700	<25	<25	<24	<25	46
Pyrene		2700	<21	<21	<20	<21	30
Benzo (a) anthracene		2000	<21	<21	<20	<21	<10
Chrysene		2700	<21	<21	<20	<21	20
Benzo (b) fluoranthene		5900	<63	<63	<61	<63	T 40
Benzo (k) fluoranthene		4400	<63	<63	<61	<63	<30
Benzo (a) pyrene		4100	<42	<42	<41	<42	<20
Indeno (1,2,3,-c,d) pyrene		490	<42	<42	<41	<42	<20
Dibenzo (a,h) anthracene		180	<63	<63	<61	<63	<30
Benzo (g,h,i) perylene		320	<42	<42	<41	<42	<20
Benzyl butyl phthalate		46	<21	<21	<20	<21	<10
Dibenzofuran		120	<42	<42	<41	<42	<20
Bis (2-ethylhexyl) phthalate		520	<21	120	<20	<21	B <10
Carbazole		740	<42	<42	<41	<42	<20
Aroclor 1254	PCB	2100	<42	<42	<41	<42	<20
Aroclor 1260		1400	<42	<42	<41	<42	<20
Metals (ppm)							
Aluminum		17000	7600	8400	7600	8400	9600
Antimony	G	3.7	G 1.3	G 1.3	G 1.2	G 1.3	G 1.4
Arsenic		24	7.5	6.3	6.1	6.3	E 5.4
Beryllium	E	0.37	E 0.13	E 0.26	E 0.12	E 0.13	0.27
Cadmium	E	6.5	E 0.11	E < 0.1	E 0.12	E 0.11	E 0.14
Chromium	G	98	G 11	G 11	G 11	G 12	13
Copper		200	9.7	10	10	12	16
Iron		20000	15000	15000	15000	15000	15000
Lead		260	3.8	3.8	4.9	8.9	5.4
Manganese		200	180	190	170	180	190
Mercury	E	4.8	E 0.05	E < 0.03	E < 0.02	E < 0.03	0.041
Nickel	G	33	G 9.7	G 10	G 9.5	G 11	11
Selenium		<4	<1	<1	<4	<1	<3
Silver	G	14	G 0.25	G 0.25	G 0.24	G 0.25	0.27
Thallium	E	19	E 13	E 13	E 9.8	E 13	11
Zinc	G	300	G 39	G 40	G 41	G 56	45

B - Result corrected for blank contamination.

E - Estimate

G - Estimate is greater than value shown.

T - Detected below quantification limits.

For further information on data qualifiers see Appendix B.

TABLE 4-3. Detected Chemicals at Station C3

	Under cap	First 6 inches	Second 6 inches	Thlrd 6 inches	Surface Grab VG7
Date:	5/19/92	5/19/92	5/19/92	5/19/92	5/27/92
Sample #:	9201220	9201221	9201222	9201223	9201104
% Solids:	55.00	76.00	79.00	84.00	78.00
Compound Name (ppb)	Values in Dry Weight				
Napthalene <i>LPAH</i>	160	<66	<63	<60	E <20
Acenaphthylene	190	<22	<21	<20	E <10
Acenaphthene	120	<18	<17	<16	E <8
Fluorene	110	<22	<21	<20	E <10
Phenanthrene	740	41	<21	<20	E 31
Anthracene	360	<22	<21	<20	E <10
2-Methylnapthalene	91	<66	<63	<60	E <30
Fluoranthene <i>HPAH</i>	1000	67	T 13	<24	E 46
Pyrene	2600	65	<21	<20	E 33
Benzo (a) anthracene	840	29	<21	<20	E <10
Chrysene	2000	31	<22	<21	E 20
Benzo (b) fluoranthene	2400	44	<63	<60	E <30
Benzo (k) fluoranthene	1100	<66	<63	<60	E <30
Benzo (a) pyrene	1700	<44	<42	<40	E <20
Indeno (1,2,3,-c,d) pyrene	430	<44	<42	<40	E <20
Benzo (g,h,i) perylene	560	<44	<42	<40	E <20
Dibenzofuran	120	<44	<42	<40	E <20
Bis (2-ethylhexyl) phthalate	120	47	<21	<20	BE <10
4-Methylphenol	230	<44	<42	<40	<20
Carbazole	220	<44	<42	<40	E <20
Aroclor 1254 <i>HPAH</i>	130	<44	<42	<40	<20
Metals (ppm)					
Aluminum	16000.	9100.	8500.	7400.	8500.
Antimony	G 3.6	G 1.3	G 2.5	G 1.2	G 1.3
Arsenic	22.	6.6	7.6	7.1	E 2.6
Beryllium	E 0.36	E 0.13	E 0.13	E 0.12	0.26
Cadmium	E 1.8	E 0.11	E 0.13	E 0.12	E 0.13
Chromium	G 35	G 12	G 11	G 10	11
Copper	130	12	11	9.2	12
Iron	20000	14000	15000	15000	14000.
Lead	200	3.9	3.8	3.6	5.1
Manganese	200	180	190	170	190
Mercury	E 2.7	E < 0.03	E < 0.03	E < 0.02	< 0.03
Nickel	G 29	G 10	G 10	G 9.3	11
Selenium	<2	<1	<1	<2	<1
Silver	G 4.5	G 0.13	G 0.25	G 0.24	0.26
Thallium	E 15	E 11	E 11	E 11	9
Zinc	G 200	G 39	G 41	G 37	41

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

Results and Comparisons

TABLE 4-4. Detected Chemicals at Station C4				
	Under cap	First 6 inches	Final 3.5 inches	Surface Grab VG3
Date:	5/19/92	5/19/92	5/19/92	5/27/92
Sample #:	9201224	9201225	9201226	9201101
% Solids:	53.00	51.00	79.00	69.00
Compound Name (ppb)	Values in Dry Weight			
Napthalene <i>LPAH</i>	220	<98	<63	<40
Acenaphthylene	230	<33	<21	<10
Acenaphthene	110	<26	<17	<9
Fluorene	170	<33	<21	<10
Phenanthrene	1100	170	<21	41
Anthracene	510	110	<21	T 20
2-Methylnaphthalene	97	<98	<63	<40
Fluoranthene <i>HPAH</i>	2000	240	<25	67
Pyrene	6900	470	<21	54
Benzo (a) anthracene	920	180	<21	30
Chrysene	1400	200	<21	39
Benzo (b) fluoranthene	4100	<98	<63	T 50
Benzo (k) fluoranthene	3000	<98	<63	<40
Benzo (a) pyrene	2800	<65	<42	<20
Indeno (1,2,3,-c,d) pyrene	400	<65	<42	<20
Benzo (g,h,i) perylene	250	<65	<42	<20
Benzyl butyl phthalate	550	<33	<21	<10
Dibenzofuran	110	<65	<42	<20
Bis (2-ethylhexyl) phthalate	110	<33	<21	B <10
Carbazole	410	<65	<42	<20
Aroclor 1260 <i>PCB</i>	T 44	<65	<42	<20
Metals (ppm)				
Aluminum	13000	15000	8200	10000
Antimony	G 1.9	G 2	G 1.3	G 1.4
Arsenic	17	16	6.3	E 4.3
Beryllium	E 0.19	E 0.2	E 0.13	0.29
Cadmium	E 1.5	E 1.1	E 0.089	E 0.14
Chromium	G 26	G 31	G 11	13
Copper	120	65	9.5	13
Iron	16000	22000	14000	16000
Lead	170	100	3.8	5.8
Manganese	160	270	180	190
Mercury	E 3.0	E 1.5	E <0.03	0.029
Nickel	G 25	G 22	G 10	12
Selenium	< 4	< 4	< 1	< 4
Silver	G 4	G 3.3	G 0.25	0.29
Thallium	E 11	E 16	E 8.9	10
Zinc	G 160	130	G 38	48

B - Result corrected for blank contamination.

E - Estimate

G - Estimate is greater than value shown.

T - Detected below quantification limits.

For further information on data qualifiers see Appendix B.

TABLE 4-5. Detected Chemicals at Station C5

	Under cap	First 6 inches	Final 2 inches	Surface Grab VG4
Date:	5/19/92	5/19/92	5/19/92	5/27/92
Sample #:	9201227	9201228	9201229	9201099
% Solids:	61.00	82.00	73.00	74.00
Compound Name (ppb)		Values in Dry Weight		
Napthalene <i>LPAH</i>	87	<82	E <63	<30
Acenaphthylene	47	<27	E <21	<10
Acenaphthene	31	<22	E <17	<9
Fluorene	51	<27	E <21	<9
Phcnanthrene	390	<27	E <21	51
Anthracene	200	<27	E <21	T 20
HPAH (ppb)				
Fluoranthene	540	<33	F <25	81
Pyrene	930	<27	E <21	62
Benzo (a) anthracene	390	<27	E <21	<10
Chrysene	400	<27	E <21	50
Benzo (b) fluoranthene	890	<82	E <63	70
Benzo (k) fluoranthene	650	<82	E <63	<30
Benzo (a) pyrene	510	<55	E <42	T 30
Dibenzofuran	I 28	<55	E <42	<20
Carbazole	140	<55	E <42	<20
PCB (ppb)				
Aroclor 1254	81	<55	E <42	<20
Aroclor 1260	150	<55	E <42	<20
Metals (ppm)				
Aluminum	16000	7800	- 8200	9600
Antimony	G 3.3	G 1.2	G 1.3	G 1.4
Arsenic	18	6.1	7.5	E 4.1
Beryllium	E 0.33	E 0.12	E 0.13	0.27
Cadmium	E 1.4	E 0.098	E 0.13	E 0.12
Chromium	G 39	G 11	G 11	12
Copper	75	9.4	9.3	13
Iron	20000	NA	NA	16000.
Lead	120	3.7	3.8	5.4
Manganese	230	170	180	200
Mercury	E 1.2	E <0.02	E <0.03	0.041
Nickel	G 34	G 12	G 10	11
Selenium	< 3	< 1	< 3	< 3
Silver	G 2.6	G 0.24	G 0.25	0.27
Thallium	E 15	9.8	10	9.5
Zinc	G 140	G 40	G 40	45

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

NA - Not available

Results and Comparisons

concentrations of chemicals in the core samples of the sediment cap were very similar to the chemical concentrations found in the Duwamish River sediment study of capping material before it was dredged (Appendix E).

Six semi-volatile compounds, two PCBs, and five metals were chosen for vertical profile plots (Figures 4-2 through 4-8). The profile plots show a sharp difference between the lower concentrations in the cap and the substantially higher concentrations in the sediments underneath the cap.

Organic Compounds

In the under-cap samples, there were 20 organic compounds present in concentrations ranging from several hundred to several thousand ppb. All of these chemicals were detected in much higher concentrations in the under-cap samples than in the within-cap samples. PCBs were detected in the under-cap material at all five core stations, but were not detected within the cap. The concern of chemical migration up into the cap focuses on the compounds detected under the cap.

Under Cap. The under-cap samples for Stations C1 and C2 have the highest organic compound concentrations. The two stations are located on the 3-foot sediment cap over the area of highest pre-cap contamination along the abandoned sewer pipeway. Under-cap concentrations appear to be higher near the old outfall pipeway and decrease with distance from the outfall. However, concentrations are lower at C3, which is the next nearest station to the outfall, than at Station C4. Concentrations decrease again at C5, which is the station farthest to the north. Station C4 is offshore of the northwest corner of Pier 54 in the area where the 1989 Station 43 and the 1992 Station S9 showed high chemical concentrations. Stations C2, C3, C4, and C5 are all in similar water depths.

The compounds detected in the highest concentrations in the under-cap samples were phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b and k)fluoranthene, and benzo(a)pyrene. Fluoranthene concentrations ranged from 3,700 ppb dry weight at Station C2 to 390 ppb at Station C5. Phenanthrene concentrations ranged from 2,300 ppb at Station C2 to 490 ppb at Station C1. Pyrene concentrations ranged from 6,900 ppb at Station C4 to 930 ppb at Station C5. Benzo(a)anthracene concentrations ranged from 2,200 ppb at Station C1 to 390 ppb at Station C5. Chrysene concentrations ranged from 3,500 ppb at Station C1 to 400 ppb at Station C5. Benzo(b)fluoranthene concentrations ranged from 7,300 ppb at Station C1 to 890 ppb at Station C5. Benzo(k)fluoranthene concentrations ranged from 5,000 ppb at Station C1 to

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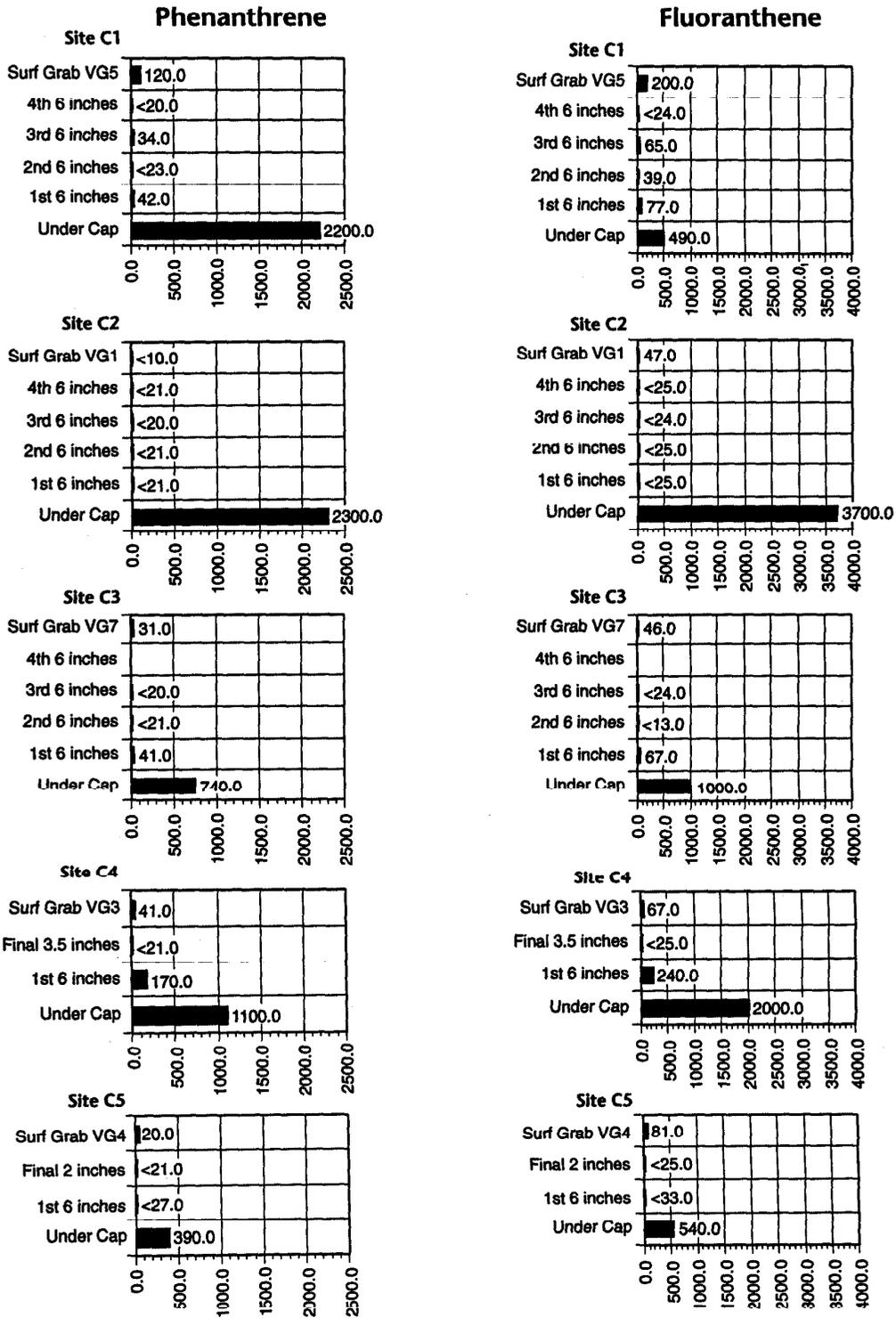


Figure 4-2. Phenanthrene and Fluoranthene Concentrations

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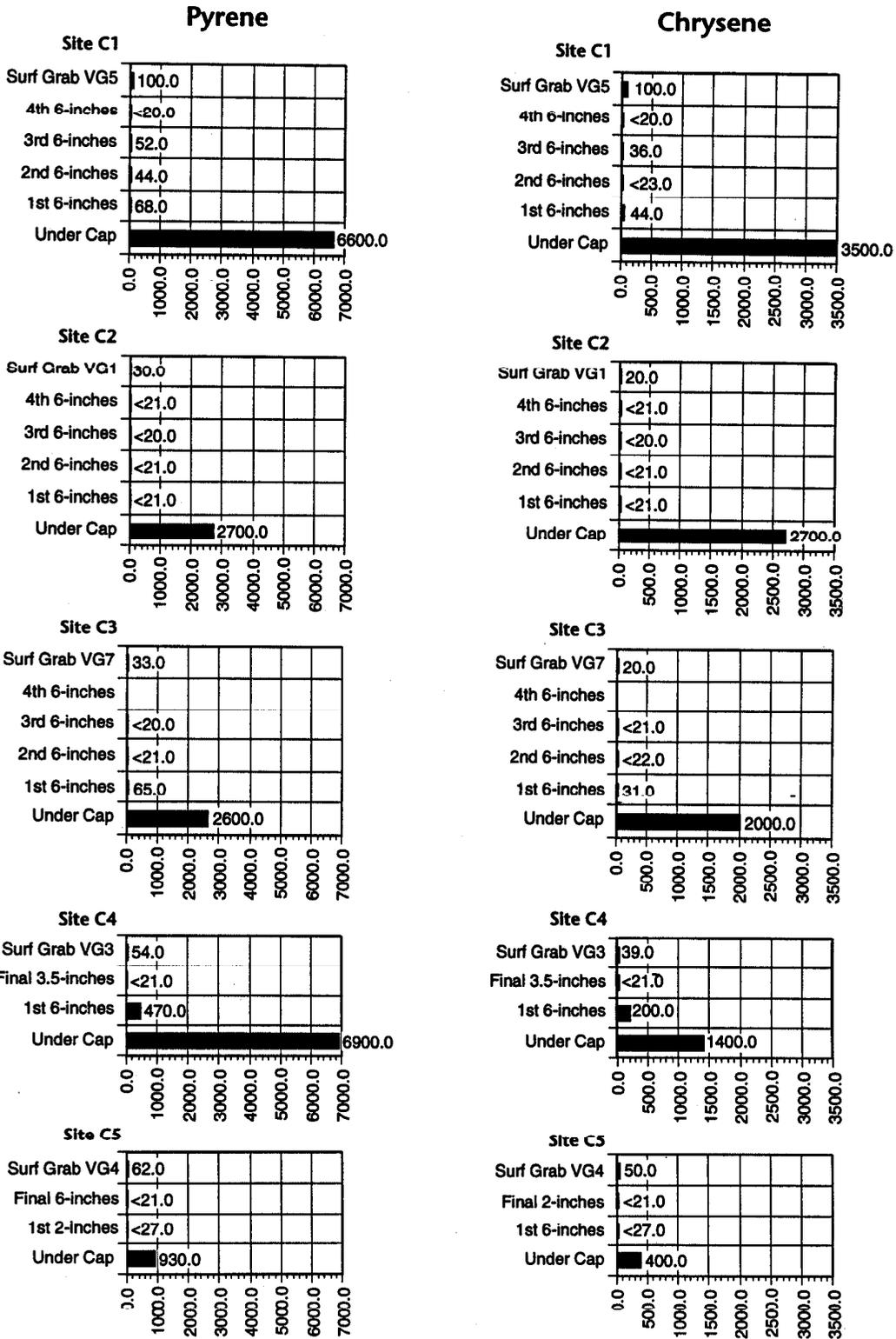


