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Chemical Contaminants in Salmon Bay Sediments

Results of Phase II Sampling

November 1996

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Chemical Contaminants in Salmon Bay Sediments

Results of Phase II Sampling

by
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Abstract

During 1995, the Washington State Department of Ecology conducted a survey of chemical contaminants in bottom sediments from 29 areas throughout Salmon Bay. Sediments were analyzed for metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc), semivolatile organics, PCBs, and butyltins. Chemical data were compared to earlier studies in the basin and areal distributions were evaluated. Data were also compared to criteria to assess potential effects on aquatic organisms. Recommendations for further actions are included

The survey was the second phase in a study of Salmon Bay: Phase I study evaluated the potential for contamination based on visual observation of sediments; Phase III will likely include both intensive chemistry and bioassay testing in contaminated areas. The overall objectives of the Salmon Bay study are to delineate areas of contaminated sediments, evaluate their toxicity, identify the contaminants contributing to sediment toxicity, and if possible, identify likely historical and current sources of contaminants to the problem areas.

Summary of Findings

Salmon Bay is a narrow body of water in Seattle, Washington located between Lake Union to the east and Puget Sound to the west. The numerous industries located along the shores of Salmon Bay, in addition to marinas, dock facilities, and combined sewer overflows (CSOs), have all contributed to contamination of Salmon Bay sediments. However, little was known about the nature and extent of this contamination. The Salmon Bay Phase II study was designed to fill that void.

Objectives of the Salmon Bay study were to:

- Identify areas of contaminated sediment in Salmon Bay
- Evaluate the toxicity of these problem areas
- Identify the contaminants contributing to sediment toxicity
- To the extent possible, identify likely historical and current sources of contaminants to these problem areas

Phase II of the Salmon Bay study consisted of sampling bottom sediments from 29 areas throughout Salmon Bay. Sediments were analyzed for metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc), semivolatile organics, PCBs, and butyltins.

The eight metals analyzed were detected at all sample stations except for cadmium, which was below detectable levels at five stations. Median concentrations of metals in Salmon Bay were similar to those previously reported for the Ship Canal area, but arsenic, mercury, lead, cadmium, and zinc were 2 to 4 times higher in Lake Union sediments. Metals in Salmon Bay sediments were found at the following dry weight concentrations:

	Median	Range
Arsenic	20 mg/Kg	1.6 - 210 mg/Kg
Cadmium	0.6 mg/Kg	<0.3 - 3.2 mg/Kg
Chromium	60 mg/Kg	14 - 380 mg/Kg
Copper	319 mg/Kg	7.7 - 2,200 mg/Kg
Lead	151 mg/Kg	3.5 - 530 mg/Kg
Mercury	0.8 mg/Kg	0.01 - 5.0 mg/Kg
Nickel	48 mg/Kg	21 - 480 mg/Kg
Zinc	319 mg/Kg	27 - 2,000 mg/Kg

Less than half of the 74 semivolatile organic compounds analyzed were detected. With few exceptions, however, all ten high molecular weight polycyclic aromatic hydrocarbons (PAHs) and seven low molecular weight PAHs were detected at all sample stations. Median PAH concentrations in the present study are higher than those previously reported for either the Ship Canal or Lake Union (outside of the Gas Works Park area). Other semivolatile organics frequently detected include dibenzofuran, retene, 4-methylphenol, 3β-coprostanol, and butylbenzylphthalate. All other semivolatile organics were detected at fewer than 60% of the stations, and at concentrations generally less than 1,000 μg/Kg.

PCBs were detected at 26 of the 29 sample stations. Median PCB concentrations were similar to those in Ship Canal and Lake Union sediments. Tributyltin (TBT), once a principal component of anti-fouling paints, was found at all but one station. The major classes of organic compounds were detected at the following organic carbon-normalized (PAH and PCB) or dry weight (TBT) concentrations:

	Median	Range
Total PAH	490 mg/Kg OC	107 - 2,300 mg/Kg OC
Total PCB	4.8 mg/Kg OC	nd - 150 mg/Kg OC
TBT	326 μg/Kg	nd - 6,500 μg/Kg

Results of the study indicate there are no clear areal gradients throughout Salmon Bay for any of the chemicals analyzed. Instead, contaminant concentrations tend to show a "patchy" distribution which suggests that local conditions are the major determinant of concentration. With one possible exception, there is also a lack of gradation or geographical pattern with respect to clean sediments. However, the cleanest area appears to be at the terminus of the Ship Canal in the easternmost section of Salmon Bay.