Figure 4-3. Pyrene and Chrysene Concentrations

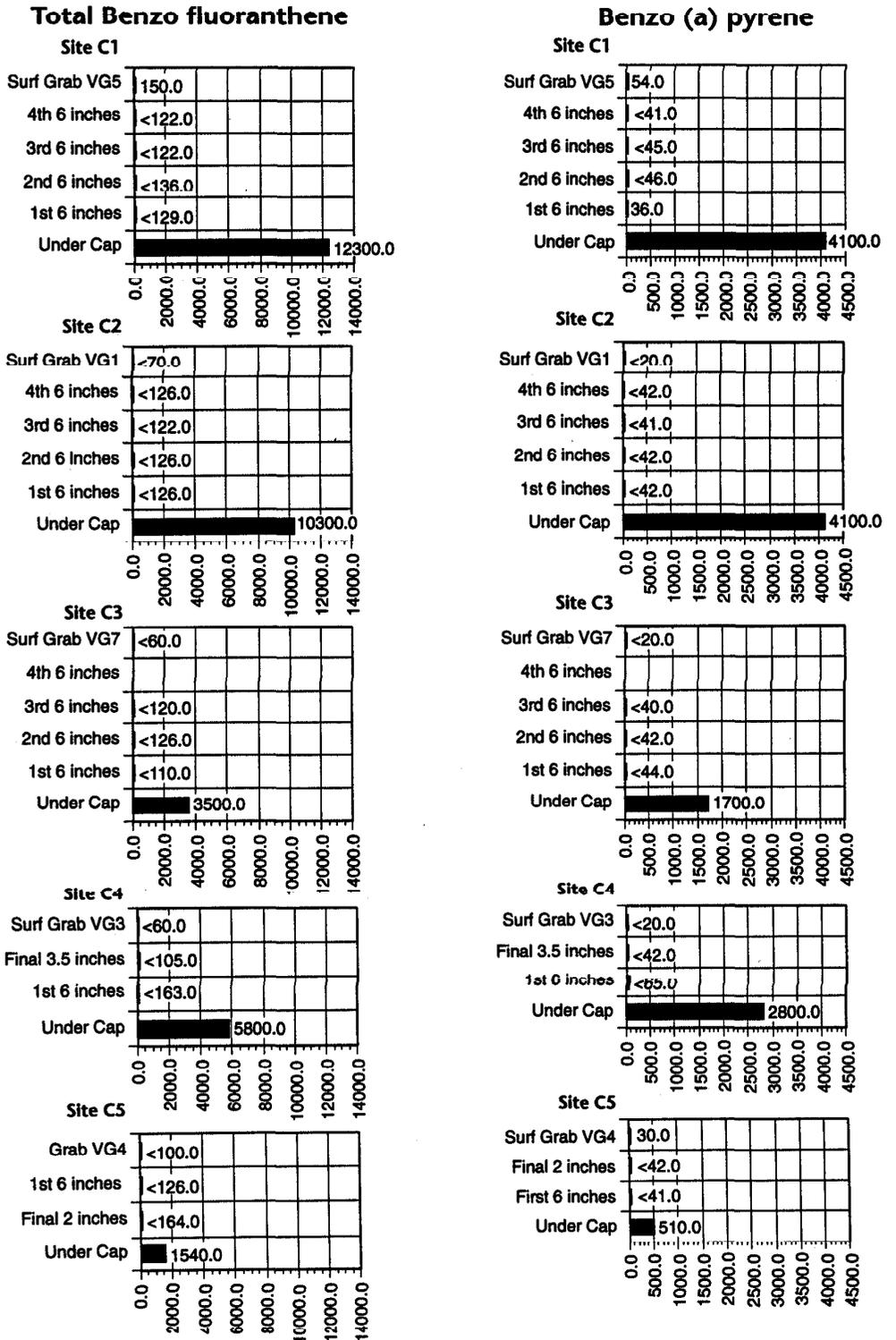


Figure 4-4. Total Benzo Fluoranthenes and Benzo(a)pyrene Concentrations

Aroclor 1254 and 1260

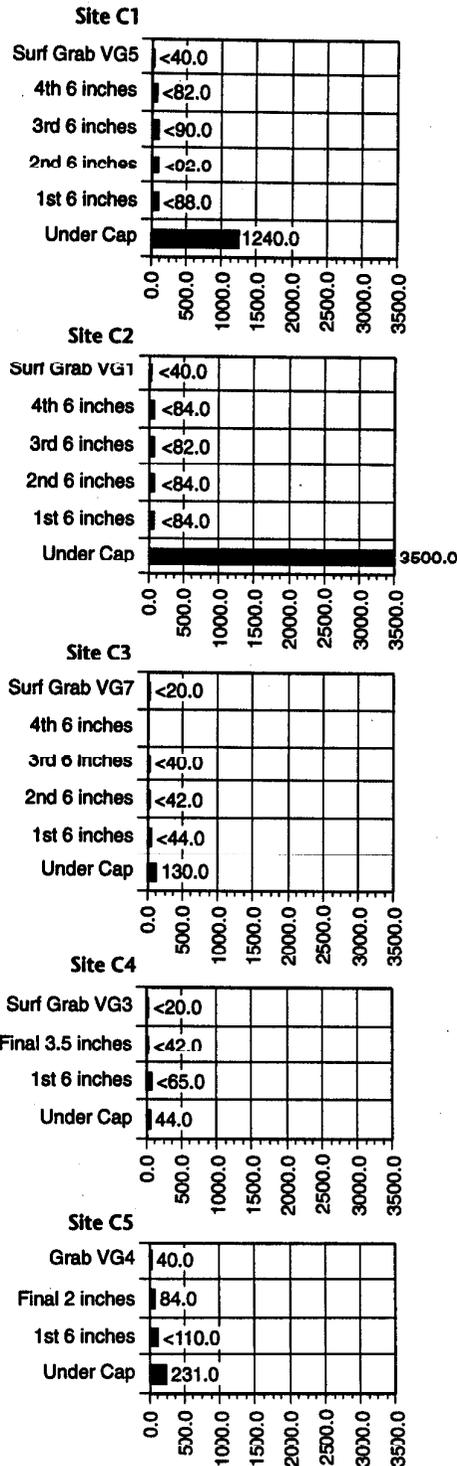


Figure 4-5. Aroclor 1254 and 1260 Concentrations

Results and Comparisons

Mercury

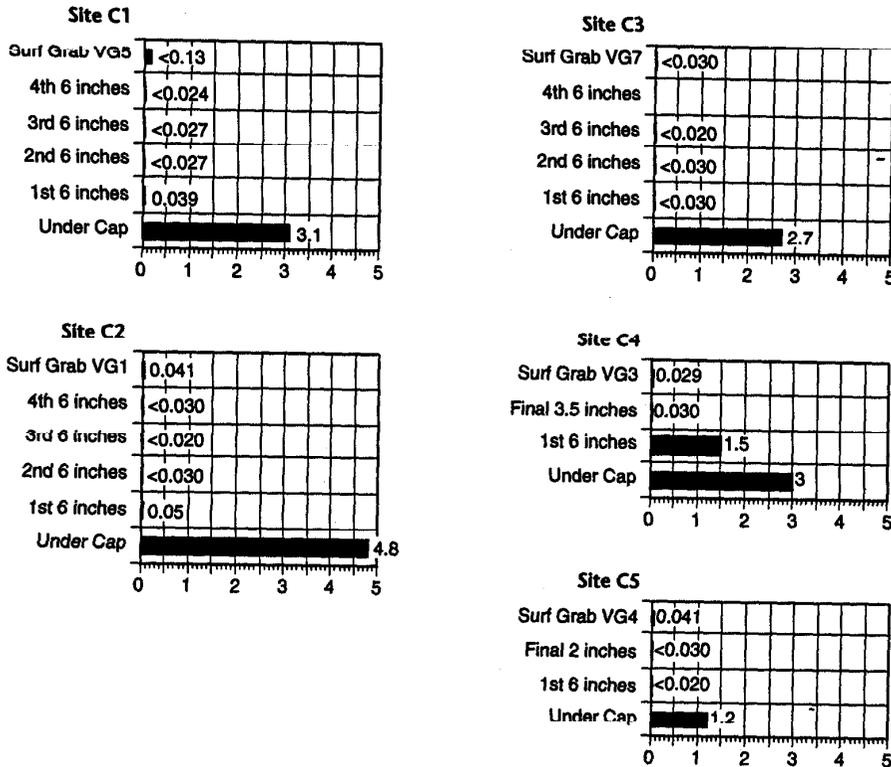


Figure 4-6. Mercury Concentrations

650 ppb at Station C5. And benzo(a)pyrene concentrations ranged from 4,100 ppb at Station C1 to 510 ppb at Station C5.

Aroclor 1254 was detected in the under-cap samples at Stations C1, C2, C3, and C5, ranging from 2,100 ppb at Station C2 to 81 ppb at Station C5. Aroclor 1,260 was detected in the under-cap samples at Stations C1, C2, C4, and C5, ranging from 1,400 at C2 to 44 ppb at C4.

Spatial distribution of under-cap sediment concentrations is similar to pre-cap data, which showed a general pattern of higher values offshore of Pier 54 near the old outfall and lower concentrations offshore from the north end of Pier 55.

Results and Comparisons

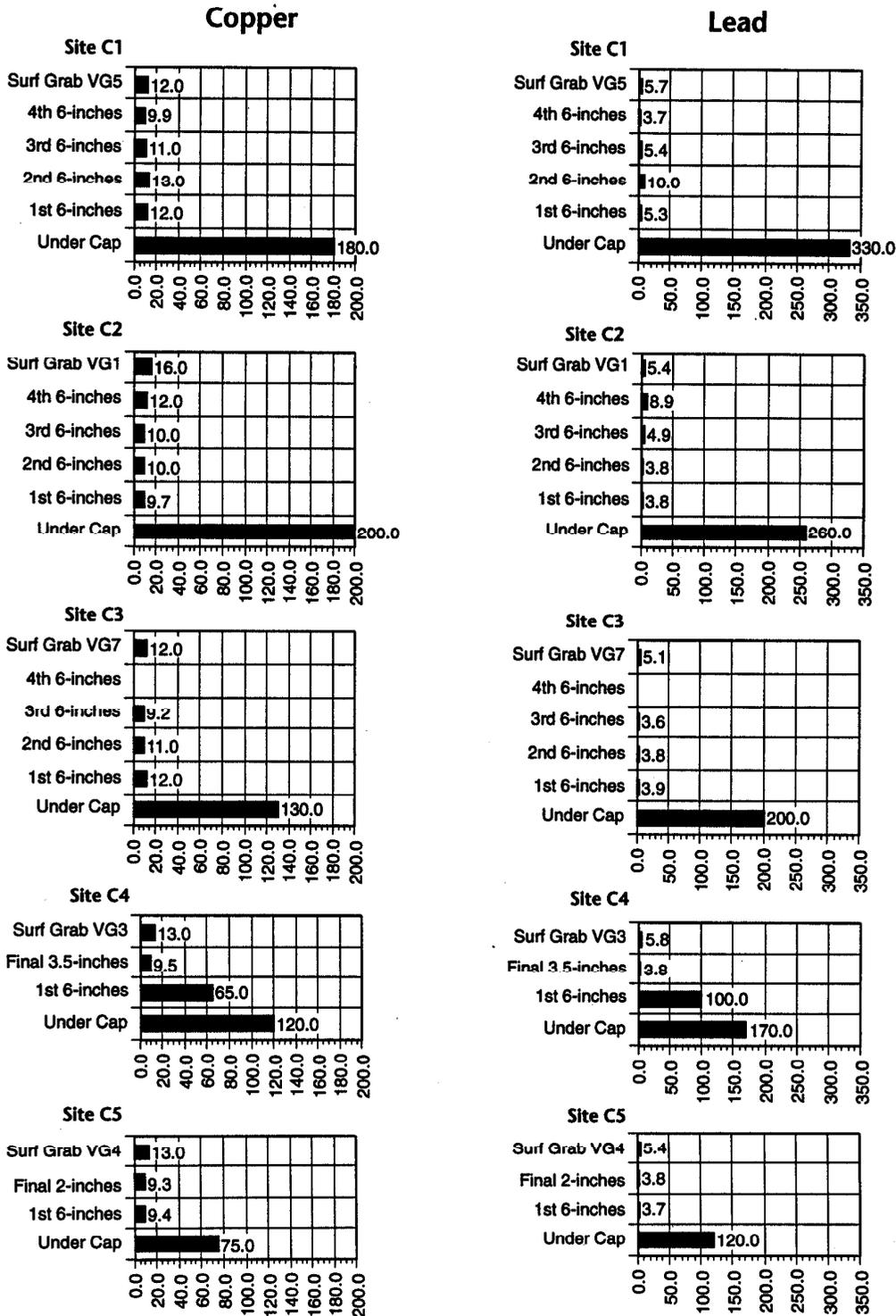


Figure 4-7. Copper and Lead Concentrations

Results and Comparisons

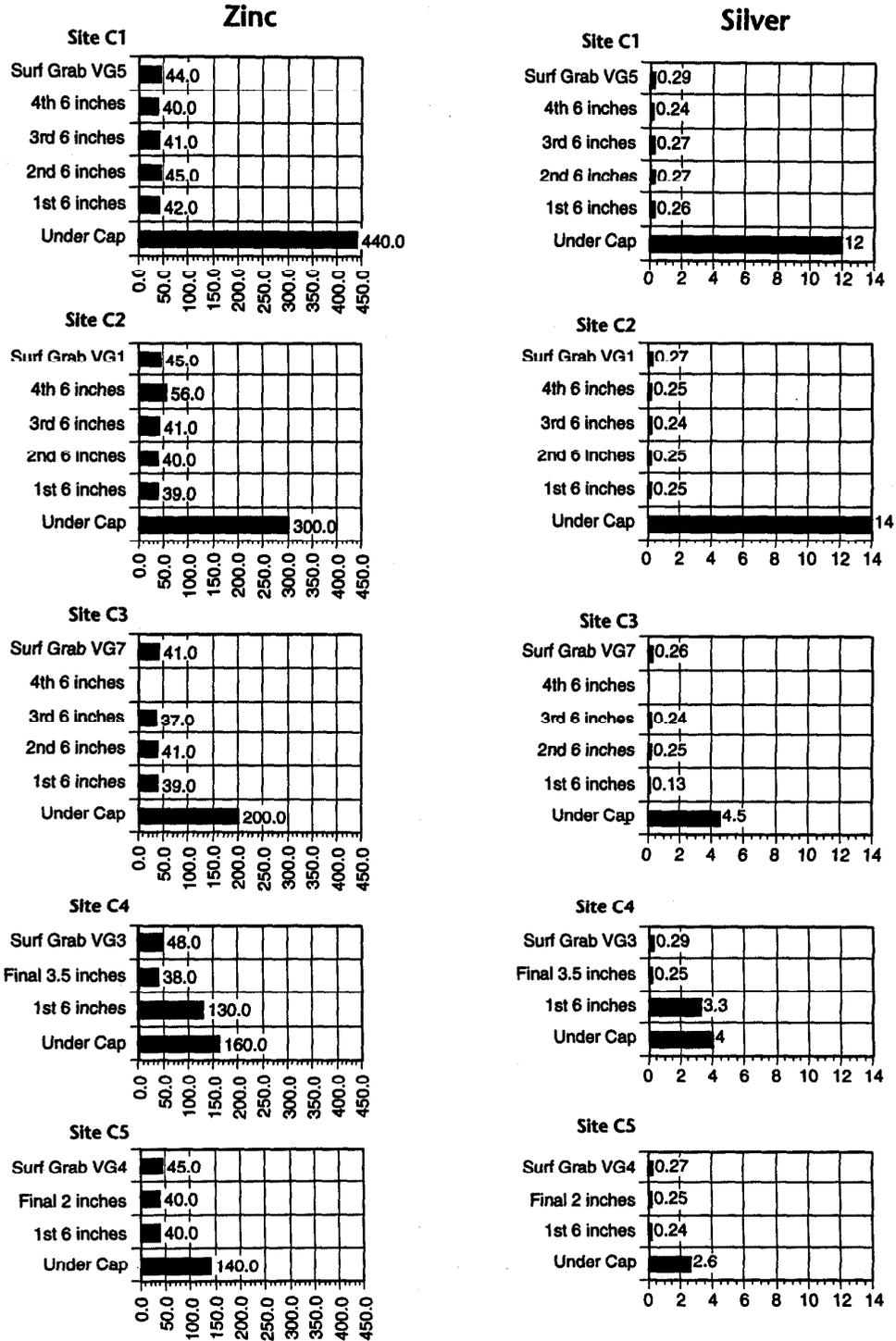


Figure 4-8. Silver and Zinc Concentrations

Results and Comparisons

Within-Cap. Eleven organic compounds were present in the capping material, at concentrations ranging from 200 to less than 20 ppb. The most frequently detected organic compounds in the capping material were phenanthrene, fluoranthene, pyrene, benzo(a)pyrene, chrysene, and benzo(b)fluoranthene. When these compounds were detected, they were either at the surface or in the first 6 inches above the contaminated sediments. At Station C1, the concentrations ranged from 77 ppb for fluoranthene to 30 ppb for benzo(a)anthracene. At Station C3 the concentrations ranged from 67 ppb for fluoranthene to 29 ppb for benzo(a)anthracene. At Stations C2 and C5, all organic compounds went undetected.

At Station C4, the concentrations were higher in the first 6-inch section, ranging from 470 ppb for benzo(a)pyrene to 110 ppb for anthracene. In comparison to all other within-cap samples, these concentrations were an anomaly. Based on the core cutting log, this sample apparently contained clay dredged from the Duwamish that caused an increase in concentration of several chemicals.

Duwamish River Comparison. Organic chemical analysis of the pre-dredge Duwamish River samples showed that concentrations were similar to the cap material core samples, except for the first 6-inch section at Station C4. Chemicals detected in the Duwamish River composite sample C1 were phenanthrene at 26 ppb dry weight, fluoranthene at 23 ppb, and pyrene at 21 ppb.

Twelve organic chemicals, three pesticides, and one PCB were detected in the Duwamish River composite sample C3. Organic concentrations ranged from 180 ppb dry weight for bis(2-ethylhexyl)phthalate to 29 ppb for benzo(a)anthracene. Pesticides ranged from 3.8 ppb dry weight for DDD to 1.1 ppb for lindane. Aroclor 1260 was detected at 28 ppb. No PCBs or pesticides were detected in any samples of the capping material at the Pier 53 site.

Metals

Metals were also in low concentrations in the cap material relative to the under-cap sediments. Comparisons between concentrations of mercury, lead, copper, silver, and zinc in the cap and under-cap sediments are shown in Figures 4-6 through 4-8.

Within-Cap and Under-Cap Comparison. Aluminum and iron were the most abundant metals in both the under-cap and capping sediments. Both metals are common elements in the earth's crustal sediments and are a good indicator of similarities or differences in types of sediments. Under-cap samples are largely clay and have high aluminum and iron values, ranging from 13,000 to 18,000 ppm and

16,000 and 24,000 ppm respectively. The sand capping material has a low clay content with aluminum and iron values of 7,400 to 9,600 ppm and 14,000 to 16,000 respectively.

At Station C1, the under-cap concentrations of metals were higher than the within-cap samples and ranged from a factor of 79 greater for mercury to a factor of 4 greater for arsenic. Lead was in higher concentrations in the under-cap sample by a factor of 66. Cadmium was 60 times higher and silver was 46 times higher.

At Station C2, mercury was in concentrations 96 times higher in the under-cap sediments than in the cap material. Cadmium was in concentrations 59 times higher in the under-cap sediments; lead was 57 times higher and silver was 56 times higher.

At Station C3, mercury was 2.7 ppm in the under-cap sediments but was undetected in the cap material. Cadmium was in concentrations 15 times higher in the under-cap material; lead was 51 times higher and silver was 18 times higher.

At Station C5, mercury was 1.2 ppm in the under-cap sediments and was undetected in the cap. Cadmium was in concentrations 11 times higher in the under-cap sediments; lead was 31 times higher and silver was 10 times higher.

At Station C4 in the first 6-inch sample, levels of arsenic, cadmium, copper, lead, mercury, silver, and zinc were elevated relative to the second 6-inch section and to the rest of the capping material. The higher metals values are apparently caused by clay from the Duwamish River in the sample. The eight metals, however, were all in lower concentrations than the under-cap sediments.

Duwamish River Comparison. Trace metal analysis of the pre-dredge Duwamish River samples showed that concentrations were similar to the cap material core samples, except for the first 6-inch section at Station C4. Arsenic concentrations for within-cap core samples ranged from 8.1 ppm in the third 6 inches at C1 to 6.1 ppm at Stations C1, C2, and C5. The Duwamish River sample concentrations were 5.2 ppm for sample DRC1 and 3.4 ppm for sample DRC3.

Cadmium concentrations for within-cap core samples ranged from being undetected in the second 6-inch sample at Station C2 to 0.14 ppm in the third 6-inch section at Station C1. The Duwamish River sample concentrations were 0.06 ppm for sample DRC1 and 0.2 ppm for sample DRC3.

Results and Comparisons

Lead concentrations for within-cap core samples ranged from being undetected in the second 6-inch section at Station C4 to 10 ppm in the second 6-inch section at Station C1. The Duwamish River concentrations were 18 ppm for sample DRC1 and 17 ppm for sample DRC3.

Mercury concentrations for within-cap core samples ranged from being undetected at most stations to 0.05 ppm in the first 6-inch section at Station C2. The Duwamish River concentrations were 0.158 ppm for sample DRC1 and 0.042 ppm for sample DRC3.

Silver concentrations for within-cap core samples ranged from 0.13 ppm in the first 6-inch section at Station C3 to 0.27 ppm in the second and third 6-inch sections at Station C2. For the Duwamish River samples, silver went undetected in sample DRC1 and was 0.14 ppm for sample DRC3.

Comparison to State Sediment Standards

The state sediment standard list of 47 chemical parameters includes eight metals for comparison in ppm dry weight, seven organic compounds for comparison in ppb dry weight, and 32 organic chemicals and PCBs that are normalized using the total organic carbon content of the sample for comparison to the sediment standards. The standards are composed of Table I, Marine Sediment Quality Standards-Chemical Standards (SQS), and Table III, Marine Sediment Cleanup Screening Levels (CSLs). Tables 4-6 through 4-10 compare the SQS and the CSLs to the section from each core station. These tables also compare the core samples to the nearest surface grab sample. The reported detection limit on the tables is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed the standards but are not so marked because the true detection limit did not exceed the standards.

All of the detected organic chemicals in the capping sands were well below the sediment standards. However, the comparison of detection limits to the standards was complicated by the low total organic carbon content of the capping sands. The low total organic carbon content meant that when the detection limit for some compounds was normalized to total organic carbon, the resulting values regularly exceeded the standards. Detection limits for two compounds, 1,2,4 trichlorobenzene and hexachlorobenzene, exceeded the SQS for at least one sample at every station. Detection limits for 1,2 dichlorobenzene, 1,4 dichlorobenzene, hexachlorobutadiene, and n-nitrosodiphenylamine exceeded the SQS for at least one section at Station C2. The detection limit for 2,4-dimethylphenol exceeded the standards in the first 6-inch section at Station C4.

TABLE 4-6. Sediment Standard Comparison for Core Samples at Station C1

Station:	Standards		Under cap	1st 6"	2nd 6"	3rd 6"	4th 6"	VGS
	Sediment Quality Standards	Cleanup Screening Levels	9201215	9201216	9201217	9201218	9201219	9201096
5/19/92			5/19/92	5/19/92	5/19/92	5/19/92	5/26/92	
Sample#:			54	76	73	74	82	70
Date:			6.3	1.9	7.8	1.2	1.1	1
% Solids:								
% T.O.C. dry								
Naphthalene <i>LPAHs ppm OC</i>	99	170	3.2	<3.5	<0.87	<5.6	<5.5	<4
Acenaphthylene	66	66	4.6	<1.2	<0.29	<1.9	<1.8	<1
Acenaphthene	16	57	3	<0.95	<0.23	<1.5	<1.4	<0.9
Fluorene	23	79	4.8	<1.16	<0.29	<1.9	<1.8	T 1
Phenanthrene	100	480	35	2.2	<0.29	2.8	<1.8	12
Anthracene	220	1,200	19	<1.2	<0.29	<1.9	<1.8	4.6
2-Methylnaphthalene	38	64	T 1	<3.5	<0.59	<3.7	<3.7	<4
Total LPAHs	370	780	71	13.71	2.0	19	18	27.5
Fluoranthene <i>HPAHs ppm OC</i>	160	1,200	7.8	4.1	0.5	5.4	<1.8	20
Pyrene	1,000	1,400	100	3.6	0.56	4.3	<1.8	10
Benzo (a) anthracene	110	270	35	1.6	<0.29	2.7	<1.8	6.9
Chrysene	110	460	55	2.3	<0.29	3	<1.8	10
Total benzo fluoranthenes	230	450	190	T 7	1.7	10	T 10	13
Benzo (a) pyrene	99	210	65	T 2	<0.59	<3.7	<3.7	5.3
Indeno (1,2,3-cd) pyrene	34	88	8.8	<2.3	<0.59	<3.7	<3.7	<2
Dibenzo (a,h) anthracene	12	33	3.2	<3.5	<0.87	<5.6	<5.5	<4
Benzo (g,h,i) perylene	31	78	7.3	2.4	<0.59	<3.7	<3.7	<2
1,2-Dichlorobenzene	2.3	2.3	<0.49	<1.2	<0.29	<1.9	<1.8	<1
1,4-Dichlorobenzene	3.1	9	<0.49	<1.2	<0.29	<1.9*	<1.8*	<1*
1,2,4-Trichlorobenzene	0.81	1.8	<0.49	<1.2	<0.29	<1.9*	<1.8*	<1*
Hexachlorobenzene	0.38	2.3	<0.49	<1.2	<0.29	<1.9*	<1.8*	<1*
Total HPAHs	960	5,300	480	33.6	7.2	50	42	79.2
<i>ppm OC</i>								
Dimethyl phthalate	53	53	<0.3	<0.68	<0.17	<1.2	<1.1	<0.7
Diethyl phthalate	61	110	<0.98	<2.3	<0.59	<3.7	<3.7	<2
Di-n-butyl phthalate	220	1,700	<0.98	B < 5.3	B < 0.59	B < 3.7	B < 3.7	B < 2
Butyl benzyl phthalate	4.9	64	2.2	<1.2	<0.29	<1.9	<1.8	<1
Bis (2-ethylhexyl) phthalate	47	78	28	3.7	0.66	6.2	<1.8	B < 1
Di-n-octyl phthalate	58	4,500	<0.49	<1.2	<0.29	<1.9	<1.8	<1
Dibenzofuran	15	58	2.7	<2.3	<0.59	<3.7	<3.7	<2
Hexachlorobutadiene	3.9	6.2	<0.98	<2.3	<0.59	<3.7	<3.7	<2
N-nitrosodiphenylamine	11	11	<3	<6.8	<1.79	<12	<11	B < 2
Total PCBs	12	65	20*	<2.3	<0.73	<7.1	<6.5	<2
<i>ppb dry</i>								
Phenol	420	1,200	<190	<130	<140	<140	<120	<70
2-methylphenol	63	63	<62	<44	<46	<45	<41	<20
4-methylphenol	670	670	<62	<44	<46	<45	<41	<20
2,4-dimethyl phenol	29	29	<62**	<44	<46	<45	<41	<20
Pentachlorophenol	360	690	<62	<44	<46	<45	<41	<20
Benzyl alcohol	57	73	<62	<44	<46	<45	<41	<20
Benzoic Acid	650	650	<190	<130	<140	<140	<120	<70
<i>Metals ppm dry</i>								
Arsenic	57	93	30	7.9	6.8	8.1	6.1	E 4.3
Cadmium	5.1	6.7	E 7.8**	E 0.13	E 0.12	E 0.14	E 0.12	E 0.14
Chromium	260	270	G 94	G 13	G 13	G 13	G 10	12
Copper	390	390	180	12	13	11	9.9	12
Lead	450	530	330	5.3	10	5.4	3.7	5.7
Mercury	0.41	0.59	E 3.1**	E 0.039	E < 0.03	E < 0.03	E 0.02	0.13
Silver	6.1	6.1	G 12**	G 0.26	G 0.27	G 0.27	G 0.24	0.29
Zinc	410	960	G 440*	G 42	G 45	G 41	G 40	44

E - Estimate
T - Detected below quantification limits.
G - Estimate is greater than value shown.
*Exceeds Marine Sediment Cleanup Screening Levels.
**Exceeds Marine Sediment Quality Standards.
The reported organic detection limit is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed sediment standards but are not so marked because the true detection limit did not exceed sediment standards.
For further information on data qualifiers see Appendix B.

Results and Comparisons

Station:	Standards		Under cap	1st 6"	2nd 6"	3rd 6"	4th 6"	VC1	
Sample#:	Sediment Quality Standards	Cleanup Screening Levels	9201210	9201211	9201212	9201213	9201214	9201098	
Date:			5/19/92	5/19/92	5/19/92	5/19/92	5/19/92	5/26/92	
% Solids:			54	80	80	82	79	74	
% T.O.C. dry			6.5	0.33	0.77	1.8	0.56	1.2	
Naphthalene	LPAs ppm OC	99	170	2.5	< 19	< 8.2	< 3.4	< 11	< 2.5
Acenaphthylene		66	66	3.1	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
Acenaphthene		16	57	2.5	< 5.2	< 2.2	< 0.89	< 3	< 0.75
Fluorene		23	79	3.4	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
Phenanthrene		100	480	35	< 6.4	< 2.7	< 1.1	< 3.7	T 0.8
Anthracene		220	1,200	11	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
2-Methylnaphthalene		38	64	T 70	< 19	< 8.2	< 3.4	< 11	< 2.5
Total LPAHs		370	780	59	68.8	29	12	40	9.07
Fluoranthene	HPAs ppm OC	160	1,200	57	< 7.6	< 3.2	< 1.3	< 4.5	3.8
Pyrene		1,000	1,400	41	< 6.4	< 2.7	< 1.1	< 3.7	2.5
Benzo (a) anthracene		110	270	31	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
Chrysene		110	460	41	< 6.4	< 2.7	< 1.1	< 3.7	T 2
Total benzo fluoranthenes		230	450	160	< 38	16	6.7	22	< 5.8
Benzo (a) pyrene		99	210	63	< 13	< 5.4	< 2.3	< 7.5	< 1.7
Indeno (1,2,3-cd) pyrene		34	88	7.5	< 13	< 5.4	< 2.3	< 7.5	< 1.7
Dibenzo (a,h) anthracene		12	33	2.8	< 19	< 8.2	< 3.4	< 11	< 2.5
Benzo (g,h,i) perylene		31	78	4.9	< 13	< 5.4	< 2.3	< 7.5	< 1.7
1,2-Dichlorobenzene		2.3	2.3	< 0.48	< 6.4**	< 2.7	< 1.1	< 3.7	< 0.83
1,4-Dichlorobenzene		3.1	9	< 0.48	< 6.4*	< 2.7	< 1.1	< 3.7	< 0.83
1,2,4-Trichlorobenzene		0.81	1.8	< 0.48	< 6.4**	< 2.7*	< 1.1	< 3.7*	< 0.83
Hexachlorobenzene		0.38	2.3	< 0.48	< 6.4**	< 2.7*	< 1.1*	< 3.7*	< 0.83*
Total HPAHs		960	5,300	490	148.4	44	18	61	25
	ppm OC								
Dimethyl phthalate		53	53	< 0.29	< 3.9	< 1.7	< 0.67	< 2.3	< 0.58
Diethyl phthalate		61	110	< 0.95	< 13	< 5.4	< 2.3	< 7.5	< 1.7
Di-n-butyl phthalate		220	1,700	B < 0.95	B < 33	B < 5.4	B < 2.3	B < 7.5	B < 1.7
Butyl benzyl phthalate		4.9	64	0.7	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
Bis (2-ethylhexyl) phthalate		47	78	8	< 6.4	16	< 1.1	< 3.7	B < 0.83
Di-n-octyl phthalate		58	4,500	< 0.48	< 6.4	< 2.7	< 1.1	< 3.7	< 0.83
Dibenzofuran		15	58	1.8	< 13	< 5.4	< 2.3	< 7.5	< 1.7
Hexachlorobutadiene		3.9	6.2	< 0.95	< 13**	< 5.4	< 2.3	< 7.5	< 1.7
N-nitrosodiphenylamine		11	11	B < 2.9	B < 33**	< 17	< 6.7	< 23**	B < 1.7
Total PCBs		12	65	54*	< 13	< 5.4	< 2.3	< 7.5	< 1.7
Phenol	ppb dry	420	1,200	< 190	< 130	< 130	< 120	< 130	< 70
2-methylphenol		63	63	< 62	< 42	< 42	< 41	< 42	< 20
4-methylphenol		670	670	< 62	< 42	< 42	< 41	< 42	< 20
2,4-dimethyl phenol		29	29	< 62**	< 42	< 42	< 41	< 42	< 20
Pentachlorophenol		360	690	< 62	< 42	< 42	< 41	< 42	< 20
Benzyl alcohol		57	73	< 62	< 42	< 42	< 41	< 42	< 20
Benzoic Acid		650	650	< 190	< 130	T 67	< 120	< 130	< 70
Arsenic	Metals ppm dry	57	93	24	7.5	6.3	6.1	6.3	E 5.4
Cadmium		5.1	6.7	E 6.5*	E 0.11	E < 0.1	0.12	0.11	E 0.14
Chromium		260	270	G 98	G 11	G 11	11	12	13
Copper		390	390	200	9.7	10	10	12	16
Lead		450	530	260	3.8	3.8	4.9	8.9	5.4
Mercury		0.41	0.59	E 4.8**	E 0.05	E < 0.03	< 0.024	< 0.025	0.04
Silver		6.1	6.1	G 14**	G 0.25	G 0.25	0.24	0.25	0.27
Zinc		410	960	G 300	G 39	G 40	41	56	45

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

The reported organic detection limit is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed sediment standards but are not so marked because the true detection limit did not exceed sediment standards.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

*Exceeds Marine Sediment Quality Standards.

Results and Comparisons

Station:	Standards		Under cap	1st 6"	2nd 6"	3rd 6"	VG7
Sample#:	Sediment Quality Standards	Cleanup Screening Levels	9201220	9201221	9201222	9201223	9201104
Date:			5/19/92	5/19/92	5/19/92	5/19/92	5/27/92
% Solids:			55	76	79	84	78
% T.O.C. dry			4.9	2.3	0.9	1.2	0.33
Naphthalene <i>LPAHs ppm OC</i>	99	170	3.7	< 2.9	<7	<5	E < 9.1
Acenaphthylene	66	66	3.9	< 0.96	<2.3	<1.7	E < 3
Acenaphthene	16	57	2.4	< 0.78	<1.8	<1.3	E < 2.4
Fluorene	23	79	2.2	< 0.96	<2.3	<1.7	E < 3
Phenanthrene	100	480	15	1.8	<2.3	<1.7	E 9.4
Anthracene	220	1,200	7.3	< 0.96	<2.3	<1.7	E < 3
2-Methylnaphthalene	38	64	1.9	< 2.9	<7	<5	E < 9.1
Total LPAHs	370	780	36	11.26	25	18	39
Fluoranthene <i>HPAHs ppm OC</i>	160	1,200	20	2.9	T 1	<2	E 14
Pyrene	1,000	1,400	53	2.8	<2.3	<1.7	E 10
Benzo (a) anthracene	110	270	17	1.3	<2.3	<1.7	E < 3
Chrysene	110	460	41	1.3	<2.3	<1.7	E 6.1
Total benzo fluoranthenes	230	450	71	T 5	14	10	E < 18.2
Benzo (a) pyrene	99	210	35	< 1.9	<4.7	<3.3	E < 6.1
Indeno (1,2,3-cd) pyrene	34	88	8.8	< 1.9	<4.7	<3.3	E < 9.1
Dibenzo (a,h) anthracene	12	33	<1.9	< 2.9	<7	<5	E < 6.1
Benzo (g,h,i) perylene	31	78	11	< 1.9	<4.7	<3.3	E < 12
1,2-Dichlorobenzene	2.3	2.3	<0.61	< 0.96	<2.3	<1.7	E < 3**
1,4-Dichlorobenzene	3.1	9	<0.61	< 0.96	<2.3	<1.7	E < 3
1,2,4-Trichlorobenzene	0.81	1.8	<0.61	< 0.96	<2.3*	<1.7*	E < 3**
Hexachlorobenzene	0.38	2.3	<0.61	< 0.96*	<2.3*	<1.7*	E < 3**
Total HPAHs	960	5,300	260	25.54	54	39	96.6
<i>ppm OC</i>							
Dimethyl phthalate	53	53	<.37	< 0.57	<1.4	<1	E < 1.8
Diethyl phthalate	61	110	<1.2	< 1.9	<4.7	<3.3	E < 6.1
Di-n-butyl phthalate	220	1,700	B <1.2	B < 4.2	B <4.7	B <3.3	BE < 6.1
Butyl benzyl phthalate	4.9	64	<0.61	< 0.96	<2.3	<1.7	E < 3
Bis (2-ethylhexyl) phthalate	47	78	2.4	2	<2.3	<1.7	BE < 3
Di-n-octyl phthalate	58	4,500	<0.61	< 0.96	<2.3	<1.7	E < 3
Dibenzofuran	15	58	2.4	< 1.9	<4.7	<3.3	E < 6.1
Hexachlorobutadiene	3.9	6.2	<1.2	< 1.9	<4.7	<3.3	E < 6.1*
N-nitrosodiphenylamine	11	11	<1.2	< 1.9	<4.7	<3.3	BE < 6.1
Total PCBs	12	65	2.6	< 1.9	<4.7	<3.3	< 6.1
Phenol <i>ppb dry</i>	420	1,200	<180	< 130	<130	<120	< 60
2-methylphenol	63	63	<61	< 44	<42	<40	< 20
4-methylphenol	670	670	230	< 44	<42	<40	< 20
2,4-dimethyl phenol	29	29	<61**	< 44	<42	<40	< 20
Pentachlorophenol	360	690	<61	< 44	<42	<40	< 20
Benzyl alcohol	57	73	<61	< 44	<42	<40	E < 20
Benzoic Acid	650	650	<180	< 130	<130	<120	< 60
<i>Metals ppm dry</i>							
Arsenic	57	93	22	6.6	7.6	7.1	E 2.6
Cadmium	5.1	6.7	E 1.8	E 0.11	E 0.13	E 0.12	E 0.13
Chromium	260	270	G 35	G 12	G 11	G 10	11
Copper	390	390	130	12	11	9.2	12
Lead	450	530	200	3.9	3.8	3.6	5.1
Mercury	0.41	0.59	E 2.7**	E < 0.03	< 0.03	< 0.02	< 0.03
Silver	6.1	6.1	G 4.5	G 0.13	G 0.25	G 0.24	0.26
Zinc	410	960	G 200	G 39	G 41	G 37	41

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

The reported organic detection limit is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed sediment standards but are not so marked because the true detection limit did not exceed sediment standards.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

*Exceeds Marine Sediment Quality Standards.

Results and Comparisons

TABLE 4-9. Sediment Standard Comparison for Core Samples at Station C4							
Station:	Standards		Under cap	1st 6"	2nd 6"	VG3	
Sample#:	Sediment Quality Standards	Cleanup Screening Levels	9201224	9201225	9201226	9201101	
Date:			5/19/92	5/19/92	5/19/92	5/27/92	
% Solids:			53	51	79	69	
% T.O.C. dry			6	2.5	0.75	0.92	
Naphthalene	LPAHs ppm OC	99	170	3.7	<3.9	<8.4	< 4.3
Acenaphthylene		66	66	3.8	<1.3	<2.8	< 1.1
Acenaphthene		16	57	1.8	<1	<2.3	< 1
Fluorene		23	79	2.8	<1.3	<2.8	<1.1
Phenanthrene		100	480	18	6.8	<2.8	4.5
Anthracene		220	1,200	8.5	4.4	<2.8	T 2
2-Methylnaphthalene		38	64	1.6	<3.9	<8.4	< 4.3
Total LPAHs		370	780	41	23	30	18.5
Fluoranthene	HPAHs ppm OC	160	1,200	33	9.6	<3.3	7.3
Pyrene		1,000	1,400	110	19	<2.8	5.9
Benzo (a) anthracene		110	270	15	7.2	<2.8	3.3
Chrysene		110	460	23	8	<2.8	4.2
Total benzo fluoranthenes		230	450	120	7.8	<17	< 9.7
Benzo (a) pyrene		99	210	47	<2.6	<5.6	< 2.2
Indeno (1,2,3-cd) pyrene		34	88	6.7	<2.6	<5.6	< 2.2
Dibenzo (a,h) anthracene		12	33	<1.6	<3.9	<8.4	< 4.3
Benzo (g,h,i) perylene		31	78	4.2	<2.6	<5.6	< 2.2
1,2-Dichlorobenzene		2.3	2.3	<0.52	<1.3	<2.8	< 1.1
1,4-Dichlorobenzene		3.1	9	<0.52	<1.3	<2.8	< 1.1
1,2,4-Trichlorobenzene		0.81	1.8	<0.52	<1.3	<2.8*	< 1.1*
Hexachlorobenzene		0.38	2.3	<0.52	<1.3*	<2.8*	< 1.1*
Total HPAHs		960	5,300	370	68	65	45.7
ppm OC							
Dimethyl phthalate		53	53	<0.32	<0.8	<1.7	< 0.76
Diethyl phthalate		61	110	<1	<2.6	<5.6	< 2.2
Di-n-butyl phthalate		220	1,700	B < 2.3	B <5.6	B <5.7	B < 2.2
Butyl benzyl phthalate		4.9	64	9.2*	<1.3	<2.8	< 1.1
Bis (2-ethylhexyl) phthalate		47	78	1.8	<1.3	<2.8	B < 1.1
Di-n-octyl phthalate		58	4,500	<0.52	<1.3	<2.8	< 1.1
Dibenzofuran		15	58	1.8	<2.6	<5.6	< 2.2
Hexachlorobutadiene		3.9	6.2	<1	<2.6	<5.6	< 2.2
N-nitrosodiphenylamine		11	11	<1	<2.6	<5.6	B < 2.2
Total PCBs		12	65	T 0.7	<2.6	<5.6	< 2.2
Phenol	ppb dry	420	1,200	<190	<200	E <130	< 70
2-methylphenol		63	63	<63	<65	E <42	< 20
4-methylphenol		670	670	<63	<65	E <42	< 20
2,4-dimethyl phenol		29	29	<63**	<65**	E <42	< 20
Pentachlorophenol		360	690	<63	<65	<42	< 20
Benzyl alcohol		57	73	<63	<65	<42	< 20
Benzoic Acid		650	650	<190	<200	<130	T 80
Arsenic	Metals ppm dry	57	93	17	16	6.3	E 4.3
Cadmium		5.1	6.7	E 1.5	E 1.1	E 0.089	E 0.14
Chromium		260	270	G 26	G 31	G 11	13
Copper		390	390	120	65	9.5	13
Lead		450	530	170	100	3.8	5.8
Mercury		0.41	0.59	E 3**	E 1.5**	0.03	0.029
Silver		6.1	6.1	G 4	G 3.3	G 0.25	0.29
Zinc		410	960	G 160	130	G 38	48

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

The reported organic detection limit is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed sediment standards but are not so marked because the true detection limit did not exceed sediment standards.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

*Exceeds Marine Sediment Quality Standards.

TABLE 4-10. Sediment Standard Comparison for Core Samples at Station C5

Station:	Standards		Under cap	1st 6"	2nd 6"	VG4	
Sample#:	Sediment Quality Standards	Cleanup Screening Levels	9201227	9201228	9201229	9201099	
Date:			5/19/92	5/19/92	5/19/92	5/27/92	
% Solids:			61	82	73	74	
% T.O.C. dry			4	0.73	0.74	4.8	
Naphthalene	LPAHs ppm OC	99	170	2.2	<11	<8.5	< 0.63
Acenaphthylene		66	66	1.2	<3.7	<2.8	< 0.21
Acenaphthene		16	57	0.78	<3	<2.3	< 0.19
Fluorene		23	79	1.3	<3.7	<2.8	< 0.21
Phenanthrene		100	480	9.8	<3.7	<2.8	1.1
Anthracene		220	1,200	5	<3.7	<2.8	T 0.4
2-Methylnaphthalene		38	64	< 2.1	<11	<8.5	< 0.63
Total LPAHs		370	780	20.28	40	31	3.39
Fluoranthene	HPAHs ppm OC	160	1,200	14	<4.5	<3.4	1.7
Pyrene		1,000	1,400	23	<3.7	<2.8	1.3
Benzo (a) anthracene		110	270	9.8	<3.7	<2.8	< 0.21
Chrysene		110	460	10	<3.7	<2.8	1
Total benzo fluoranthenes		230	450	38.5	<22	<17	< 2.13
Benzo (a) pyrene		99	210	13	<7.5	<5.7	T 0.6
Indeno (1,2,3-cd) pyrene		34	88	< 1.4	<7.5	<5.7	< 0.42
Dibenzo (a,h) anthracene		12	33	< 2.1	<11	<8.5	< 0.63
Benzo (g,h,i) perylene		31	78	< 1.4	<7.5	<5.7	< 0.42
1,2-Dichlorobenzene		2.3	2.3	< 0.68	<3.7	<2.8	< 0.21
1,4-Dichlorobenzene		3.1	9	< 0.68	<3.7	<2.8	< 0.21
1,2,4-Trichlorobenzene		0.81	1.8	< 0.68	<3.7*	<2.8*	< 0.21
Hexachlorobenzene		0.38	2.3	< 0.68	<3.7*	<2.8*	< 0.21
Total HPAHs		960	5,300	115.92	86	66	9.28
	ppm OC						
Dimethyl phthalate		53	53	< 0.4	<2.1	<1.7	< 0.15
Diethyl phthalate		61	110	< 1.4	<7.5	<5.7	< 0.42
Di-n-butyl phthalate		220	1,700	B < 3	<7.5	<5.7	B < 0.42
Butyl benzyl phthalate		4.9	64	< 0.68	<3.7	<2.8	< 0.21
Bis (2-ethylhexyl) phthalate		47	78	< 0.68	<3.7	<2.8	B < 0.21
Di-n-octyl phthalate		58	4,500	< 0.68	<3.7	<2.8	< 0.21
Dibenzofuran		15	58	T 0.7	<7.5	<5.7	< 0.42
Hexachlorobutadiene		3.9	6.2	< 1.4	<7.5	<5.7	< 0.42
N-nitrosodiphenylamine		11	11	< 1.4	<7.5	<5.7	B < 0.42
Total PCBs		12	65	5.8	<7.5	<5.6	< 0.42
Phenol	ppb dry	420	1,200	<160	<160	<130	< 70
2-methylphenol		63	63	<55	<55	<42	< 20
4-methylphenol		670	670	<55	<55	<42	< 20
2,4-dimethyl phenol		29	29	<55	<55	<42	< 20
Pentachlorophenol		360	690	<55	<55	<42	< 20
Benzyl alcohol		57	73	<55	<55	<42	< 20
Benzoic Acid		650	650	<160	<160	<130	< 70
Arsenic	Metals ppm dry	57	93	18	6.1	7.5	E 4.1
Cadmium		5.1	6.7	E 1.4	E 0.098	E 0.13	E 0.12
Chromium		260	270	G 39	G 11	G 11	12
Copper		390	390	75	9.4	9.3	13
Lead		450	530	120	3.7	3.8	5.4
Mercury		0.41	0.59	E 1.2**	E < 0.02	E < 0.03	0.041
Silver		6.1	6.1	G 2.6	G 0.24	G 0.25	0.27
Zinc		410	960	G 140	G 40	G 40	45

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

The reported organic detection limit is a quantification limit that is approximately twice the true detection limit. Some detection limits exceed sediment standards but are not so marked because the true detection limit did not exceed sediment standards.

For further information on data qualifiers see Appendix B.

E - Estimate

T - Detected below quantification limits.

*Exceeds Marine Sediment Quality Standards.

Results and Comparisons

The concentrations of trace metals were below the sediment standards for all sections at all stations except the first 6-inch section at Station C4, where mercury exceeded the CSL with 1.5 ppm. All metals in this section were elevated relative to the rest of the within-cap samples at all other stations, apparently because of clay in the dredged capping material.

The under-cap samples showed several detected chemicals that exceeded the sediment standards. Mercury exceeded the CSLs at all stations. Silver exceeded the CSLs at Stations C1 and C2. Cadmium exceeded the CSLs at Station C1 and the SQS at Station C2. Total PCBs were the only detected organic compounds above the sediment standards; they exceeded the SQS at Stations C1 and C2. Detection limits for 2,4-dimethyl phenol exceeded the standards at Stations C1, C2, C3, and C4.

Particle Size Distribution

Sediment size analysis of each core section showed that 80 percent of the capping material is 1 to 2 phi medium-grained sands. Adding in 3 to 4 phi fine sands showed that medium plus fine sands 1 to 4 phi accounted for 98 percent of the cap material. In contrast, the under-cap samples were generally made up of 70 percent silts and clays. The under-cap samples showed that the native sediments are made up of some sands but are mostly silts and clays (see Table 4-11).

DISCUSSION

Core samples showed the expected dissimilarity between the cap sediments and the under-cap sediments. The core samples also showed the expected similarities with the Duwamish Waterway Sediment Study. However, there were two differences. First, some organic compounds were detected in slightly higher concentrations in the first 6 inches at Station C4 than the rest of the samples. Second, one of the Duwamish River sediment samples showed higher concentrations of certain contaminants in the pre-dredge sediment than the cap sediments.

Duwamish Waterway Sediment Study

A comparison between the chemical concentrations of the Duwamish waterway sediments and the capping sediments show that more chemicals were detected in one composite sample of the Duwamish sediments. A possible

Table 4-11. Summary of Particle Size Distribution for Core Samples

Units are Percentage of Sample			
	1 to 2 phi	-1 to 4 phi	5 to <12 phi
C1 First 6"	77	91	9
C1 Second 6"	77	91	9
C1 Third 6"	77	89	11
C1 Fourth 6"	87	98	2
C2 First 6"	88	99	1
C2 Second 6"	85	98	2
C2 Third 6"	84	98	2
C2 Fourth 6"	86	98	2
C3 First 6"	75	88	12
C3 Second 6"	83	97	3
C4 First 6"	74	89	11
C5 First 6"	86	98	2
C1 Under-cap	14	30	70
C2 Under-cap	12	32	68
C3 Under-cap	9	29	71
C4 Under-cap	7	16	84
C5 Under-cap	6	17	83

explanation for this is how the samples were composited. During the study of the Duwamish sediments, the sample collection team formed two composite samples characterizing the sediments that would be used at the Pier 53 site. One of the composite samples (C3) contained two core samples from an area downstream of the area where the Pier 53 capping sediments were dredged. Other samples showed this downstream area to have higher concentrations of the organic compounds phenanthrene, fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene. Therefore, the Duwamish sample DRC3 likely contained additional chemicals that were not characteristic of the cap material.