Of the 29 stations sampled, 21 were located adjacent to marinas, boat repair facilities, marine terminals (including Fisherman's Terminal), shipyards, or other vessel-related facilities. Proximity to these facilities alone did not appear to dictate concentrations of TBT. Two of the six stations with TBT levels greater than 1,000 μg/Kg were not adjacent to these facilities while seven of eight sites with TBT less than 100 μg/Kg were located adjacent to areas with marinas, etc. Stations located near vessel-related facilities were, however, more likely to have high metals concentrations. There is also mixed evidence that CSO discharges account for a substantial portion of the contamination in Salmon Bay.

The biological significance of chemical concentrations in Salmon Bay sediments was evaluated by comparing them to guidelines for freshwater sediment quality, Ecology's Marine Sediment Management Standards, and Puget Sound Dredged Disposal Analysis (PSDDA) screening level. Based on these comparisons, sediments in most areas of Salmon Bay can be expected to have some degree of adverse impact on benthic organisms.

Tributyltin may pose the most serious threat to aquatic life in Salmon Bay due to its toxicity and high concentrations in sediments. All but five stations exceeded the PSDDA sediment screening level (SL) for TBT (73 µg/kg), and 30% of the stations had TBT concentrations elevated one to two orders of magnitude above the SL. However, recent work by the PSDDA agencies indicates that sediment concentrations are poor predictors of TBT bioavailability and toxicity to aquatic life. Therefore, additional studies may be needed in Phase III to assess the actual toxicity of TBT in Salmon Bay.

Chemicals other than TBT likely to harm aquatic life at one or more stations include copper, mercury, arsenic, lead, nickel, zinc, chromium, benzyl alcohol, 4-methylphenol, bis(2-ethylhexyl)phthalate, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, 1,4-dichlorobenzene, and PCB-1260.

Recommendations for the near term include conducting further investigations of chemical concentrations in the vicinity of the most contaminated stations, as well as identifying and prioritizing the needs for aquatic life protection in Salmon Bay in order to select appropriate biological tests to confirm predicted adverse impacts. It is also recommended that, for the long term, the translocation of sediments within Salmon Bay should be studied especially in areas considered for cleanup actions where on-site or off-site movement of sediments may be an important factor in selection of cleanup alternatives.

Recommendations

- Results of the Phase II study indicate that distribution of contaminants throughout Salmon Bay is spotty, although some highly contaminated locations have been identified. This raises questions about the areal extent of the contamination around the sample locations. Do nearby sediments contain similar contaminant levels? Do the sediments adjacent to the Phase II stations exhibit areal concentration gradients? If so, does the gradient suggest a particular contaminant source? The answer to these questions is an immediate concern to parties involved in efforts to cleanup or control contamination sources to Salmon Bay. With these considerations in mind, a near-term recommendation is for Ecology to conduct or oversee further investigations of chemical concentrations in the vicinity of the most contaminated stations. At least one relatively clean area should also be examined in such a manner.

- The Phase II study provides a fairly thorough characterization of chemical concentrations in sediments throughout Salmon Bay. However, essentially nothing is known about the toxicity of Salmon Bay sediments to aquatic organisms. Toxicity is difficult to predict based on available literature or criteria because of 1) the combination of chemicals present, and 2) the influence of saltwater in Salmon Bay. The toxicity, bioavailability, or bioaccumulation potential of tributyltin may be especially difficult to surmise because of the possibility that at least some of the tributyltin is in paint-chip form. Given the complex nature of these issues, a toxicity bioassessment of Salmon Bay sediments would require a large expenditure of time and money. Therefore it is recommended that the focus of toxicity testing be narrowed considerably. This can be achieved by first identifying and prioritizing the needs for aquatic life protection in Salmon Bay. Toxicity testing can then be designed to match the need for ecological resource protection. Agencies and tribes responsible for protecting or otherwise managing aquatic biota in Salmon Bay should be asked for input. Any information they can share about aquatic life implications based on Phase II results would be useful.