Contaminants in Lower 6 Inches of Cap

Chemical levels in the lower 6 inches of the cap will be monitored over time to look for increases that could indicate the migration of chemicals up into the cap from the underlying contaminated sediment. The 1992 cores were taken 2 months after cap placement and will serve as the background for future measurements.

Discussion

Also, it is important to recognize that there are at least two other factors besides chemical migration that could cause increased chemical levels in the lower 6 inches of the cap. These other factors are (1) bottom sediment mixing with the capping material during placement and (2) the presence of bands of clay in the sediment capping material. The detection of organic compounds in the lower 6 inches of three out of five core samples likely reflects one or a combination of factors, although it is probably too soon to reflect migration.

Mixing During Placement. During cap placement, the barge operator spread the sand 6 inches at a time. The descending sand impacted the contaminated bottom, creating currents and some physical displacement that could suspend some of the contaminants in the water column. The contaminants would then settle with the first layer. During subsequent applications of sand, the same process would occur, but less contaminants would be displaced, resulting in undetectable amounts of compounds in the layers higher up in the cap.

Sediment mixing does not appear to be the explanation for the elevated chemical concentration in the first 6-inch section at Station C4, however. If the chemicals in the first section are elevated uniformly (Table 4-4), it would indicate that a process such as mixing occurred, by which all chemicals were selected equally as opposed to leaching or another process that would select particular metals. Sediment mixing does not explain why the compounds benzo(a, k)fluoranthene and benzo(a)pyrene were not also found in concentrations similar to those of fluoranthene, pyrene, benzo(a)anthracene, and chrysene.

Clay Bands. The log documenting the core cutting procedures indicated that black clay bands interlaced the sample from the first 6-inch section at Station C4. This same black clay was noticed as cohesive clasts during surface grab and core sampling procedures and also during the sediment-profile-camera survey and the video camera survey. The clay appears to have been dredged along with the sand from the Duwamish River. The Denny Way sediment cap monitoring team also noticed the clay, as capping material for the Denny Way project also came from the Duwamish River.

Other indicators of clay in the first 6-inch section at Station C4 include lower total solids percentage, higher total organic carbon percentage, higher concentrations of iron and aluminum, and particle sizes that show more clays and silts. The clean capping sand has a low water content, making the total solids much higher than the clay. Solids are 51 percent in the sample taken from the first 6 inches at Station C4 and resemble clay or silt more than the sandy material higher up at Station C4 and other coring stations. In addition, the sample has a

higher percentage of total organic carbon and higher levels of aluminum and iron. The clay tends to be correlated with elevated levels of metals and organics in the samples in which it appears; but there are no specific studies or chemical characterizations of the clay. Since the clay came from the turning basin sediments and is in small amounts, it probably has little effect on overall sediment quality of the capping sand, but it can cause isolated increases in sediment chemical concentrations.

Chemical Migration From Below. A third possible reason for chemical elevations in the first 6 inches of the cap is that chemicals have migrated from the under-cap sediments into the capping sediments. Chemicals that are most likely to be detected due to migration are the compounds with the highest concentrations under the cap. High concentrations of organics exist under the cap at all four stations C1 through C4. While organics were detected at three of the four stations, the findings at C4 may be attributed to clay in the sample. At the remaining two stations, the concentrations of chemicals in the first 6 inches at C1 and C3 are low, ranging between 77 and 29 ppb. These concentrations are very close to detection limits for both the Pier 53 and the Duwamish sediment analysis and their presence as detected compounds could vary between sampling tests. To conclusively determine whether chemicals are migrating into the capping materials, future monitoring of Pier 53 is needed.

SECTION 5

SURFACE SEDIMENT CHEMISTRY OF CAP AND SURROUNDING AREAS

On May 26 and 27, 1992, the monitoring team collected surface sediment samples from the cap, the ENR, and surrounding areas near the cap. The samples were analyzed for metals and organic chemicals to establish baseline data on the distribution of chemicals in the study area. The monitoring plan requires comparison of surface samples from subsequent years to the baseline samples to identify trends. The baseline study is reported in this section and compared to the state sediment standards to establish whether the cap meets the state cleanup standards. Also, if the cap becomes recontaminated, surface sediment monitoring may help to determine contamination sources.

In addition to information about the cap surface, EPA and Ecology requested that the surface contamination of adjacent property be examined to provide information on the extent of sediment contamination in the area. If significant concentrations of chemicals accumulate on the cap surface, the monitoring team will evaluate the data from the surrounding sites to determine whether they are a contributing source.

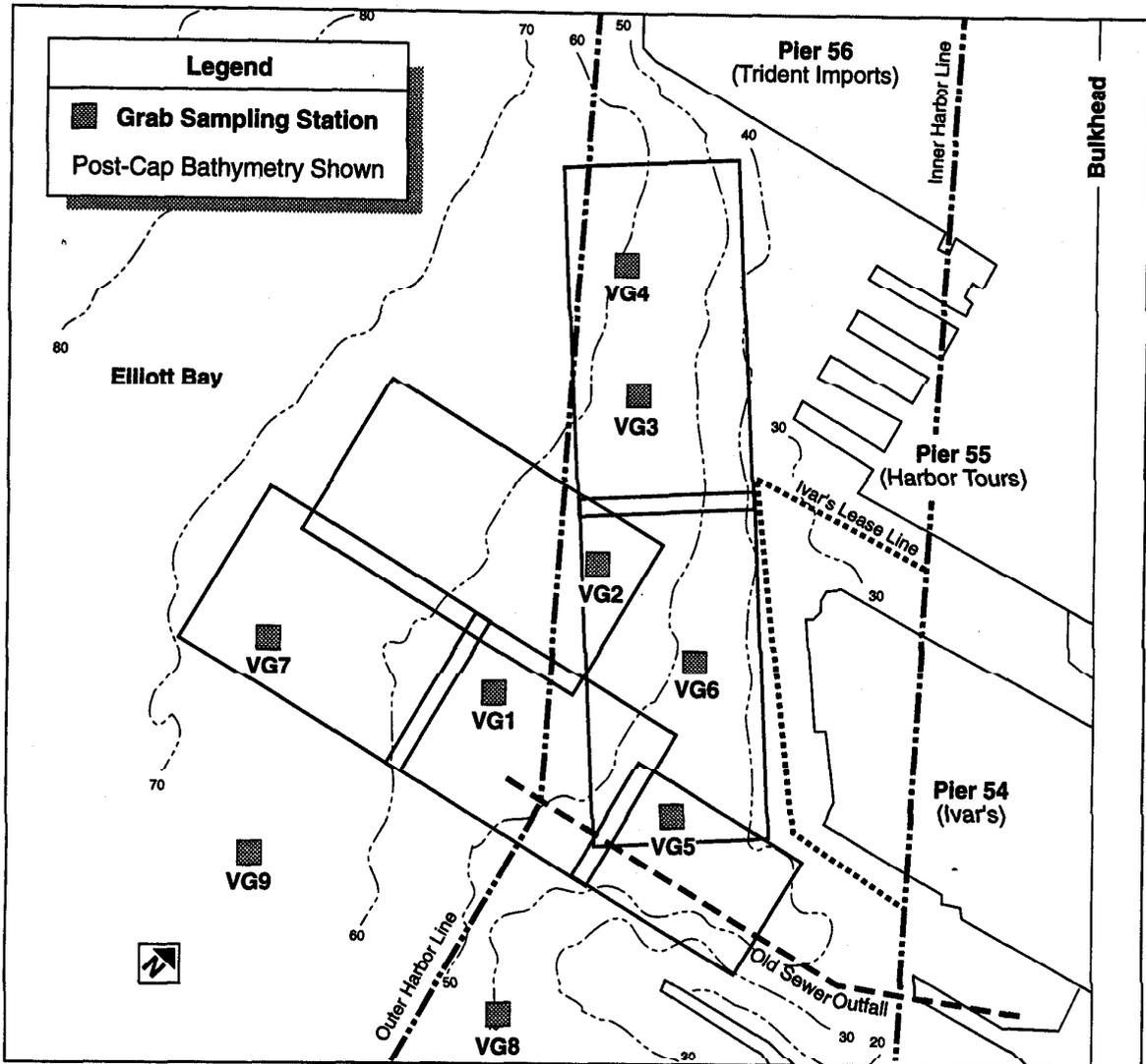
METHODS

The monitoring plan defined seven surface sampling stations (VG-1 through VG-7), which provide spatial coverage across the Pier 53 cap (see Map 5-1). The monitoring team collected sediment chemistry samples from all seven stations in May of 1992.

Benthic taxonomy samples were taken from four stations, VG-1 through VG-4, in August 1992. Four stations (VG3, VG4, VG5, and VG6) were placed along the centerline of the ENR, parallel to the shoreline. The remaining three stations (VG-1, VG2, and VG-7) provide coverage of the deeper sections of the sediment cap.

The monitoring plan also prescribed six surface sampling stations outside the boundary of the capping site to define surrounding sediment conditions that could influence the cap. Two of the stations (VG-8 and VG-9), directly offshore from the

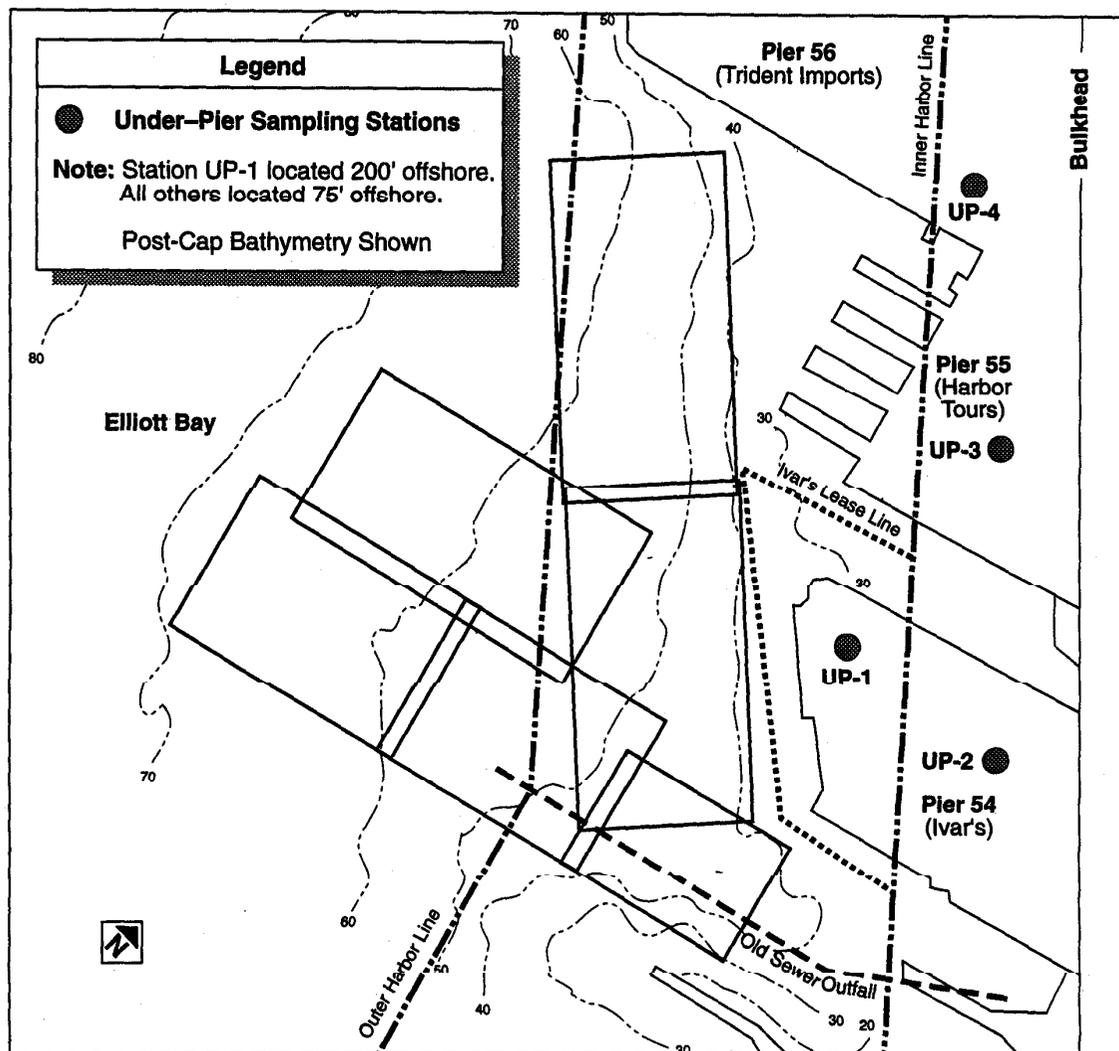
Methods



Map 5-1. On-Cap Surface Sampling Stations

ferry terminal, were situated to cover the area along the southern boundary of the cap. The remaining four stations (UP-1 to UP-4) are under piers inshore and east of the capping area (see Map 5-2).

Different sampling methods were required for sampling under the pier and outside the pier. Under the pier, the monitoring team collected the surface sediment samples with a 20-square-centimeter Van Veen grab sampler operated by hand from an aluminum skiff. Outside the piers, subtidal sediment samples were



Map 5-2. Under-Pier Surface Sampling Stations

collected with a 0.1-square-meter Van Veen grab sampler operated from the research vessel, *R V Liberty*. When possible, three individual grabs were taken at each station. Field personnel then used a stainless-steel "cookie cutter" sampler to remove a 2-cm-deep subsample from the top of each grab sample. They collected three grab samples at each station, taking one subsample from each grab sample. They composited the three subsamples in a 4-liter beaker that had been cleaned in a muffle furnace at 500° C. At the stations on the cap, only the top 2 cm were collected, in order to reflect the most recent conditions for future sampling.

Methods

At some stations surrounding the cap, a 10-cm-deep subsample was taken in addition to the 2-cm surface subsample. These subsamples extended to the bottom of the grab sample and were a composite of three grab samples. These 10-cm samples are noted in Table 5-2 and in Appendix B. The extra sediment in the deeper samples gives a clearer picture of the depth and concentration of toxic sediments in the areas surrounding the cap and whether there is any difference in concentrations in the deeper samples that represent biologically active depths.

The Metro environmental laboratory analyzed the samples for metals, organic priority pollutants, and particle size distribution. Amtest laboratory analyzed the samples for total organic carbon, enabling comparison of the samples to the state sediment standards. The under-pier samples, UP-1 through UP-4, were collected and analyzed twice, because one group of organic parameters was inadvertently omitted on the first samples.

RESULTS

Tables 5-1 through 5-3 show the dramatic difference between the low organic compound concentrations on the surface of the cap and the higher concentrations on the sediments surrounding the cap. Metals concentrations were also much lower on the cap than in the surrounding area. The metal and organic concentrations were especially high at the under-pier (inshore) sampling sites compared to the surrounding area samples.

On the cap, chemical concentrations were nearly uniform over the entire surface. Typically less than eight organic chemicals were above detection limits, and these were at consistently low concentrations. These conditions are similar to those found in core samples from within the cap, and in the study of the Duwamish River sediments.

Cap-Surface Samples

Organic Compounds. Only eight organic PAH compounds were detected on the surface of the sediment cap. The organic compounds most frequently above detection limits were one LPAH (phenanthrene), and three HPAHs (fluoranthene, pyrene, and chrysene). Where these compounds were detected, they were in low concentrations. Phenanthrene concentrations ranged from 10 to 120 ppb dry weight, while fluoranthene ranged from 46 to 200 ppb; pyrene ranged from 30 to

TABLE 5-1. Detected Chemicals in Surface Grab Samples On Cap

Station:	VG1	VG2	VG3	VG4	VG5	VG6	VG7
Sample#:	9201098	9201105	9201101	9201099	9201096	9201097	9201104
Date:	5/26/92	5/27/92	5/27/92	5/27/92	5/26/92	5/26/92	5/27/92
% Solids:	74.00	62.00	69.00	74.00	70.00	66.00	78.00
Compound Name		Values in Dry Weight					
LPAH (ppb)							
Phenanthrene	T 10	60	41	51	120	56	E 31
Anthracene	<10	T 20	T 20	T 20	46	20	E <10
HPAH (ppb)							
Fluoranthene	46	110	67	81	200	88	E 46
Pyrene	30	79	54	62	100	58	E 33
Benzo (a) anthracene	<10	<10	30	<10	69	39	E <10
Chrysene	20	60	39	50	100	52	E 20
Benzo (b) fluoranthene	T 40	T 70	T 50	70	110	T 70	E <30
Benzo (k) fluoranthene	<30	<40	<40	<30	T 40	<30	E <30
Benzo (a) pyrene	<20	T 30	<20	T 30	53	T 30	E <20
Metals (ppm)							
Aluminum	9,600	13,000	10,000	9,600	9,600	10,000	8,500
Antimony	G 1.4	G 1.6	G 1.4	T 1.4	G 1.4	G 1.5	G 1.3
Arsenic	E 5.4	E 3.2	E 4.3	E 4.1	E 4.3	E 4.5	E 2.6
Beryllium	0.27	0.32	0.29	0.27	0.29	0.3	0.26
Cadmium	E 0.14	E 0.16	E 0.14	E 0.12	E 0.14	E 0.15	E 0.13
Chromium	13	15	13	12	12	17	11
Copper	16	18	13	13	12	13	12
Iron	15,000	19,000	16,000	16,000	16,000	15,000	14,000
Lead	5.4	6.5	5.8	5.4	5.7	6.1	5.1
Manganese	190	260	190	200	210	200	190
Mercury	0.041	0.27	0.029	0.041	0.13	0.03	<0.026
Nickel	11	13	12	11	12	11	11
Selenium	<3	<2	<4	<3	<1	<2	<1
Silver	0.27	0.32	0.29	0.27	0.29	0.3	0.26
Thallium	11	15	10	9.5	7.1	11	9
Zinc	45	53	48	45	44	44	41

E - Estimate

T - Detected below quantification limit.

G - Estimate is greater than value shown.

100 ppb, and chrysene ranged from 20 to 100 ppb. Spatially, the data show that station VG5 had slightly higher values and a few more detected compounds than other on-cap surface samples. VG5 is closest to shore in an area of the highest pre-cap contamination and is near two edges of the cap where contaminants surrounding the cap could be affecting concentrations at this station. Also, VG5 is closest to the auxiliary ferry dock and the Madison Street outfall. Future monitoring will be needed to determine if this contamination is from an off-cap source or if it is from the capping sediments.

Results

TABLE 5-2. Detected Chemicals in Surface Grab Samples Surrounding Cap

Station:	VG8	VG8	VG9	UP-1	UP-1
Sample#:	9201103	9201123	9201102	L84-2	L84-1
Date:	5/27/92	5/27/92	5/27/92	6/16/92	6/17/92
% Solids:	68.00	63.00	71.00	47.00	46.00
Sample Depth:	Top 2cm	Top 10cm	Top 2cm	Top 2cm	Top 10cm
Compound Name (ppb)	Values in Dry-Weight				
Phenol <i>LPAH</i>	T 100	200	<70	<600	<700
Naphthalene	T 60	<40	<40	<200	<200
Acenaphthylene	76	87	T 10	T 100	<90
Acenaphthene	38	100	54	280	<70
Fluorene	180	190	150	300	<90
Phenanthrene	1,000	1,100	1,700	1,800	700
Anthracene	1,100	510	320	1,200	520
Fluoranthene <i>HPAH</i>	11,000	1,500	1,800	4,500	3,000
Pyrene	7,500	2,500	1,500	1,900	1,800
Benzo (a) anthracene	4,300	860	420	1,500	1,300
Chrysene	5,100	1,300	510	2,000	1,600
Benzo (b) fluoranthene	4,900	2,400	280	1,300	1,100
Benzo (k) fluoranthene	2,100	900	150	600	400
Benzo (a) pyrene	2,500	1,100	170	940	850
Indeno (1,2,3--c,d) pyrene	870	290	70	600	460
Dibenzo (a,h) anthracene	180	<40	<40	T 200	<200
Benzo (g,h,i) perylene	720	240	75	550	500
Aroclor 1254 <i>PCB</i>	<20	<30	<20	110	460
Aroclor 1260	<20	270	<20	170	300
Bis (2-ethylhexyl) phthalate	B <85	B <160	B <10	B <90	B <90
Dibenzofuran	T 40	86	54	<200	<200
Carbazole	750	210	280	<200	<200
Metals (ppm)					
Aluminum	10,000	9,700	9,900	11,000	12,000
Antimony	G 1.3	G 1.6	G 1.4	G <4	G <4
Arsenic	E 4.4	E 25	E 4.2	E <6	E <7
Beryllium	0.29	0.16	0.28	T 0.4	T 0.4
Cadmium	E 0.15	E 0.81	E 0.14	T 0.4	T 0.7
Chromium	15	24	15	18	20
Copper	22	62	20	E 36	E 46
Iron	15,000	15,000	14,000	16,000	17,000
Lead	24	160	14	30	37
Manganese	190	160	170	170	180
Mercury	0.13	0.54	0.13	T 0.2	T 0.2
Nickel	13	16	13	13	15
Selenium	<3	<2	<1	<6	T 7
Silver	0.44	1.6	0.42	TG 0.4	TG 0.7
Thallium	15	16	8.5	<20	<20
Zinc	53	100	46	G 79	91

B- Result corrected for blank contamination.
T - Detected below quantification limit.

G - Estimate is greater than value shown.
For further information on qualifiers see Appendix B.

E - Estimate

TABLE 5-3. Detected Chemicals in Under-Pier Samples

Station:	UP-2	UP-2	UP-2	UP-3	UP-4
Sample#:	L84-4	L84-3	L84-7	L84-6	L84-5
Date:	11/24/92	11/24/92	11/24/92	11/24/92	11/24/92
% Solids:	26.00	26.00	27.00	31.00	27.00
Sample Depth:	Top 2cm	Top 10cm	10cm Rep	Top 2cm	Top 2cm
Compound Name		Values in Dry-Weight			
Acenaphthylene <i>LPAH</i>	770	500	410	1,300	480
Acenaphthene	650	T 200	<100	5,500	700
Fluorene	1,800	620	350	5,800	1,300
Phenanthrene	8,500	2,800	1,900	24,000	7,400
Anthracene	5,800	2,700	1,700	9,400	5,200
Fluoranthene <i>HPAH</i>	25,000	10,000	6,300	35,000	25,000
Pyrene	16,000	13,000	5,600	22,000	11,000
Benzo (a) anthracene	12,000	6,900	4,100	22,000	11,000
Chrysene	14,000	10,000	6,700	21,000	15,000
Benzo (b) fluoranthene	9,600	8,800	5,900	19,000	8,900
Benzo (k) fluoranthene	5,400	2,600	2,100	7,700	3,500
Benzo (a) pyrene	7,300	5,400	4,100	14,000	6,300
Indeno (1,2,3-cd) pyrene	5,400	4,200	1,900	5,500	3,200
Dibenzo (a,h) anthracene	1,400	<400	<400	1,300	T 700
Benzo (g,h,i) perylene	4,200	4,200	1,200	3,900	2,900
Butyl benzyl phthalate	<200	<200	<100	<100	370
Dibenzofuran	T 400	<300	<300	4,200	<300
Benzoic acid	<1000	3700	<1000	1600	<1000
Carbazole	1200	<300	<300	1600	<300
Coprostanol	3200	<1000	<1000	5200	4400
Aroclor 1248 <i>PCB</i>	850	690	270	420	<30
Aroclor 1254	2,500	540	230	350	170
Aroclor 1260	500	300	160	250	310
Metals (ppm)					
Aluminum	16,000	19,000	17,000.	16,000	16,000.
Antimony	G <8	G <8	G <7	G <6	G <7
Arsenic	TE 10	TE 20	TE 10	TE 20	TE 30
Beryllium	T 0.4	T 0.8	T 0.4	T 0.6	T 0.7
Cadmium	T 3	T 3	T 3	2.6	3.5
Chromium	46	62	59	42	48
Copper	E 110	E 150	E 140	E 190	E 150
Iron	27,000	36,000	33,000	24,000	24,000
Lead	130	180	170	130	190
Manganese	220	250	240	190	190
Mercury	0.85	1	1.1	2.4	2.6
Nickel	23	31	29	25	29
Selenium	<10	T 10	<10	<10.	<10
Silver	G 4.2	G 4.6	G 4.4	G 3.5	G 6.3
Thallium	<40	<40	<40	<30	<40
Zinc	G 270	G 300	G 260	G 390	G 340

E - Estimate

G - Estimate is greater than value shown.

T - Detected below quantification limit.

Results

Metals. There were no spatial differences of metals concentrations in the seven samples from the cap surface. They were also similar to concentrations in the core samples. These values were at background levels for sand from the Duwamish River and are consistent with pre-dredge samples. Dry-weight copper values ranged from 12 to 18 ppm, lead ranged from 5.4 to 6.5 ppb, mercury ranged from 0.27 to less than 0.026 ppb, and zinc ranged from 41 to 53 ppb.

Comparison of State Sediment Standards to Cap-Surface Samples. The state sediment standard list of 47 chemical parameters includes eight metals for comparison in ppm dry-weight, seven organic compound for comparison in ppb dry-weight, and 32 organic chemicals and PCBs that are normalized using the total organic carbon content of the sample for comparison to the sediment standards. Tables 5-4 compares the state sediment standards to each surface grab sample.

All of the organic compounds and metals detected in the capping sediments were well below the state sediment standards. However, the comparison of some non-detected compounds to the standards was complicated by the low total-organic carbon content of the capping sands. The low total-organic carbon content meant that the total organic carbon normalized detection limit for some compounds regularly exceeded the standards. Detection limits for hexachlorobenzene exceeded the sediment quality standards (SQS) at five stations and the cleanup screening levels (CSLs) at one station. Detection limits for 1,2,4-trichlorobenzene exceeded the SQS at two stations and the CSL at one station. Detection limits for 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, hexachlorobenzene, and hexachlorobutadiene all exceeded at least the SQS at VG7. The comparison to the standards at this station was problematic because of the low total organic carbon of 0.33 percent.

Surrounding and Under-Pier Samples

Organics A total of 20 organic compounds were detected at the two offshore sample stations (VG8 and VG9) south of the capping area, including the PCB Aroclor-1260. Two samples were taken at VG8: a sample from the top 2 cm and a sample from the top 10-cm biologically active zone. For all three samples, dry-weight values for fluoranthene, pyrene, and chrysene ranged from 510 to 11,000 ppb and were similar to pre-cap concentrations in the capping area. Comparing the top 2 cm with the top 10 cm at Station VG8 shows that most LPAH compounds have similar concentration at both depths. However, the HPAH compounds were in greater concentration in the top 2 cm. The values ranged from seven times greater for fluoranthene to two times greater for benzo(b and k)fluoranthene, benzo(a)pyrene and benzo(g,h,i)perylene.

TABLE 5-4. Sediment Standard Comparison for Surface Samples on Cap

Station:	Standards		VG1	VG2	VG3	VG4	VG5	VG6	VG7
Sample#:	Sediment Quality Standards	Cleanup Screening Levels	9201098	9201105	9201101	9201099	9201096	9201097	9201104
Date:			5/26/92	5/27/92	5/27/92	5/27/92	5/26/92	5/26/92	5/27/92
% Solids:			74	62	69	74	70	66	78
% T.O.C. dry			1.2	2.4	0.92	4.8	1	4.4	0.33
Naphthalene <i>LPAHs ppm OC</i>	99	170	<2.5	<1.7	<4.3	<0.63	<4	<0.91	E < 9.1
Acenaphthylene	66	66	<0.83	<0.42	<1.1	<0.21	<1	<0.23	E < 3
Acenaphthene	16	57	<0.75	<0.42	<1	<0.19	<0.9	<0.23	E < 2.4
Fluorene	23	79	<0.83	<0.42	<1.1	<0.21	T 1	<0.23	E < 3
Phenanthrene	100	480	T 0.8	2.5	4.5	1.1	12	1.3	E 9.4
Anthracene	220	1,200	<0.83	T 0.8	T 2	T 0.4	4.6	T 0.4	E < 3
2-Methylnaphthalene	38	64	<2.5	<1.7	<4.3	<0.63	<4	<0.91	E < 9.1
Total LPAHs	370	780	9.07	7.99	18.5	3.39	27.5	4.26	39
Fluoranthene <i>HPAHs ppm OC</i>	160	1,200	3.8	4.6	7.3	1.7	20	2	E 14
Pyrene	1,000	1,400	2.5	3.3	5.9	1.3	10	1.3	E 10
Benzo (a) anthracene	110	270	<0.83	<0.42	3.3	<0.21	6.9	0.89	E < 3
Chrysene	110	460	T 2	2.5	4.2	1	10	1.2	E 6.1
Total benzo fluoranthenes	230	450	<5.8	<4.6	<9.7	<2.1	15	<2.5	E < 18
Benzo (a) pyrene	99	210	<1.7	T 1	<2.2	T 0.6	5.3	T 0.6	E < 6.1
Indeno (1,2,3-cd) pyrene	34	88	<1.7	<1.3	<2.2	<0.42	<2	<0.68	E < 9.1
Dibenzo (a,h) anthracene	12	33	<2.5	<1.7	<4.3	<0.63	<4	<0.91	E < 6.1
Benzo (g,h,i) perylene	31	78	<1.7	<1.3	<2.2	<0.42	<2	<0.68	E < 12
1,2-Dichlorobenzene	2.3	2.3	<0.83	<0.42	<1.1	<0.21	<1	<0.23	F < 3**
1,4-Dichlorobenzene	3.1	9	<0.83	<0.42	<1.1	<0.21	<1	<0.23	E < 3
1,2,4-Trichlorobenzene	0.81	1.8	<0.83*	<0.42	<1.1*	<0.21	<1*	<0.23	E < 3**
Hexachlorobenzene	0.38	2.3	<0.83*	<0.42*	<1.1*	<0.21	<1*	<0.23	E < 3**
Total HPAHs	960	5,300	24.19	22.7	45.7	9.28	79.2	11.77	96.6
<i>ppm OC</i>									
Dimethyl phthalate	53	53	<0.58	<0.33	<0.76	<0.15	<0.7	<0.18	E < 1.8
Diethyl phthalate	61	110	<1.7	<1.3	<2.2	<0.42	<2	<0.68	E < 6.1
Di-n-butyl phthalate	220	1,700	B < 1.7	B < 1.3	B < 2.2	B < 0.42	B < 2	B < 0.68	BE < 6.1
Butyl benzyl phthalate	4.9	64	<0.83	<0.42	<1.1	<0.21	<1	<0.23	E < 3
Bis (2-ethylhexyl) phthalate	47	78	B < 0.83	B < 0.42	B < 1.1	B < 0.21	B < 1	B < 0.23	BE < 3
Di-n-octyl phthalate	58	4,500	<0.83	<0.42	<1.1	<0.21	<1	<0.23	E < 3
Dibenzofuran	15	58	<1.7	<1.3	<2.2	<0.42	<2	<0.68	E < 6.1
Hexachlorobutadiene	3.9	6.2	<1.7	<1.3	<2.2	<0.42	<2	<0.68	E < 6.1*
N-nitrosodiphenylamine	11	11	B < 1.7	B < 1.3	B < 2.2	B < 0.42	B < 2	B < 0.45	BE < 6.1
Total PCBs	12	65	<1.7	<1.3	<2.2	<0.42	<2	<0.68	<6.1
Phenol <i>ppb dry</i>	420	1,200	<70	<80	<70	<70	<70	<70	<60
2-methylphenol	63	63	<20	<30	<20	<20	<20	<20	<20
4-methylphenol	670	670	<20	<30	<20	<20	<20	<20	<20
2,4-dimethyl phenol	29	29	<20	<30**	<20	<20	<20	<20	<20
Pentachlorophenol	360	690	<20	<30	<20	<20	<20	<20	<20
Benzyl alcohol	57	73	<20	<30	<20	<20	<20	<20	E < 20
Benzoic Acid	650	650	<70	<80	T 80	<70	<70	<70	<60
Arsenic <i>Metals ppm dry</i>	57	93	E 5.4	E 3.2	E 4.3	E 4.1	E 4.3	E 4.5	E 2.6
Cadmium	5.1	6.7	E 0.14	E 0.16	E 0.14	E 0.12	E 0.14	E 0.15	E 0.13
Chromium	260	270	13	15	13	12	12	17	11
Copper	390	390	16	18	13	13	12	13	12
Lead	450	530	5.4	6.5	5.8	5.4	5.7	6.1	5.1
Mercury	0.41	0.59	0.041	0.27	0.03	0.041	0.13	0.03	< 0.03
Silver	6.1	6.1	0.27	0.32	0.29	0.27	0.29	0.3	0.26
Zinc	410	960	45	53	48	45	44	44	41

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

*Exceeds Marine Sediment Quality Standards.

E - Estimate

T - Detected below quantification limits.

For further information on data qualifiers see Appendix B.

Results

Comparing the top 2-cm sample at VG8 with VG9, which is also from the top 2 cm, shows that the concentrations at VG8 were much higher. VG8 is closer inshore in approximately 40 feet of water near the ferry terminal and VG9 is farther offshore in about 50 feet of water. Both VG8 and VG9 are in areas that could possibly receive scouring turbulence from car ferries docking and departing the auxiliary slip on the north side of the ferry dock. The HPAH concentrations ranged from 17 times greater for benzo(b)fluoranthene to five times greater for pyrene at VG8 than at VG9. Benzo(a)pyrene concentrations were 14 times greater, concentrations for fluoranthene were six times greater, chrysene concentrations were ten times greater, and benzo(k)fluoranthene concentrations were 14 times greater at VG8 than at VG9.

There were four under-pier stations UP1, UP2, UP3 and UP4. At Stations UP1 and UP2, a 10-cm-deep sample was taken in addition to the 2-cm sample. A 10-cm field replicate sample was also taken at UP2. At Stations UP3 and UP4, 2-cm samples were taken. In all, 23 organic chemicals were detected in the under-pier samples. Generally, the concentrations were lower at UP1, which is the farthest offshore and in the deepest water (approximately 30 feet). All concentrations of PAHs were lowest at the 10-cm sample at UP1. The highest concentrations were found at UP3, which is a 2-cm sample. The next highest concentrations were found in the top 2 cm at UP2.

All of the samples with the highest concentrations were 2-cm surface samples. Comparing UP1 2-cm and 10-cm samples shows that the 2-cm sample was consistently higher in concentration, ranging from a factor of 2 greater for phenanthrene to 10 percent greater for benzo(g,h,i)perylene. At Station UP2, the surface 2-cm sample was higher in concentrations, ranging from a factor of 5 higher for Aroclor 1254 to no difference in concentration for benzo(g,h,i)perylene. Most organics in the 2-cm sample ranged from a factor of 2 to 20 percent higher than the 10-cm sample.

Metals. A comparison of the 10-cm sample with the 10-cm field replicate at Station UP2 showed all detected chemicals were lower in concentration in the replicate except cadmium, which was the same, and mercury. In some cases the decrease was by a factor of 2 and 3, with most decreases in the range of 25 to 40 percent.

The metals concentrations were several times higher in the surrounding areas than on the cap. Mercury levels reached a high of 2.6 ppm at Station UP-4, as compared with a high of 0.27 ppm on the cap. The mean mercury level for Stations UP-2, UP-3, and UP-4, which are closest to the shore, was 1.16 ppm for the top 2 cm, as compared to 0.077 ppm on the cap. Lead levels were high at the

surrounding area stations, with the highest concentration of 190 ppb at Station UP-4 in the top 2-cm sample. The lowest concentration was 14 ppm at the farthest offshore site, Station VG9. The mean lead concentration at Stations UP-2, UP-3, and UP-4 was 147.5 ppm (the top 2 cm) as compared to 5.7 ppm for the cap surface. The mean lead concentration for all under-pier sites was 115.4 ppm.

Comparison of State Sediment Standards to Surrounding and Under-Pier Samples.

Analysis of the three samples from Stations VG8 and VG9 showed that the top 2-cm sample from VG8 exceeded the sediment standards the most often, with 7 organic parameters above the CSLs and 6 organic parameters above the SQS (see Tables 5-5 and 5-6). In the 2-cm sample from VG8, fluoranthene, benzo(a)anthracene, chrysene, total benzo fluoranthenes, benzo(a)pyrene, indeno(1,2,3--cd)pyrene, and benzo(g,h,i)perylene exceeded the CSLs. Fluorene, phenanthrene, dibenzo(a,h,)anthracene, and total HPAHs exceeded the SQS in the same sample. Also, phenanthrene and fluoranthene exceeded the SQS at VG9.

In contrast, in the 10-cm sample at VG8 only two organic detection limits and mercury exceeded the sediment standards. In all, there were six cases where detection limits exceeded at least the SQS. Detection limits for 1,2,4-trichlorobenzene exceeded the SQS at VG9 and the top 2 cm at VG8. Detection limits for hexachlorobenzene exceeded the SQS in both samples at VG8 and at VG9. The detection limit for 2,4-dimethylphenol exceeded the CSL in the top 10-cm sample at VG8.

For metals, mercury was the only metal to exceed either sediment standard at the stations south of the cap, exceeding the SQS at VG8 in the 10-cm sample.

At the under-pier stations, 37 detected organic parameters exceeded at least the SQS. At Station UP2 in the top 2-cm sample, 10 detected organic parameters exceeded the SQS. At UP3, a 2-cm sample, 10 detected organic parameters exceeded the SQS and five exceeded the CSLs. At UP2 in the 10-cm sample, eight parameters exceeded at least the SQS. At UP4, a 2-cm sample, four parameters exceeded the SQS. Fluoranthene exceeded the SQS at UP1 in the 2-cm sample, and PCBs exceeded the SQS at UP1 in the 10-cm sample. At UP2 in the 10-cm replicate, all detected organic compounds were below the standards.

Results

TABLE 5-5. Sediment Standard Comparison for Surface Samples Surrounding Cap

Station:	Sediment		VG8	VG8	VG9	UP-1	UP-1
Sample#:	Standards		9201103	9201123	9201102	L84-2	L84-1
Date:			5/27/92	5/27/92	5/27/92	6/16/92	6/17/92
% Solids:	Sediment Quality Standards	Cleanup Screening Levels	68	63	71	47	46
Sample Depth:			Top 2cm	Top 10cm	Top 2cm	Top 2cm	Top 10cm
% T.O.C. Dry			0.77	2.4	0.86	2.6	3.9
Naphthalene <i>LPAHs ppm OC</i>	99	170	T 8	< 1.3	< 4.7	< 7.7	< 5.1
Acenaphthylene	66	66	9.9	3.6	T 1	T 4	< 2.3
Acenaphthene	16	57	4.9	4.2	6.3	11	< 1.8
Fluorene	23	79	23*	7.9	17	12	< 2.3
Phenanthrene	100	480	130*	46	200*	69	18
Anthracene	220	1,200	140	21	37	46	13
2-Methylnaphthalene	38	64	< 5.2	< 1.7	< 4.7	< 7.7	< 5.1
Total LPAHs	370	780	320	86	270	160	48
Fluoranthene <i>HPAHs ppm OC</i>	160	1,200	1,400**	63	210*	170*	77
Pyrene	1,000	1,400	970	100	170	73	46
Benzo (a) anthracene	110	270	560**	36	49	58	33
Chrysene	110	460	660**	54	59	77	41
Total benzo fluoranthenes	230	450	910**	140	50	73	38
Benzo (a) pyrene	99	210	325**	4.2	20	36	22
Indeno (1,2,3-c,d) pyrene	34	88	110**	12	8.1	23	12
Dibenzo (a,h) anthracene	12	33	23*	< 1.7	< 4.7	7.7	< 5.1
Benzo (g,h,i) perylene	31	78	94**	10	8.7	21	13
1,2-Dichlorobenzene	2.3	2.3	< 1.3	< 0.42	< 1.2	< 3.5**	< 2.3**
1,4-Dichlorobenzene	3.1	9	< 1.3	< 0.42	< 1.2	< 3.5*	< 2.3
1,2,4-Trichlorobenzene	0.81	1.8	< 1.3*	< 0.42	< 1.2*	< 3.5**	< 2.3**
Hexachlorobenzene	0.38	2.3	< 1.3*	< 0.42*	< 1.2*	< 3.5**	< 2.3**
Total HPAHs	960	5,300	5100*	420	580	550	230
<i>ppm OC</i>							
Dimethyl phthalate	53	53	< 0.91	< 0.33	< 0.81	< 2.3	< 1.8
Diethyl phthalate	61	110	< 2.6	< 1.3	< 2.3	< 7.7	< 5.1
Di-n-butyl phthalate	220	1,700	B < 2.6	B < 1.3	B < 2.3	B < 7.7	B < 5.1
Butyl benzyl phthalate	4.9	64	< 1.3	< 0.42	< 1.2	< 3.5	< 2.3
Bis (2-ethylhexyl) phthalate	47	78	B 11	B 6.7	B < 1.2	B < 3.5	B < 2.3
Di-n-octyl phthalate	58	4,500	< 1.3	< 0.42	< 1.2	< 3.5	< 2.3
Dibenzofuran	15	58	T 5	3.6	6.3	< 7.7	< 5.1
N-nitrosodiphenylamine	3.9	6.2	B < 3.9	B < 1.3	B < 2.3	< 7.7	< 5.1
Hexachlorobutadiene	11	11	< 2.6	< 1.3	< 2.3	< 7.7**	< 5.1*
Total PCBs	12	65	< 2.6	11	< 2.3	11	19*
Phenol <i>ppb dry</i>	420	1,200	T 100	200	< 70	< 600*	< 700*
2-methylphenol	63	63	< 20	< 30	< 20	< 200**	< 200**
4-methylphenol	670	670	50	< 30	< 20	< 200	< 200
2,4-dimethyl phenol	29	29	< 20	< 30**	< 20	< 200**	< 200**
Pentachlorophenol	360	690	< 20	< 30	< 20	< 200	< 200
Benzyl alcohol	57	73	< 20	< 30	< 20	< 200**	< 200**
Benzoic Acid	650	650	< 70	< 80	< 70	< 600	< 700**
<i>Metals ppm dry</i>							
Arsenic	57	93	E 4.4	E 25	E 4.2	E < 6	E < 7
Cadmium	5.1	6.7	E 0.15	E 0.81	E 0.14	T 0.4	T 0.7
Chromium	260	270	15	24	15	18	20
Copper	390	390	22	62	20	E 36	E 46
Lead	450	530	24	160	14	30	37
Mercury	0.41	0.59	0.13	0.54*	0.13	T 0.2	T 0.2
Silver	6.1	6.1	0.44	1.6	0.42	TC 0.7	TC 0.4
Zinc	410	960	53	100	46	79	91

B - Result corrected for blank contamination.

G - Estimate is greater than value shown.

**Exceeds Marine Sediment Cleanup Screening Levels.

*Exceeds Marine Sediment Quality Standards.

E - Estimate

T - Detected below quantification limits.

For further information on data qualifiers see Appendix B.

TABLE 5-6. Sediment Standard Comparison for Under-Pier Samples

Station:	Sediment Standards		UP-2 L84-4	UP-2 L84-3	UP-2 L84-7	UP-3 L84-6	UP-4 L84-5	
Sample#:			6/17/92	6/17/92	6/17/92	6/16/92	6/16/92	
Date:			26	26	27	31	27	
% Solids:	Sediment Quality Standards	Cleanup Screening Levels	Top 2cm	Top 10cm	10cm Rep	Top 2cm	Top 2cm	
Sample Depth:			6.5	7.7	6.7	6.8	9.3	
% T.O.C.								
Naphthalene <i>LPAHs ppm OC</i>	99	170	< 6.2	< 5.2	< 6	< 4.4	< 4.3	
Acenaphthylene	66	66	12	6.5	6.1	19	5.2	
Acenaphthene	16	57	10	2.6	< 1.5	81**	7.5	
Fluorene	23	79	28*	8.1	5.2	85**	14	
Phenanthrene	100	480	130*	36	28	350*	80	
Anthracene	220	1,200	89	35	25	140	56	
2-Methylnaphthalene	38	64	< 6.2	< 5.2	< 6	< 4.4	< 4.3	
Total LPAHs	370	780	281.4	98.6	77.8	683.8*	171.3	
Fluoranthene <i>HPAHs ppm OC</i>	160	1,200	380	130	94	510*	270*	
Pyrene	1,000	1,400	250	170	84	320	120	
Benzo (a) anthracene	110	270	180*	90	61	320**	120*	
Chrysene	110	460	220*	130*	100	310*	160*	
Total benzo fluoranthenes	230	450	230	410*	120	390*	130	
Benzo (a) pyrene	99	210	110*	70	61	210**	68	
Indeno (1,2,3-cd) pyrene	34	88	83*	55*	28	81*	34*	
Dibenzo (a,h) anthracene	12	33	22*	5.2	< 6	19*	8	
Benzo (g,h,i) perylene	31	78	65*	55*	18	57*	31	
1,2-Dichlorobenzene	2.3	2.3	< 3.1**	< 2.6**	< 1.5	< 1.5	< 1.1	
1,4-Dichlorobenzene	3.1	9	< 3.1**	< 2.6	< 1.5	< 1.5	< 1.1	
1,2,4-Trichlorobenzene	0.81	1.8	< 3.1**	< 2.6**	< 1.5	< 1.5	< 1.1	
Hexachlorobenzene	0.38	2.3	< 3.1**	< 2.6**	< 1.5	< 1.5	< 1.1	
Total HPAHs	960	5,300	1,552*	1,126*	578	2,223*	944.9	
<i>ppm OC</i>								
Dimethyl phthalate	53	53	< 1.5	< 1.3	< 1.5	< 1.5	< 1.1	
Diethyl phthalate	61	110	< 4.6	< 3.9	< 4.5	< 4.4	< 3.2	
Di-n-butyl phthalate	220	1,700	B < 4.6	B < 3.9	B < 4.5	B < 4.4	B < 3.2	
Butyl benzyl phthalate	4.9	64	< 3.1	< 2.6	< 1.5	< 1.5	3.2	
Bis (2-ethylhexyl) phthalate	47	78	B < 3.1	B < 2.6	B < 1.5	B < 1.5	B < 1.1	
Di-n-octyl phthalate	58	4,500	< 3.1	< 2.6	< 1.5	< 1.5	< 1.1	
Dibenzofuran	15	58	T 6	< 3.9	< 4.5	62**	< 3.2	
Hexachlorobutadiene	3.9	6.2	< 4.6	< 3.9*	< 4.5*	< 4.4*	< 3.2	
N-nitrosodiphenylamine	11	11	< 4.6	< 3.9	< 4.5	< 4.4	< 3.2	
Total PCBs	12	65	59*	20*	9.9	15*	5	
Phenol <i>ppb dry</i>	420	1,200	< 1,000*	< 1,000*	< 1,000*	< 1,000*	< 1,000*	
2-methylphenol	63	63	< 300**	< 300**	< 300**	< 300**	< 300**	
4-methylphenol	670	670	< 300	< 300	< 300	< 300	< 300	
2,4-dimethyl phenol	29	29	< 300**	< 300**	< 300**	< 300**	< 300**	
Pentachlorophenol	360	690	< 300	< 300	< 300	< 300	< 300	
Benzyl alcohol	57	73	< 300**	< 300**	< 300**	< 300**	< 300**	
Benzoic Acid	650	650	< 1,000*	3,700**	< 1,000*	< 1,600**	< 1,000*	
Arsenic <i>Metals ppm dry</i>	57	93	TE 10	TE 20	TE 10	TE 20	TE 30	
Cadmium	5.1	6.7	T 3	T 3	T 3	2.6	3.5	
Chromium	260	270	46	62	59	42	48	
Copper	390	390	110	150	E 140	E 190	E 150	
Lead	450	530	130	180	170	130	190	
Mercury	0.41	0.59	0.85**	1**	1.1**	2.4**	2.6**	
Silver	6.1	6.1	G 4.2	G 4.6	G 4.4	G 3.5	G 6.3**	
Zinc	410	960	G 270	G 300	G 260	G 390	G 340	

B - Result corrected for blank contamination.
 G - Estimate is greater than value shown.
 **Exceeds Marine Sediment Cleanup Screening Levels.
 *Exceeds Marine Sediment Quality Standards.