- Once contaminated areas are better characterized with respect to chemical concentrations and toxicity, it will be useful to understand the extent to which sediments are translocated within Salmon Bay. This is especially important in areas considered for cleanup actions where on-site or off-site movement of sediments may be an important factor in selection of cleanup alternatives. Therefore, a recommendation for the long term is to study the translocation of sediments within Salmon Bay. Sediment traps have been used successfully in Puget Sound to assess the transport of sediment-bound contaminants. Chemical and radionuclide examination of sediment cores may be a useful means to determine sedimentation rates.

Credits

- ◊ *Project Officer* - James Cubbage
- ◊ *Field Sampling* - James Cubbage, Dale Norton, Rick Huey, and Joanne Polayse-Wien
- ◊ *Sample Handling and Tracking* - Will White and Pam Covey
- ◊ *Lab Contracts* - Karin Feddersen
- ◊ *Lab Analyses* - Randy Knox, Jim Ross, Myrna McIntosh, Dickey Huntamer, Roy Araki (EPA), and Bob Reick (EPA)
- ◊ *Data Quality Reviews* - Stew Lombard, Pam Covey, Karin Feddersen, Myrna McIntosh, Bill Kammin, and Dickey Huntamer
- ◊ *Report Preparation* - Dave Serdar and James Cubbage
- ◊ *Report Review* - Dale Norton, Larry Goldstein, Teresa Michelsen, and Dan Cargill
- ◊ *Report Proofreading and Formatting* - Joan LeTourneau

Introduction

Background

Salmon Bay and the Lake Washington Ship Canal comprise a narrow body of water in Seattle, Washington connecting Lake Union to the east with Puget Sound to the west, through the Hiram Chittenden Locks (Figure 1). Salmon Bay was originally a salt water bay which was inundated with freshwater in 1914 when the locks were constructed to the west of Salmon Bay and connected to Lake Union through the Lake Washington Ship Canal. The Ship Canal is a narrow channel with some shallow embayments on the southern shoreline near the west end of the canal.

Numerous industries have been located along the shores of Salmon Bay and the Ship Canal, including shipyards, marinas, bulk fuel plants, fish processing, wood treating, lumber mills and plywood plants, bulk materials handling facilities, a large steel manufacturing plant, and an asphalt plant. In addition, stormwater from urbanized areas including the Ballard Bridge, Fremont Bridge, and combined sewer overflows (CSOs) discharge into Salmon Bay and the Ship Canal. These various sources have contributed to contamination in Salmon Bay and the west end of the Ship Canal, but the nature and extent and specific sources of contamination are not well defined. This lack of information has hampered attempts at source control and associated improvements in sediment quality.

Detailed studies of nearby Lake Union, including both chemistry and bioassays, have been conducted in the past by the Environmental Investigations and Laboratory Services (EILS) Program at Ecology, Municipality of Metropolitan Seattle (METRO), the City of Seattle, and others. These studies are summarized in *Survey of Contaminants in Sediments in Lake Union and Adjoining Waters* (Cubbage, 1992). However, few samples have been collected in Salmon Bay or the Ship Canal. In addition, the presence or absence of butyltins has not been evaluated in previous studies, and could be a significant source of toxicity in sediments given the ubiquitous presence of vessel traffic, shipyards, and marinas.