F - Estimate
 T - Detected below quantification limits.
 For further information on data qualifiers see Appendix B.

Results

Also at the under-pier stations, there were 54 cases where detection limits exceeded at least the SQS. Detection limits for 2-methylphenol, 2,4-dimethyl phenol and benzyl alcohol exceeded the CSLs at all stations. Detection limits for phenol exceeded the SQS at all stations, and 1,2-dichlorobenzene, 1,4-trichlorobenzene, and hexachlorobutadiene exceeded the CSLs for four of the seven samples.

For the under-pier stations, mercury exceeded the CSLs for all samples at UP2, UP3 and UP4. Silver also exceeded the CSLs at Station UP4.

Particle Size Distribution

Particle size analysis of the surface of the cap showed the samples were mostly composed of fine and medium sands 1 to 4 phi (0.063 to 0.5 mm) in size with a majority of the material medium sand in the 1 to 2 phi (0.25 to 0.5 mm) range. The seven on-cap surface samples ranged from 93 to 97 percent fine and medium sands. Samples from Stations VG2, VG4, VG5, and VG7 were mostly composed of medium sands 1 to 2 phi ranging from 67 percent for VG2 to 82 percent for VG7. Samples from Stations VG1, VG3, and VG6 were mostly composed of medium to fine sands 2 to 3 phi ranging from 72 percent for VG6 to 78 percent for VG3.

The two off-cap stations to the south of the cap, VG8 top 2-cm and top 10-cm samples, and VG9 top 2-cm were also mostly sand. VG9, which is farthest offshore, was 76 percent medium and fine sand from 1 to 4 phi in size. The top 2-cm sample at VG8 was 91 percent medium and fine sand, and the top 10-cm sample was 83 percent medium and fine sand.

It is possible that these two stations were covered with a thin layer of sand during cap placement. The sediment profile camera survey showed a layer of sand from 2.9 to 7.5 cm thick in the general area of VG8 and VG9. It is also possible that this area receives propeller wash from docking ferries and that the higher percentage of sand, relative to the surrounding area, indicates a higher energy environment.

Particle size analysis for the under-pier samples showed that the top 2 cm at UP1 are 61 percent medium and fine sand, and the top 10 cm are 63 percent medium and fine sand. This is in contrast to UP2 and UP3, where all samples ranged from 55 to 45 percent medium and fine sand. Because UP1 is only 75 to 100 feet inshore of the cap, it is possible that sand from cap placement settled onto UP1.

DISCUSSION

Surface sediment sampling on the cap showed that the cap material is clean and chemical concentrations are well below the SQS. The concentrations are uniform over the surface of the cap, and the results agree with the Duwamish River sediment study. Sediment samples surrounding the cap showed elevated concentrations of both organics and metals similar to, and in some cases higher than, the pre-cap study.

Cap Surface

The cap surface sampling stations (VG1, VG3, VG4, VG5, and VG7) that roughly correspond to the core sampling stations showed slightly higher concentrations of a few organic compounds than the within-cap core samples. These stations show the compounds at the surface slightly above detection limits, while the core samples showed the compounds to be undetected. Higher surface concentrations at single stations usually indicated the presence of clay from the Duwamish River. It is also probable that the higher concentrations were caused during the application of the capping material, in which the coarser denser sand settled first, and any silt and organic material settled last. The organic compounds are more likely to adhere to the organic material and silts.

The two metals aluminum and iron are not considered pollutants, but their concentrations give an indication of the presence of clay mixed with the sand. Station VG2 had higher concentrations of aluminum and iron, lower percent solids, and slightly higher concentrations of cadmium (0.02 ppm higher than the average of the seven on-cap samples), chromium (0.02 ppm higher than the average), copper (0.04 ppm higher than the average) lead (0.8 ppm higher), mercury (0.19 ppm higher), silver (0.04 ppm higher), and zinc (0.08 ppm higher). Of the on-cap surface samples, Station VG7 had the lowest concentrations of aluminum and iron, highest percent solids, and lowest concentrations of most metals. The presence of more or less clay in the capping material corresponds with the variations in metal concentrations. For some samples, small pieces of black clay were visible in the surface sample sands. This same type of clay was observed in the core samples, the camera survey, and the Denny Way capping project, which also used sand dredged from the Duwamish River.

In the case of VG5, however, it is possible that the slightly higher concentrations may be recontamination from off-cap sources. VG5 shows an elevation in PAH compounds but not metals. It is in the area of the cap closest to the Madison Street CSO. Flow volumes from stormwater and CSO events are

Discussion

unknown at this time but could be a factor. Another possibility is the proximity of VG5 to the ferry terminal, where propeller scour from docking ferries could stir up contamination from south of the cap. Some of the suspended contaminants could then be resettling on the cap, causing the increase in concentrations. Further sampling will be needed to determine whether the slightly elevated concentrations at VG5 are from off-cap sources.

Surrounding and Under-Pier Samples

South of the cap at Station VG8, the top 2-cm sample had concentrations of HPAHs that are two to three times higher than those of the 10-cm-deep sample (Table 5-2), indicating these compounds may be more recent. The concentrations of six metals, however, were two to six times lower in the top 2-cm samples than in the 10-cm-deep samples. Metals values were similar for the top 2-cm samples at Stations VG8 and VG9. Metals values south of the cap were similar to lower values on the cap, except for silver, lead, and copper, which are two to three times higher.

Concentrations at Station VG9 were only slightly higher than the cap values and may have been caused by a layer of capping sand at this site. Lead values on the cap averaged about 6 ppm, and south of the cap surface values were 14 to 24 ppm. Whereas under the pier, surface lead values were much higher nearshore, at 200 to 380 ppm. It is possible that some clean capping sand was included in the surface sample at Station VG9 and diluted the concentrations from the underlying mud. However, the presence of underlying contaminated sediment is evident because the PAH compounds are substantially elevated compared to the capping sand.

A total of seven parameters in the top 2-cm sample from VG8 exceeded the CSLs and six parameters exceeded the SQS. Mercury exceeded the SQS in the top 10-cm sample at VG8. And at VG9, two parameters exceeded the SQS.

Of the four under-pier stations, the one farthest offshore (UP1) had the lowest concentrations. The lower concentrations could be due to a thin layer of capping material that may have settled on the station during cap placement. However, UP1 is also near the pre-cap sample stations, which show chemical concentrations at similar levels. It is most likely that UP1 has lower concentrations relative to other under-pier samples because it is farthest offshore.

At Station UP1 in the top 2-cm sample, fluoranthene exceeded the SQS, and in the top 10-cm sample, total PCBs exceeded the SQS. At Station UP2 in the top 2-cm sample, 10 parameters exceeded the SQS and mercury exceeded the CSL. In the

Discussion

top 10-cm sample at UP2, six parameters exceeded the SQS and two exceeded the CSL. In the top 10-cm replicate at UP2, one parameter exceeded the CSL. At UP3, a 2-cm sample, 10 parameters exceeded the SQS and five exceeded the CSL. At UP4, a top 2-cm sample, four parameters exceeded the SQS and two exceeded the CSL.

SECTION 6

BENTHIC RECOLONIZATION

The monitoring plan for Pier 53 calls for pre-cap and post-cap studies of the benthic organisms at the project site. Post-cap studies are to continue at intervals for 10 years. The pre-cap study and the first post-cap study have been completed. The first post-cap study is a baseline and will be compared to subsequent studies to determine the rate of recolonization, types of organisms populating the cap, and the relative strength of the benthic communities.

This section describes and compares the pre-cap study and the first post-cap study. Comparisons are also made between the population of organisms on the 3-foot-thick cap and the 1-foot-thick ENR, and between the post-cap study and the first year benthic taxonomy data from the Denny Way sediment cap. In addition, this section summarizes the sediment-profile camera survey report by SAIC (described in Section 3), which documented the nature of the benthic communities in the capped and non-capped areas.

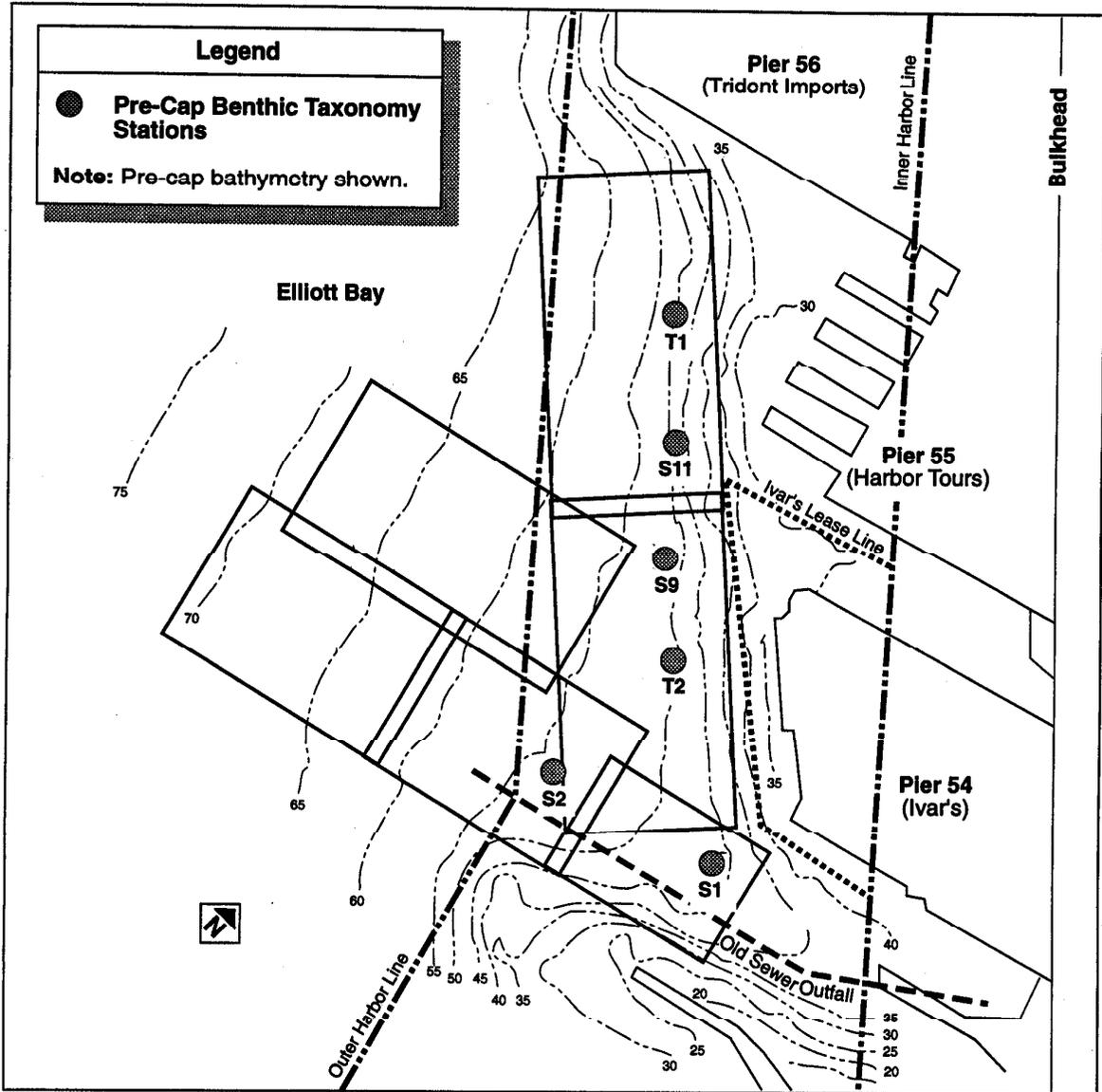
PRE-CAP STUDY

In March 1992, the Pier 53 monitoring team collected samples for a pre-cap benthic taxonomy study to determine the types and numbers of benthic organisms present at the Pier 53 site before the cap was placed (Appendix H). These data will be compared to post-cap benthic taxonomy studies to learn how the cap has been recolonized.

EVS Consultants directed the collection of samples from six stations along the shore at the Pier 53 site (see Map 6-1). All stations were within the eventual cap boundaries in 40 to 55 feet of water. Stations S1 and S2 were in the area of highest toxic chemical concentrations.

Method

The sampling team collected the benthic taxonomy samples using a 0.1-square-meter Van Veen grab sampler that they operated from the *RV Kittywake*. Once a sample was brought on board, the monitoring team drained the sea water through a screen and measured the sample thickness to gauge the depth penetration of the sampler. A team member then emptied it into a tub and washed



Map 6-1. Pre-Cap Benthic Taxonomy Stations

it through a 1-mm mesh screen with water from a hose. Everything that did not wash through the screen was put into a jar and labeled by station and replicate number. The team took five samples per station. The screened samples were preserved in buffered formalin and later transferred to alcohol. Taxonomic analysis was conducted by Marine Taxonomic Services.

Results

The dominant fauna in the pre-cap samples were the bivalve *Axinoposida serricata*, the polychaetes *Heteromastus filobranthus*, *Prionospio steenstrupi* and *Lumbrineridae*, and the ostracod, *Euphilomedes carcharodonta*. At all six stations the bivalve *Axinoposida serricata* was the most abundant, ranging from an average of 452 at Station T2 to 103 at Station S1. A total of 659 individuals were counted for one sample at Station T2. *Heteromastus filobranthus* ranged from an average of 57 individuals at Station S2 to an average of 13 individuals at Station S11. *Prionospio steenstrupi* ranged from an average of 155 individuals at Station T2 to 50 individuals at Station S2. *Lumbrineridae* ranged from 65 at Station S11 to 26 at Station S1. *Euphilomedes carcharodonta* ranged from 122 at Station T2 to 20 at Station S1. Representative species are presented in Tables 6-1 through 6-6.

Abundance. Abundance was determined by averaging the number of individuals for five replicate samples at each station (see Table 6-7). Polychaetes were the most abundant taxonomic group at Stations S1, S9, and S11. At Station S1 they averaged 237 individuals, at S9 they averaged 300, and at S11 they averaged 340. Mollusks were the most abundant at Stations S2, T1 and T2. At Station S2 they averaged 299 individuals, at T1 they averaged 437, and at T2 they averaged

Table 6-1. Representative Species at Station S1

Taxon	Numbers of Individuals per 0.1 m ²					Average
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	0	1	23	8	9	8.2
<i>Glycera nana</i>	1	8	0	6	9	4.8
<i>Heteromastus filobranthus</i>	29	20	16	72	33	34
<i>Lumbrineris sp. Indet.</i>	19	20	49	30	15	26.6
<i>Nephtys cornuta</i>	10	11	1	16	13	10.2
<i>Nephtys ferruginea</i>	5	3	6	9	13	7.2
<i>Notomastus tenuis</i>	9	8	7	10	15	9.8
<i>Paraprionospio pinnata</i>	5	10	1	2	2	4
<i>Pectinaria californiensis</i>	1	0	0	1	4	1.2
<i>Polydora brachycephala</i>	6	0	2	0	0	1.6
<i>Prionospio steenstrupi</i>	65	103	45	80	81	74.8
Mollusks						
<i>Axinoposida serricata</i>	26	14	109	137	231	103.4
<i>Macoma calcarea</i>	1	1	2	9	3	3.2
<i>Macoma sp. Juv.</i>	10	13	6	17	22	13.6
<i>Nucula tenuis</i>	0	2	4	5	2	2.6
<i>Parvilucina tenuisculpta</i>	23	11	25	29	37	25
Crustaceans						
<i>Eudorella pacifica</i>	2	7	2	9	0	4
<i>Euphilomedes carcharodonta</i>	4	5	26	13	54	20.4
<i>Euphilomedes producta</i>	1	0	1	2	4	1.6
<i>Heterophoxus oculatus</i>	0	0	1	2	1	0.8

Pre-Cap Study

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	5	4	5	9	9	6.4
<i>Glycera nana</i>	8	7	8	6	6	7
<i>Heteromastus filobranchus</i>	61	43	57	55	69	57
<i>Lumbrineris sp. Indet.</i>	46	26	29	36	29	33.2
<i>Nephtys cornuta</i>	16	7	5	14	24	13.2
<i>Nephtys ferruginea</i>	9	4	5	5	3	5.2
<i>Notomastus tenuis</i>	9	16	21	36	31	22.6
<i>Paraprionospio pinnata</i>	0	0	2	1	0	0.6
<i>Pectinaria californiensis</i>	1	5	2	0	4	2.4
<i>Polydora brachycephala</i>	2	0	3	1	4	2
<i>Prionospio steenstrupi</i>	94	9	24	43	82	50.4
Mollusks						
<i>Axinopsida serricata</i>	301	105	154	188	342	218
<i>Macoma calcarea</i>	13	3	7	8	6	7.4
<i>Macoma sp. Juv.</i>	17	9	6	10	25	13.4
<i>Nucula tenuis</i>	5	2	2	7	2	3.6
<i>Parvilucina tenuisculpta</i>	43	31	29	27	39	33.8
Crustaceans						
<i>Eudorella pacifica</i>	14	2	2	4	2	4.8
<i>Euphilomedes carcharondonta</i>	94	60	65	60	86	73
<i>Euphilomedes producta</i>	14	11	7	6	13	10.2
<i>Heterophoxus oculatus</i>	4	1	3	2	4	2.8

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	7	4	18	3	7	7.8
<i>Glycera nana</i>	10	8	12	7	7	8.8
<i>Heteromastus filobranchus</i>	41	41	23	42	30	35.4
<i>Lumbrineris sp. Indet.</i>	23	48	38	27	17	30.6
<i>Nephtys cornuta</i>	10	11	12	6	6	9
<i>Nephtys ferruginea</i>	4	5	13	5	6	6.6
<i>Notomastus tenuis</i>	26	28	14	4	6	15.6
<i>Paraprionospio pinnata</i>	1	2	1	0	1	1
<i>Pectinaria californiensis</i>	4	1	1	2	0	1.6
<i>Polydora brachycephala</i>	21	2	1	10	13	9.4
<i>Prionospio steenstrupi</i>	111	95	148	89	96	107.8
Mollusks						
<i>Axinopsida serricata</i>	181	214	265	191	157	201.6
<i>Macoma calcarea</i>	3	12	9	0	13	7.4
<i>Macoma sp. Juv.</i>	7	11	7	7	24	11.2
<i>Nucula tenuis</i>	9	5	5	14	3	7.2
<i>Parvilucina tenuisculpta</i>	22	17	24	17	17	19.4
Crustaceans						
<i>Eudorella pacifica</i>	10	5	7	3	9	6.8
<i>Euphilomedes carcharondonta</i>	72	65	16	36	48	47.4
<i>Euphilomedes producta</i>	6	7	50	4	2	13.8
<i>Heterophoxus oculatus</i>	9	2	13	6	1	6.2

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	12	7	20	18	6	12.6
<i>Glycera nana</i>	9	10	8	6	10	8.6
<i>Heteromastus filobranchus</i>	24	26	13	3	3	13.8
<i>Lumbrineris sp. Indet.</i>	62	36	64	104	60	65.2
<i>Nephtys cornuta</i>	14	10	10	11	8	10.6
<i>Nephtys ferruginea</i>	8	5	5	10	8	7.2
<i>Notomastus tenuis</i>	16	19	19	6	12	14.4
<i>Paraprionospio pinnata</i>	2	0	1	4	0	1.4
<i>Pectinaria californiensis</i>	6	19	4	1	4	6.8
<i>Polydora brachycephala</i>	0	3	6	3	0	2.4
<i>Prionospio steenstrupi</i>	100	128	120	178	104	126
Mollusks						
<i>Axinopsida serricata</i>	220	309	239	267	196	246.2
<i>Macoma calcarea</i>	3	17	5	1	4	6
<i>Macoma sp. Juv.</i>	14	6	6	4	1	6.2
<i>Nucula tenuis</i>	7	7	5	12	3	6.8
<i>Parvilucina tenuisculpta</i>	6	28	8	4	12	11.6
Crustaceans						
<i>Eudorella pacifica</i>	9	5	1	10	3	5.6
<i>Euphilomedes carcharodonta</i>	84	83	96	146	96	101
<i>Euphilomedes producta</i>	16	10	16	26	18	17.2
<i>Heterophoxus oculatus</i>	10	11	8	16	10	11

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	14	0	6	7	5	6.4
<i>Glycera nana</i>	10	11	15	13	13	12.4
<i>Heteromastus filobranchus</i>	15	38	48	7	26	26.8
<i>Lumbrineris sp. Indet.</i>	55	41	83	52	35	53.2
<i>Nephtys cornuta</i>	28	9	34	5	14	18
<i>Nephtys ferruginea</i>	8	4	8	0	2	4.4
<i>Notomastus tenuis</i>	20	10	17	12	20	15.8
<i>Paraprionospio pinnata</i>	0	1	1	2	2	1.2
<i>Pectinaria californiensis</i>	8	4	3	3	7	5
<i>Polydora brachycephala</i>	0	1	7	5	3	3.2
<i>Prionospio steenstrupi</i>	174	116	174	154	111	145.8
Mollusks						
<i>Axinopsida serricata</i>	458	311	456	193	292	342
<i>Macoma calcarea</i>	11	24	6	2	17	12
<i>Macoma sp. Juv.</i>	29	7	13	12	0	12.2
<i>Nucula tenuis</i>	38	23	42	14	29	29.2
<i>Parvilucina tenuisculpta</i>	22	8	23	3	14	14
Crustaceans						
<i>Eudorella pacifica</i>	16	5	14	9	9	10.6
<i>Euphilomedes carcharodonta</i>	137	55	140	107	87	105.2
<i>Euphilomedes producta</i>	30	8	22	15	20	19
<i>Heterophoxus oculatus</i>	18	7	17	17	16	15

Pre-Cap Study

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Exogone lourei</i>	7	8	9	6	0	6
<i>Glycera nana</i>	13	12	16	13	10	12.8
<i>Heteromastus filobranchus</i>	39	47	34	35	52	41.4
<i>Lumbrineris sp. Indet.</i>	23	33	38	31	30	31
<i>Nephtys cornuta</i>	15	25	14	19	11	16.8
<i>Nephtys ferruginea</i>	6	4	4	7	7	5.6
<i>Notomastus tenuis</i>	24	13	33	24	12	21.2
<i>Paraprionospio pinnata</i>	1	1	3	1	0	1.2
<i>Pectinaria californiensis</i>	9	4	7	13	5	7.6
<i>Polydora brachycephala</i>	1	2	9	12	15	7.8
<i>Prionospio steenstrupi</i>	152	194	160	148	122	155.2
Mollusks						
<i>Axinopsida serricata</i>	314	519	659	388	383	452.6
<i>Macoma calcarea</i>	8	25	14	12	13	14.4
<i>Macoma sp. Juv.</i>	14	18	11	23	16	16.4
<i>Nucula tenuis</i>	8	23	18	15	16	16
<i>Parvilucina tenuisculpta</i>	14	24	10	9	22	15.8
Crustaceans						
<i>Eudorella pacifica</i>	23	13	12	15	4	13.4
<i>Euphilomedes carcharondonta</i>	120	131	142	104	114	122.2
<i>Euphilomedes producta</i>	25	32	16	30	20	24.6
<i>Heterophoxus oculatus</i>	3	8	20	7	15	10.6

549. All taxonomic groups were most abundant at Station T2, with an average of 377 polychaetes, 549 mollusks, and 191 crustaceans. All taxonomic groups were least abundant at Station S1, with an average of 237 polychaetes, 161 mollusks, and 31 crustaceans. Total average abundance for all species ranged from 1,131 individuals at Station T2 to 432 individuals at Station S1.

Number of Species. Polychaetes were the taxonomic group with the most number of species per station, with a total of 109 species counted at all stations (see Table 6-8). They ranged from 73 species at Station T1 to 53 species at S2. There were 53 species of mollusks counted at all the stations, ranging from 30 species at Station S11 to 23 species at Station T1. There were 34 species of crustaceans, ranging from 20 species at Station S11 to 11 species at Station S1. The total for all taxonomic groups was 203 species.

Biomass. Averaging five replicate samples per station, mollusks had the highest biomass weight at all stations except S9 (see Table 6-9). One high replicate

5 reps x 0.1 m ²	S1	S2	S9	S11	T1	T2	Totals
Polychaetes	237	260	300	340	376	377	315
Mollusks	161	299	272	305	437	549	337
Crustaceans	31	104	80	151	165	191	120
Other	2	7	7	5	10	12	7
Totals	432	671	660	801	989	1131	781

5 reps x 0.1 m ²	S1	S2	S9	S11	T1	T2	Totals
Polychaetes	66	53	68	69	73	64	109
Mollusks	24	28	26	30	23	29	53
Crustaceans	11	15	15	20	18	19	34
Other	4	4	4	4	4	4	7
Totals	105	100	113	123	118	116	203

at Station S2 (71 grams) contributed to a molluscan biomass that was a factor of 2 greater than the next nearest average sample weight. Totaling all of the average weights per station, mollusks were close to twice as high as polychaetes and 25 times as high as crustaceans. Average replicates for mollusks ranged from 20.44 grams at Station S2 to 5.6 grams at Station T1. Average replicates for polychaetes ranged from 6.7 grams at Station S9 to 4.5 grams at Station T1. Average replicates for crustaceans ranged from 0.97 grams to 0.13 grams.

STATION	Polychaetes	Crustaceans	Mollusks	Total Average
S1	5	0.13	9.6	14.73
S2	4.5	0.33	20	24.83
S9	6.7	0.25	6.1	13.05
S11	5.6	0.97	7	13.57
T1	4.5	0.67	5.1	10.27
T2	5.1	0.53	9.8	15.43

Discussion

Of the top five most abundant species, *Euphilomedes carcharodonta*, *Prionospio steenstrupi* and *Heteromastus filobranthus* are all likely to be among the first to recolonize a recently disturbed area. *E. carcharodonta* is predominantly an epifaunal organism, inhabiting debris and structures at or above the bottom sediments.

P. steenstrupi is a tube dwelling deposit feeder (SAIC 1992). The large numbers of these initial colonizers may indicate that contamination has had an impact on the benthic habitat.

POST-CAP STUDY

In August 1992, the monitoring team collected samples for the first post-cap benthic taxonomy study (Appendix I). The study provides information on the number and species of organisms recolonizing the cap within 5 months after cap placement. August was chosen because it was anticipated that biomass would be highest.

The monitoring plan defined four benthic taxonomy sampling stations that provided spatial coverage across the Pier 53 cap (see Map 6-2). Two stations are in the ENR (VG3 and VG4) and two stations are in the 3-foot-thick cap area (VG1 and VG2). All four stations are at similar water depths of 40 to 55 feet. The stations are also in an area where the bottom slope is less steep than it is inshore. The stations are all situated near the center of the cap, to decrease interference from offsite benthic organisms that would otherwise skew the test results.

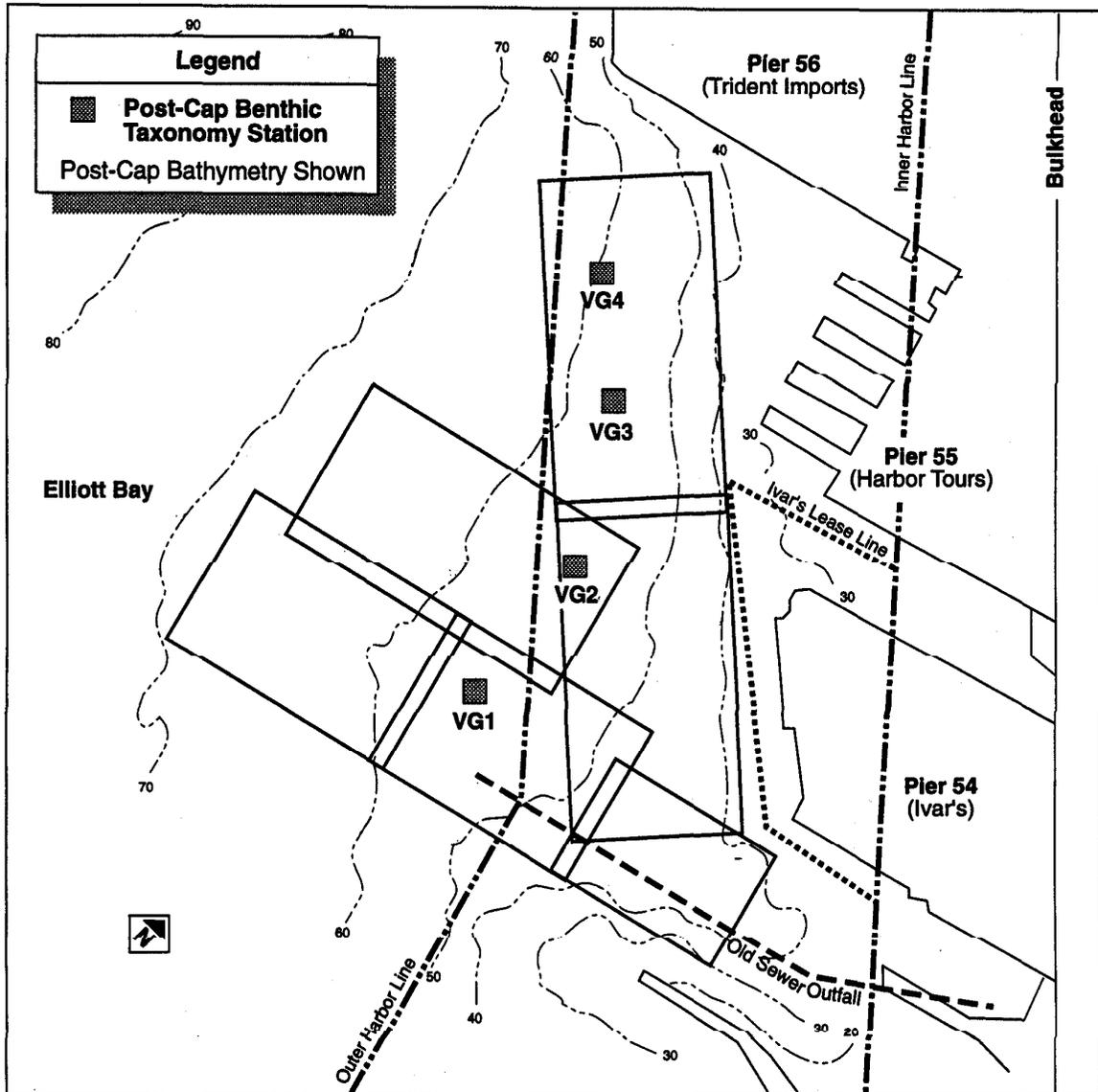
Method

The sampling method for the post-cap study was similar to that of the pre-cap study except that Pentec Environmental Consultants directed the screening and preservation of the samples from the *RV Liberty*. Marine Taxonomic Services also conducted the taxonomic identification.

Results

The progress of benthic recolonization of an area can be described by the types of organisms that move into a recently disturbed environment. The first invertebrates to re-populate an area are relatively short-lived and have relatively low biomass. They are filter feeders, assimilating their food from the water column, and do not depend on the substrate for nourishment. These organisms add organic material to the bottom sediment, allowing the next stage of organisms to gain a foothold in the area.

The next type of organisms to move into a recently disturbed area are deposit feeders. They feed on deposits of organic material on or just below the bottom surface and are less mobile than initial recruits but are able to take advantage of



Map 6-2. Post-Cap Benthic Taxonomy Stations

feeding opportunities over a larger area than other types of organisms that will follow. These infaunal deposit feeders continue to contribute organic material in and on the bottom sediments. By penetrating the substrate, they aerate the sediments, allowing the next stage of bottom feeders to inhabit the area. These deposit feeders are the first organisms to begin living in the bottom sediments.

The last type of benthic infauna to move into an area is completely dependent on organic material in the bottom sediments for nourishment. These organisms typically burrow into the sediment and feed at depth, head down. These organisms are the least mobile and are most likely to be found in a low-disturbance environment (SAIC 1992).

The most abundant benthic organisms detected on the Pier 53 cap were the polychaetes *Spiochaetopterus costarum*, *Prionospio steenstrupi*, *Pectinaria californiensis*, and *Nephtys cornuta*, the juvenile bivalve *Macoma sp.*, and the ostracod, *Euphilomedes carcharodonta*. Representative species are presented in Tables 6-10 through 6-13. *Spiochaetopterus costarum* ranged from 83 individuals at Station VG-1 to 27 individuals at Station VG2. *Prionospio steenstrupi* ranged from 64 individuals at Station VG2 to 16 individuals at Station VG3. *Pectinaria californiensis* ranged from 53 individuals at Station VG4 to 10 individuals at Station VG1. *Nephtys cornuta* ranged from 20 individuals at Station VG1 to one at Station VG3. *Macoma sp.* ranged from 59 individuals at Station VG3 to 5 individuals at Station VG1. *Euphilomedes carcharodonta* ranged from 49 individuals at VG4 to none for one sample at VG1.

Most of the organisms present on the Pier 53 cap are likely to be the first to inhabit a recently disturbed area. The tube-dwelling, filter-feeding *Spiochaetopterus costarum* and *Prionospio steenstrupi* are pioneering organisms found in abundance in the Pier 53 cap. A notable exception is the large number of the polychaetes *Pectinaria californiensis*, which are less likely to inhabit a recently disturbed area.

The presence of these head-down deposit feeders may be related to accelerated recolonization of the cap, differences in capping material, or an areawide biological bloom. The presence of these organisms is paradoxical, given the short recolonization time. It is worth noting that relatively few *Pectinariids* were observed in the pre-cap benthic study. Of all the head-down deposit feeders, *Pectinaria* are among the most mobile and are tolerant of sand, using it to build their tubes. The bivalve *Macoma sp.* is a surface deposit feeder typically arriving after short-lived filter-feeders have begun to recolonize a recently disturbed area. Nearly all of the *Macoma* bivalves observed in the Pier 53 cap sediments were juveniles, indicating larval recruitment. Should the juveniles survive and become long-lived, the cap progression to the next successional community will be based on the functional role of *Macoma* as a surface deposit feeder (SAIC 1992). It is also worth noting that the burrowing shrimp *Callianassa* were found at the cap and ENR stations at approximately 20 per meter square, where none were observed before. *Callianassa* shrimp burrow into the sand but are typically limited to less than 3 feet deep.

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Glycera capitata</i>	4	5	2	3	11	5
<i>Glycinde armigera</i>	0	1	1	1	2	1
<i>Nephtys cornuta</i>	20	10	5	4	5	8.8
<i>Nephtys ferruginea</i>	2	5	9	1	4	4.2
<i>Notomastus tenuis</i>	1	0	0	0	0	0.2
<i>Paraprionospio pinnata</i>	1	1	2	1	7	2.4
<i>Pectinaria californiensis</i>	14	19	24	10	21	17.6
<i>Pectinaria granulata</i>	3	1	3	2	2	2.2
<i>Phyllochaetopterus prolificu</i>	1	12	5	10	2	6
<i>Prionospio steenstrupi</i>	40	51	48	42	36	43.4
<i>Spiochaetopterus costarum</i>	83	58	82	69	47	67.8
Mollusks						
<i>Macoma sp. Juv.</i>	10	10	12	5	15	10.4
<i>Nitidella gouldi</i>	1	2	0	0	0	0.6
Crustaceans						
<i>Euphilomedes carcharodonta</i>	0	8	12	18	10	9.6
<i>Euphilomedes producta</i>	0	2	4	4	5	3
Others						
<i>Anthozoa sp. 1</i>	0	1	4	2	2	1.8
<i>Ophiuroidea sp. Juv.</i>	0	3	6	6	5	4

Taxon	Numbers of Individuals per 0.1 m ²					Average Rep
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Glycera capitata</i>	6	8	10	4	9	7.4
<i>Glycinde armigera</i>	0	3	2	4	3	2.4
<i>Nephtys cornuta</i>	7	11	6	12	12	9.6
<i>Nephtys ferruginea</i>	4	13	5	5	4	6.2
<i>Notomastus tenuis</i>	1	0	0	0	0	0.2
<i>Paraprionospio pinnata</i>	3	0	2	1	7	2.6
<i>Pectinaria californiensis</i>	15	21	13	-19	46	22.8
<i>Pectinaria granulata</i>	5	0	1	4	2	2.4
<i>Phyllochaetopterus prolifica</i>	5	11	2	1	7	5.2
<i>Prionospio steenstrupi</i>	20	64	28	62	57	46.2
<i>Spiochaetopterus costarum</i>	27	64	42	49	50	46.4
Mollusks						
<i>Macoma sp. Juv.</i>	15	26	29	35	34	27.8
<i>Nitidella gouldi</i>	0	16	3	3	4	5.2
Crustaceans						
<i>Euphilomedes carcharodonta</i>	4	12	6	11	13	9.2
<i>Euphilomedes producta</i>	1	1	0	3	7	2.4
Others						
<i>Anthozoa sp. 1</i>	0	2	11	7	9	5.8
<i>Ophiuroidea sp. Juv.</i>	1	7	11	8	4	6.2

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Taxon	Numbers of Individuals per 0.1 m ²					Average
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Glycera capitata</i>	11	10	5	3	4	6.6
<i>Glycinde armigera</i>	1	2	2	2	4	2.2
<i>Nephtys cornuta</i>	3	11	1	10	10	7
<i>Nephtys ferruginea</i>	4	6	3	3	4	4
<i>Notomastus tenuis</i>	11	4	2	2	4	4.6
<i>Paraprionospio pinnata</i>	0	5	0	5	1	2.2
<i>Pectinaria californiensis</i>	29	27	35	23	22	27.2
<i>Pectinaria granulata</i>	5	3	3	3	3	3.4
<i>Phyllochaetopterus prolifica</i>	4	4	12	3	3	5.2
<i>Prionospio steenstrupi</i>	16	45	23	18	31	26.6
<i>Spiochaetopterus costarum</i>	63	31	58	29	26	41.4
Mollusks						
<i>Macoma sp. Juv.</i>	37	54	20	45	59	43
<i>Nitidella gouldi</i>	0	1	9	0	1	2.2
Crustaceans						
<i>Euphilomedes carcharodonta</i>	14	27	17	11	13	16.4
<i>Euphilomedes producta</i>	1	3	2	0	0	1.2
Others						
<i>Anthozoa sp. 1</i>	4	2	1	6	4	3.4
<i>Ophiuroidea sp. Juv.</i>	4	12	4	7	7	6.8

Taxon	Numbers of Individuals per 0.1 m ²					Average
	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	
Polychaetes						
<i>Glycera capitata</i>	6	1	7	8	4	5.2
<i>Glycinde armigera</i>	2	6	3	1	2	2.8
<i>Nephtys cornuta</i>	2	5	2	2	6	3.4
<i>Nephtys ferruginea</i>	1	1	1	6	2	2.2
<i>Notomastus tenuis</i>	0	1	2	1	3	1.4
<i>Paraprionospio pinnata</i>	2	2	7	4	2	3.4
<i>Pectinaria californiensis</i>	33	25	53	48	31	38
<i>Pectinaria granulata</i>	1	2	6	3	4	3.2
<i>Phyllochaetopterus prolifica</i>	0	2	3	5	3	2.6
<i>Prionospio steenstrupi</i>	33	37	61	82	38	50.2
<i>Spiochaetopterus costarum</i>	47	23	41	40	32	36.6
Mollusks						
<i>Macoma sp. Juv.</i>	8	24	25	24	35	23.2
<i>Nitidella gouldi</i>	3	4	19	34	2	12.4
Crustaceans						
<i>Euphilomedes carcharodonta</i>	21	35	42	49	27	34.8
<i>Euphilomedes producta</i>	0	3	8	4	6	4.2
Others						
<i>Anthozoa sp. 1</i>	3	5	4	6	5	4.6
<i>Ophiuroidea sp. Juv.</i>	4	4	4	3	2	3.4

Abundance. Abundance was determined by averaging the number of individuals counted for five replicate samples at each station (see Table 6-14). The total average abundance ranged from 279 individuals at Station VG4 to 227 individuals at Station VG1. Polychaetes were the most abundant taxonomic group, ranging from an average of 186 individuals at Station VG2 to 163 individuals

5 reps x 0.1 m ²	VG1	VG2	VG3	VG4	Avg. Totals
Polychaetes	183	186	163	177	177
Mollusks	13	39	51	47	37
Crustaceans	20	20	24	44	27
Other	11	21	27	11	17
Totals	227	266	265	279	258

at Station VG3. Mollusks were the next most abundant group, ranging from an average of 51 individuals at Station VG3 to 13 individuals at Station VG1. Crustaceans ranged from 44 individuals at Station VG4 to 20 individuals at VG2. Average infaunal densities (means of all replicates pooled for a given station) ranged from 2,272 individuals/m² of sediment to 2,784 individuals/m².

Number of Species. In all, 139 different species of benthic infauna were detected in the Pier 53 cap (see Table 6-15). Typically, each species had only one or two individuals. There were 98 species counted at Station VG2, 92 species at VG4, 84 species at VG3, and 80 species at VG1. Polychaetes were the most diverse, ranging from 57 species at both VG2 and VG4 to 46 species at VG1. Mollusks ranged from 18 species at VG2 to 11 species at VG1. Crustaceans ranged from 17 species at VG3 to 14 species at VG4.

5 reps x 0.1 m ²	VG1	VG2	VG3	VG4	Totals
Polychaetes	46	57	48	57	80
Mollusks	11	18	13	14	26
Crustaceans	16	16	17	14	24
Other	6	7	6	7	9
Totals	80	98	84	92	139

Biomass. Wet weight biomass was measured in grams and then averaged for each replicate sample. Total average biomass ranged from 2.26 grams at Station VG3 to 1.77 grams at Station VG1. Polychaetes were the taxonomic group with the highest biomass weight, averaging 1.6 grams per station, and ranging from 1.8 grams at VG3 to 1.5 grams at VG1. Crustaceans were the next highest, averaging

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0.11 grams per station, and ranging from 0.15 grams at Station VG3 to 0.08 grams at Station VG2. Mollusks averaged 0.08 per station and ranged from 0.16 at Station VG4 to 0.08 at Station VG2.

Station	Polychaetes	Mollusks	Crustaceans	Ophiuroids	Misc.	Total
VG1	1.5082	0.0326	0.0832	0.008	0.1418	1.7738
VG2	1.5388	0.0384	0.0818	0.0032	0.1796	1.8418
VG3	1.8212	0.0654	0.1516	0.0256	0.2008	2.2646
VG4	1.6438	0.166	0.1288	0.004	0.2508	2.1934

Productivity. Productivity was estimated by comparing abundance, number of species, and biomass for each station. It appears that the ENR stations (VG3 and VG4) are more productive than the 3-foot cap stations. Average total abundance was highest at VG4. VG3 had only one less average individual per replicate sample than the next highest average at VG2. Biomass was highest at VG3, and VG4 was the next highest. Biomass averaged 0.4 grams higher at the ENR stations than the 3-foot cap stations. VG1 was the least productive in all categories. Average abundance at VG1 was almost 40 individuals less than the next highest station. The number of species were also lowest at VG1. There were 18 less species counted at VG1 than at the other 3-foot cap station, VG2. VG1 was also lowest in biomass but was only about 0.07 grams less than the other 3-foot cap station. All the differences in productivity are minor, however, and recolonization is proceeding similarly in all areas of the cap and ENR. Results of future benthic monitoring will be needed to determine whether there are significant differences in productivity among the different areas of the cap and ENR.

PRE- AND POST-CAP COMPARISON

Comparisons between the pre-cap taxonomy and the post-cap taxonomy showed that there were four species in the top ten most abundant for both studies. Overall abundance was determined by averaging all five station replicate samples. *Prionospio steenstrupi* was the second most abundant species among both the pre- and post-cap samples. *Euphilomedes carcharodonta* was the third most abundant species among the pre-cap samples and the fifth most abundant among the post-cap samples. *Nephtys cornuta* was the ninth most abundant species among the pre-cap samples and the sixth most abundant among the post-cap samples. *Macoma sp. Juv.* was the tenth most abundant species among the pre-cap samples and the fourth most abundant among the post-cap samples.

First-Year Denny Way Cap Comparison

Six of the top ten most abundant species in the pre-cap samples were present in reduced numbers in the post-cap samples. *Axinopsida serricata* was the most abundant species among the pre-cap samples but was not among the top 20 most abundant in the post-cap samples. *Lumineris sp. Indet.*, *Heteromastus filobranchus*, *Parvilucina tenuisculpta*, and *Notomastus tenuis* were all in the top 10 most abundant species among the pre-cap samples but were not among the top 20 in the post-cap samples. *Euphilomedes producta* was the eighth most abundant species among the pre-cap samples and the sixteenth most abundant among the post-cap samples.

Six of the top ten most abundant species among the post-cap samples were either not found or were present in reduced numbers in the pre-cap samples. *Spiochaetopterus costarum* was the most abundant species among the post-cap samples but was the nineteenth most abundant in the pre-cap samples. *Glycera capitata*, and *Cucumaria sp. A* were seventh and ninth most abundant in the post-cap samples but were not found among the pre-cap samples. *Pectinaria californiensis*, *Nitidella gouldi*, and *Ophiuroidea sp. Juv.* all were in the top 10 most abundant in the post-cap samples but were not among the top 20 most abundant in the pre-cap samples.

FIRST-YEAR DENNY WAY CAP COMPARISON

The sediment cap at Pier 53 was in many ways similar to the Denny Way CSO sediment cap shortly after cap placement. Both are dominated by organisms most likely to be the first to inhabit a recently disturbed area. Pier 53 had a higher number of species counted due to the larger number of polychaete species. While mollusks and crustaceans made up a smaller portion of the benthic population at both caps, Denny Way had more species of both these groups. Denny Way had a higher total average abundance but both caps had similar overall average biomass weight.

Samples were taken from the Denny Way sediment cap from two benthic taxonomy stations, J and M. Collection methods, screening, and species identification were the same as the Pier 53 samples and were conducted by the same contractors. One replicate sample from the Denny Way Station J was destroyed during transit to the analytical laboratory. Averages for Station J were determined by averaging the four remaining samples.

Overall the number of species was similar, with 139 different species counted at the Pier 53 cap and 121 species counted after the first year at Denny Way. Polychaetes were the taxonomic group with the highest number of species counted

First-Year Denny Way Cap Comparison

at both caps. At Denny Way there were 68 species at Station M and 50 species at Station J. At Pier 53, polychaetes ranged from 98 species at Station VG2 to 80 species at VG1. At Denny Way there were 28 species of mollusks at Station M and 17 species at Station J. Pier 53 mollusks ranged from 18 species at VG2 to 11 species at VG1. At Denny Way there were 18 species of crustaceans at Station M and 21 species at Station J. Pier 53 crustaceans ranged from 17 species at VG3 to 14 species at VG4.

Average abundance was different between the Denny Way cap and Pier 53 because of large numbers of *Macoma sp. Juv.* For all species at Denny Way, 470 individuals per replicate sample were counted at Station M and 378 were counted at Station J. At Pier 53, all species totals ranged from an average of 279 individuals per replicate sample at Station VG4 to 228 individuals at VG1. Mollusks, with the large numbers of *Macoma sp. Juv.*, were the most numerically abundant group at Denny Way, with an average of 243 at Station M and 222 at Station J. At Pier 53, mollusks ranged from an average of 51 individuals at VG3 to 13 individuals at VG1. Polychaete numbers were similar between the two caps. At Denny Way, polychaetes averaged 195 at Station M and 128 at Station J. Polychaetes were the most abundant group at Pier 53, ranging from an average of 186 individuals at VG2 to 163 at VG3. At Denny Way there was an average of 23 crustaceans at both Stations J and M. Pier 53 crustaceans ranged from an average of 43 individuals at Station VG4 to an average of 20 at Station VG2.

Biomass weight was similar at both Denny Way and Pier 53. For comparison, biomass weight for all replicate samples (in grams) was averaged for each station. At Denny Way, all species weighed an average of 2.7 grams at Station M and 1.9 grams at Station J. At Pier 53, total species biomass ranged from 2.3 grams at Station VG3 to 1.8 grams At Station VG1. Polychaetes had the highest biomass weight at both caps. At Denny Way, polychaetes weighed an average of 1.99 grams at Station M and 1.37 grams at Station J. Pier 53 polychaetes ranged from an average of 1.8 grams at Station VG3 to 1.5 grams at Station VG1. At Denny Way, the large numbers of the mollusk *Macoma* were juvenile and therefore small in terms of biomass, giving mollusks an average biomass weight of 0.44 grams at Station M and 0.35 grams at Station J. Pier 53 mollusks ranged from 0.16 grams at VG4 to 0.032 grams at VG1. At Denny Way, crustaceans averaged 0.25 grams at Station M and 0.14 grams at Station J. Pier 53 crustaceans ranged from an average of 0.15 grams at Station VG3 to an average of 0.08 grams at Station VG2.

VIDEO CAMERA SURVEY

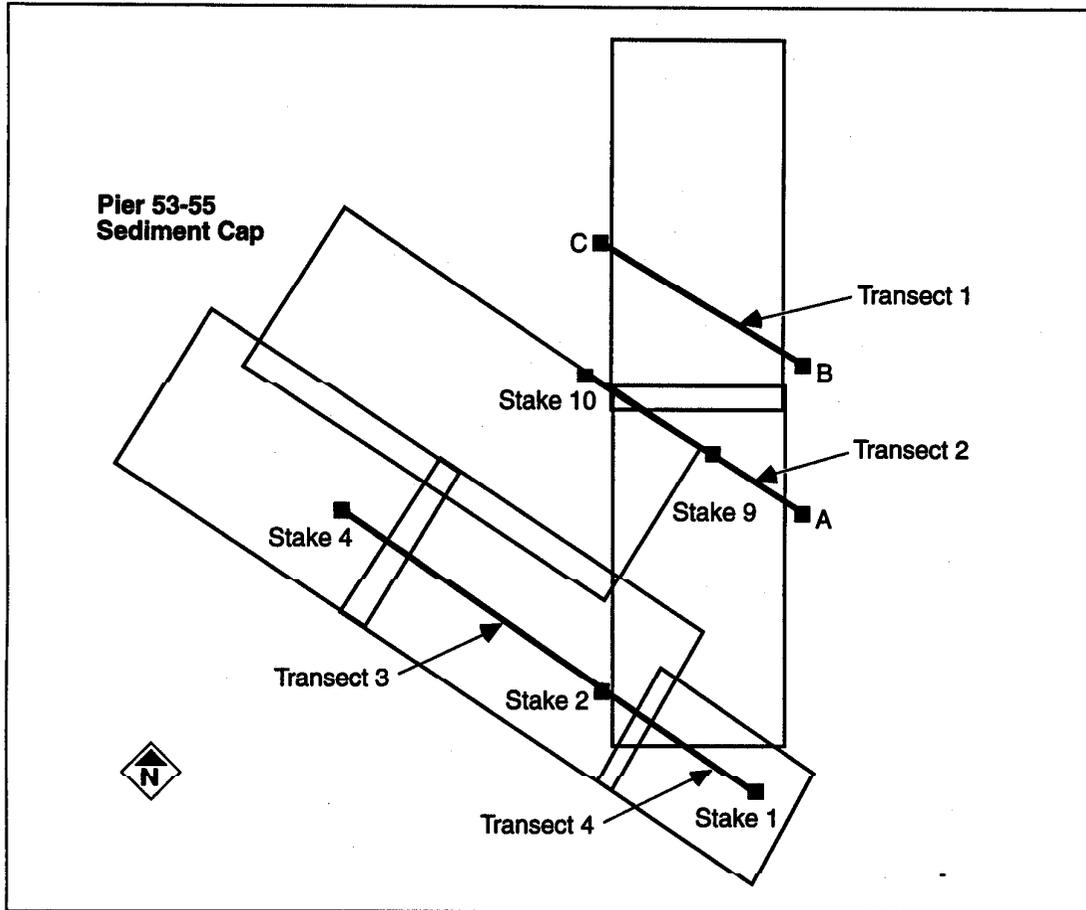
In May of 1992, two months after the sediment cap was installed, a diver-held-video-camera survey was conducted. Compared to other methods of collecting information about the cap and the cap biology, the video survey was the least expensive, and provided spatial coverage over the largest area. In the future, video surveys would be useful for comparison of large-scale trends on the cap. In addition, if large differences occur between the on-cap benthic taxonomy stations, a video investigation of the entire cap should be the first step in assessing causes. A video survey could also guide the decision to employ further sediment-profile camera surveys.

Methods

A diver, supported by a diving assistant aboard a dive boat and a research crew aboard the *RV Liberty*, conducted the video camera survey along three downslope transects on the Pier 53 cap. The diver held a waterproof video camera and swam along the transects, marked by a rope strung along the bottom, while filming the cap. Anchors, securing the transect ropes, were set in place using a range-azimuth positioning system.

The first video camera transect the diver filmed began on the inshore edge of the ENR between Pier 54 (Ivar's) and Pier 55 (Harbor Tours) and extended offshore (downslope) until reaching the edge of the capping sands (see Map 6-3). The second transect also began on the inshore edge of the cap, starting at the north corner of Pier 54, ran offshore through measuring Stake 9, and ended at measuring Stake 10. The third transect, located in the middle of the 3-foot thick cap, ran downslope from measuring Stake 2 to measuring Stake 4. The last transect ran from measuring Stake 1 in the southern inshore corner downslope to measuring Stake 2 in the center of the 3-foot-thick area. The transects provided spatial coverage on the ENR and the 3-foot-thick area. The transects also began outside the capping boundary and proceeded onto the cap to show the change from the native substrate to the cap. The entire video was approximately 60 minutes long, with a quarter of the time spent on each of the four transects.

The *Liberty* and the diver-support boat were tied together and connected to the diver by a cable. The diver was supplied air from onboard and was in contact with the crew at all times by radio. The video camera was connected to a video monitor onboard the *Liberty*, where the crew could monitor and direct the taping of the cap.



Map 6-3. Video Camera Diver Transects

Results

The video shows the cap 2 months after installation. The surface is relatively flat with mud clasts and wood debris standing in relief on the surface. When compared to the surrounding area, the cap is relatively clear, with a tan-colored fine-grained silt layer on top. The surrounding native sediments are covered by more and larger plant life, manmade debris, likely from the piers and boating activity, and greater surface relief. Some predators, flounders, octopi, and other epibenthic organisms were present.

The video shows that the capping sands spread out and formed a blanket layer on the bottom. The diver reported some large shallow depressions and rises in the cap that likely were where the barge tracks overlapped or diverged during cap

placement. There were no ripples that would indicate bottom scour or bedload transport of capping sediments by currents or wave action. Outside of the cap boundary, the native muds were a tan color and uncohesive in consistency. Mud clasts that appeared on the cap were very cohesive, gluey, and black. It is most likely that the black mud pieces and the wood debris shown in the video on the surface of the Pier 53 cap were from the Duwamish River. They were very similar to the mud pieces and wood debris shown in the videos for the Denny Way sediment cap. The sand for both the Denny Way and Pier 53 cap came from the same site in the turning basin of the Duwamish River.

Images along the transects show that the recolonization of the cap is starting at the edges. The first, second, and fourth transects showed a much richer benthic community on the edges of the cap. In each case as the diver proceeded onto the cap, the marine benthos thinned until there was only sparse evidence of a benthic community. Along the third transect, which was completely in the center of the 3-foot area, there were significantly less burrows, tubes and other signs of benthic organisms than other transects at the cap edge. Near the outside edges of the cap at the first and second transects there were many (approximately 50-100) *Achieroids*.

SEDIMENT-PROFILE CAMERA SURVEY

The primary purpose of the sediment-profile camera survey was to determine the boundaries of the capping material. This aspect of the survey and a method description are summarized in Section 3, and the SAIC report appears in Appendix I. This section summarizes biological data in the report, documenting the recolonization of the capped area.

Sediment-profile camera surveys map the succession of benthic organism stages that recolonize the cap. The mapping of successional stages is based on the theory that organism-sediment interactions follow a predictable sequence after a major seafloor disturbance. This theory states that primary succession results in "the predictable appearance of macrobenthic invertebrates belonging to specific function types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest..., our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer, 1982).

The first benthic invertebrates to recolonize a disturbed seafloor area usually consist of near-surface living, tube-dwelling polychaetes. They are considered

Sediment-Profile Camera Survey

Stage I colonizers. Stage II colonizers are typically shallow-dwelling bivalves, which are surface or near-surface deposit feeders. The final successional stage, Stage III, brings infaunal invertebrates, which live below the surface. Many are head-down deposit feeders.

Results

Camera images show that after 7 months the recolonization of the Pier 53 sediment cap is patchy and dominated by sparse Stage I communities. Stage I communities are typically early colonizers of disturbed environments, are relatively short lived, and have a relatively low biomass. Many of the stations within the cap showed no signs of biological activity. However, these areas are not conclusively devoid of benthic life.

It appears that infaunal communities present in the pre-cap environment did not survive the rapid burial of cap placement. Recolonization appears to be occurring via larval recruitment or the lateral migration of organisms as adults as opposed to vertical migration through the capping sands. Recolonization appears to be proceeding most rapidly at the edge of the cap. Of note is the appearance of small, porcelaineous benthic foraminifera as early colonizers of the cap. Many of the organisms observed are epifaunal ophiuroids and hydroids.

Within the survey area, Stage III organisms were found mostly outside of the cap boundary; this is in contrast to the large numbers of *Pectinariid* polychaetes found in the benthic taxonomy samples. It should be noted that there was approximately a 75 percent increase in the number of *Pectinariids* found after the cap was placed. Stations on the outside edge of the cap showed Stage I infauna present with Stage III. The Stage III infauna are evidenced by their domed, subsurface feeding voids. Also near the edge of the capping sand deposit, resident infauna were shown to be burrowing upward through the thin overlying sands.

Even though camera penetration into the cap material was shallow, it likely did not preclude the identification of Stage III organisms. Other features associated with Stage III organisms, such as ventilation of the sediment column, feeding mounds, fecal strings, and well-mixed surface sediments, were not seen in on-cap stations.

While the sediment profile camera survey and the video camera survey were different approaches to collecting data, both showed similar things about the cap surface. Both surveys showed that benthic recolonization is beginning at the edges of the cap and is relatively sparse and patchy in the middle. Both surveys showed

Sediment-Profile Camera Survey

no evidence of erosion on the cap surface and that the surface is mostly flat and topped with a thin layer of silt or organic particles. And finally, the mud pieces and the wood debris associated with the Duwamish River sands were seen in both surveys but there is a patchy distribution with areas of pure sand.

SECTION 7

CONCLUSIONS

The Pier 53 sediment cap and enhanced natural recovery area (ENR) project proceeded as expected, with few variations from the original plan.

The pre-cap sediment study showed the expected high concentrations of organic and metallic contaminants. The Duwamish River sediment study showed that the upper Duwamish River sediments were clean and suitable for capping.

Cap placement proceeded as planned. The amount of sediment used in the cap and ENR was similar to the amount projected except for the area farthest offshore and in deepest water. The method of applying the cap sediment directly from the barge worked well, and, by using available equipment, kept the project costs to a minimum.

Post-cap core samples showed the expected high chemical concentrations in the under-cap samples and either undetected or low concentrations in the within-cap samples.

The cap surface samples showed the cap to be clean and that the chemical concentrations were similar over the entire cap. As expected, the within-cap core and cap-surface chemistry levels were well below the cleanup standards and were very similar to the chemistry levels of the Duwamish River sediments. The presence of slightly elevated levels of metals and organics in one surface sample and one core section appeared to be related to the presence of clay from the Duwamish River capping sand.

The pre-cap benthic survey showed high numbers of species that are most likely to inhabit a stressed environment, indicating that contamination has possibly had an impact on the benthic habitat. The post-cap benthic survey showed that recolonization is beginning but numbers and biomass are low.

PRE-CAP SEDIMENT STUDIES

The pre-cap sediment study of the Pier 53 area showed high concentrations of metals and organic contaminants. All stations exceeded the state sediment cleanup screening levels (CSLs) for mercury, three stations exceeded for silver, and one

station exceeded for cadmium. The study also showed that several organic contaminants exceeded the state sediment quality standards (SOS), including PCBs at four stations.

The material used for the Pier 53 sediment cap was dredged from the Duwamish River, which was tested for chemical contaminants prior to dredging. There were a few irregularities in the test results, but the sediments were determined to be clean and suitable to be either disposed of in the PSDDA open water disposal site or used as capping material. One sample from the Duwamish study slightly exceeded a PSDDA value for 4-methylphenol. Because of the screening level and the holding time exceedances of the initial sample, the testing stations were resampled and subjected to PSDDA bioassay testing. The biotoxicity test consisted of exposing amphipods, *Neanthes* worms, and echinoderms to the sediments. The sample passed PSDDA biotoxicity standards for amphipods and *Neanthes* but failed the echinoderm sediment larvae test. The regulatory agency judged that the toxicity to the echinoderms may have been the result of ammonia produced by bacteria in the sediments and ruled the echinoderm test invalid for regulatory decision making. Since the sample had low concentrations for nearly all chemicals and passed the amphipod and *Neanthes* test, the sediment was approved for use as capping material without further testing.

CAP INSTALLATION

The area that the sediment cap and ENR covered was very close to the original plan. The plan called for the placement of 20,000 to 30,000 cubic yards of sediment in a 3-acre primary area at the Pier 53 site. If there was additional sediment available, a secondary area of 1.5 acres could be covered with a layer 1 foot thick. The actual installation used 22,000 cubic yards of sediment to cover approximately 4.5 acres. To facilitate installation, the site was divided into six barge tracks, with four covering the 3-foot-thick cap and two covering the 1-foot-thick ENR.

The planned thickness of the cap and ENR were close to the actual constructed thicknesses for four of the six barge tracks. The 3-foot cap ranged from 2.5 to 3.5 feet thick, and the 1-foot ENR ranged from 0.8 to 2.1 feet thick. It was felt that the measured thicknesses were satisfactory considering the application method. Greater thicknesses than planned occurred in one of the 1-foot-thick ENR barge tracks where there was overlap with the 3-foot-thick cap. While some sediment drifted from some barge tracks onto adjacent ones, the overall amount of sediment drift was minimal. A minimal amount of sediment drifted off the project site.

Using a bottom dump barge to install the Pier 53 3-foot-thick sediment cap and 1-foot-thick ENR was an efficient method of applying large amounts of sand at a time, covering the largest area of toxic bottom sediments to desired thicknesses while using available equipment. Because the Pier 53 project site is beyond the piers and has no other obstructions, tugboats were able to maneuver the barge into place, allowing the barge to spread the sand directly without the added expense of a crane to transfer the sand.

Special equipment needed for application of the capping sediment had been engineered for a previous capping project and was reemployed for this project. The barge and tugboat system is already used for transferring dredged material, and only one additional tug was needed for placement. The positioning system used to guide the barge is also used for other projects in the same manner and needed no modifications. A modified tide gauge was used to monitor the rate that sand was released. The modifications to the gauge were temporary, and, like the other equipment used in the project, the gauge was returned to its former use.

A sediment-profile camera survey was conducted and showed the boundary of capping sand and variations in the cap surface conditions. The study was conducted twice because a strobe light problem yielded under-exposed pictures from the first survey. A thin layer of capping sand (2 to 4 cm thick) extended about 300 feet west of the west edge of the barge tracks. Some areas of the cap surface have nearly clean sand while other areas are covered with organic detritus.

CORE SAMPLES

Core samples showed that the capping sediments were mostly clean and that their chemical makeup was similar to that of the Duwamish River sediments. Organic and metal contaminants either were undetected or were in very low concentrations. There were no PCBs in the capping material. The core samples also showed the high concentrations of chemicals in the under-cap sediments.

Only one of the 20 core sections of capping sands had elevated chemistry values. These elevated values occurred in the first 6-inch section of core sample C4, but it is unlikely that the values reflect any migration up into the cap. In that sample, laboratory personnel documented the presence of dark bands of clay. The clay appears to have been dredged along with the sand from the Duwamish River and contains higher concentrations of organics and metals than the sand. There was no specific chemical characterization of the clay but other studies have found that generally, clay has higher chemical values than sand. The clay is in small

Core Samples

amounts and has remained intact, minimizing its overall effect on the sediment cap, but it tends to elevate levels of metals and organics in the samples in which it appears. Both metals and organics values were increased and mercury exceeded the CSLs.

SURFACE SAMPLES

Like the core samples, the surface samples showed that cap sediments were mostly clean and that chemical concentrations were uniform and similar to those found in the Duwamish River sediments. Organic and metal contaminants, when detected, were in low concentrations and none exceeded the state cleanup screening levels or the sediment quality standards.

Some surface samples showed slightly higher concentrations of contaminants than the within-cap core samples. Higher concentrations at single stations usually indicated the presence of clay from the Duwamish River. Another possibility is that the higher concentrations at the surface were caused during the application of the capping material in which the coarser, denser sands settled first and any silt and organic material settled last. The organic compounds are more likely to adhere to the organic material and silts.

And finally, it is possible that at least some of the contaminants were from offsite. The sample station VG5, which showed the highest levels of contamination, is closest to the Madison street stormwater and combined sewer overflow. Flow volumes from stormwater and CSO events are unknown at this time but could be a factor. Another possible source is the station's proximity to the ferry terminal, where propeller scour from docking ferries could stir up contamination from south of the cap. Some of the suspended contaminants could then be resettling onto the cap, causing the increase in concentrations. Further sampling will be needed to determine the source of the slightly elevated levels of contamination at VG5 and elsewhere on the cap.

Surface samples from the surrounding area showed elevated levels of metals and organic contaminants. Several organic compounds exceeded both the state cleanup screening levels and sediment quality standards at the stations south of the cap. A comparison of the top 2-cm sample and a top 10-cm sample at Station VG8 showed that organic contamination was elevated in the surface 2 cm but that metal concentrations were higher in the deeper 10-cm sample. This could indicate that the organic contamination is of a more recent origin and metals inputs have decreased.

Under-pier samples also showed high concentrations of organic and metal contamination. In 42 instances contaminants in under-pier samples exceeded at least the state sediment quality standards. Higher organics concentrations were generally found in the surface 2-cm samples than in the deeper 10-cm samples. Metals concentrations, however, were similar between the surface 2-cm sample and the deeper 10-cm sample. Contamination under the piers appeared to increase closer to shore. UP1, farthest offshore, had the lowest concentrations, while the other three stations showed much higher concentrations and were closer to shore.

BENTHIC RECOLONIZATION

Benthic taxonomy sampling was completed and the results show that the benthic communities before and after cap placement are very different, suggesting the pre-cap organisms did not survive burial during cap construction. Recolonization of the cap is beginning and appears to be by juvenile recruitment or by the lateral migration of organisms as adults.

The pre-cap study showed large numbers of the species *Euphilomedes carcharodonta*, *Prionospio steenstrupi*, and *Heteromastus filobranthus*. These species are most likely to inhabit a stressed environment, indicating that contamination has possibly had an impact on the benthic habitat.

The post-cap study showed 134 species present, but numbers and biomass are low, as expected after only 5 months. Biomass is slightly higher in the ENR than in the 3-foot cap. This may mean that the ENR is more productive, but the difference is small and further study is needed to determine productivity differences. Also, further study will be needed to determine if the change in environment will cause the succession of a different post-cap community.

Images from the sediment-profile camera survey show that the Pier 53 cap is being recolonized by sparse benthic communities. It appears that infaunal communities present in the pre-cap environment did not survive the rapid burial of cap placement. Recolonization appears to be occurring via larval recruitment or the lateral migration of organisms as adults as opposed to vertical migration through the capping sands. The organisms that make up these communities are dominated by species that are usually first to recolonize a recently disturbed area.

An underwater video-camera survey completed 2 months after cap placement showed that recolonization is beginning at the edges and moving inward. Most evidence of benthic recolonization was near the edges of the cap, where there were

Benthic Recolonization

also many larger epibenthic organisms such as flounder and crab. In the middle of the cap, the video camera showed a flat gray substrate with few signs of benthic organisms. However, even in the center of the cap, there were signs of the lateral migration of organisms and signs that the benthic recolonization of the cap is beginning.

CONCLUSIONS

The capping method used for the Pier 53 project appears to have potential for economical remediation of some contaminated sediments as well as other less contaminated bottom areas. Because the contaminated sediments are not dredged but left in place, capping reduces the possible spread of contamination to surrounding areas and to the water column. The cost of remediating contaminated bottom sediments by capping can be 1 to 20 percent of the cost of dredging the contaminated material and disposing of it in an acceptable facility, assuming an acceptable facility can be found. Finally, this project demonstrated that conventional dredging and disposal equipment can be used in an innovative way to cap contaminated bottom sediments.