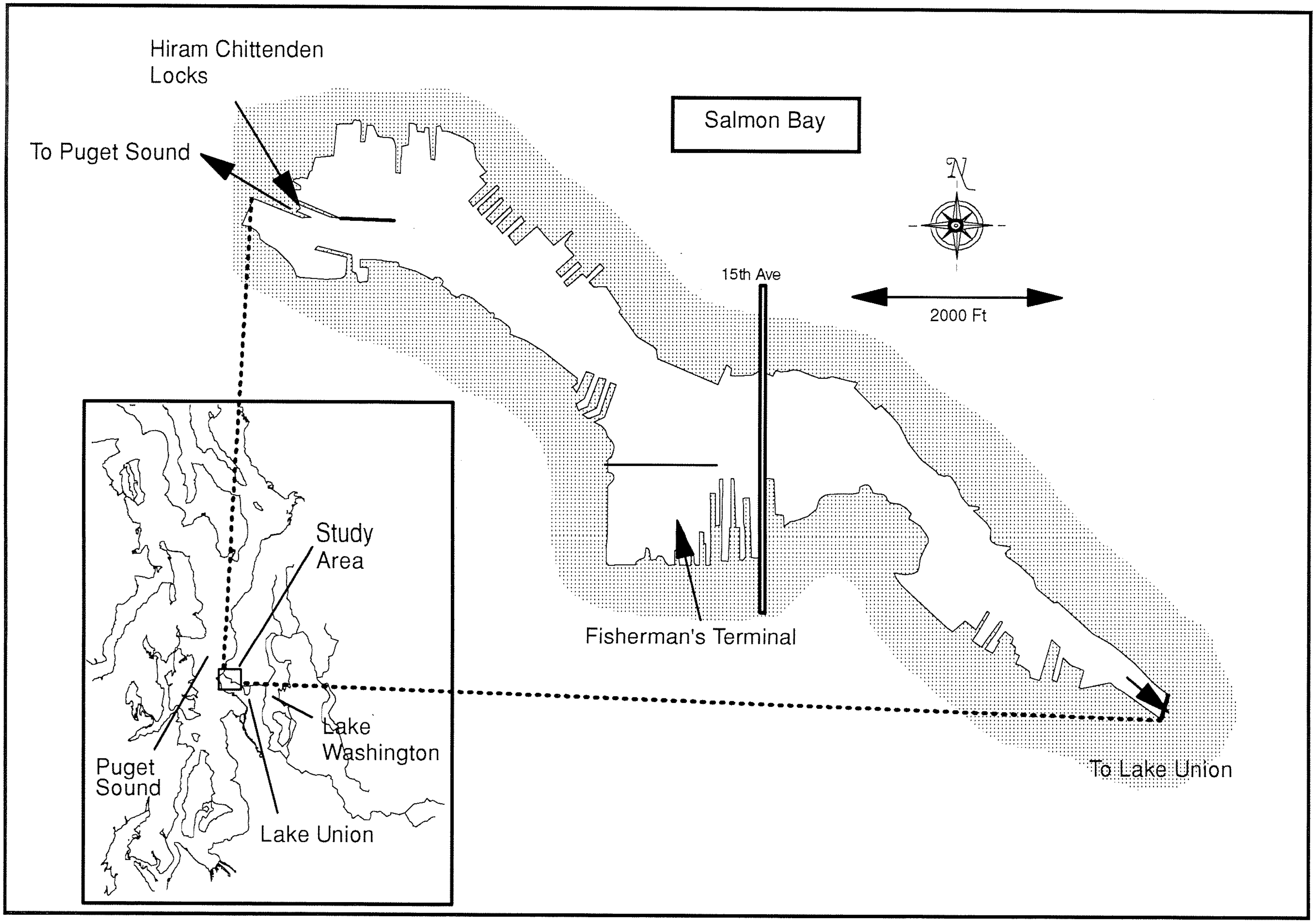

Figure 1. Study area and vicinity.

Objectives

The overall objectives of the Salmon Bay study are:

- Identify areas of contaminated sediment in Salmon Bay and nearshore areas of the Ship Canal.

- Evaluate the toxicity of these problem areas to determine whether they exceed the narrative cleanup screening levels (minor adverse effect on aquatic marine life) of the Sediment Management Standards (SMS; WAC 173-204) or freshwater sediment quality guidelines.

- Identify the contaminants contributing to sediment toxicity in the problem areas, including an evaluation of butyltins to determine whether this class of contaminant should be included in routine (*e.g.* NPDES) sediment analyses for Lake Union, Salmon Bay, and the Ship Canal.

- To the extent possible, identify likely historical and current sources of contaminants to these problem areas.

The study will provide the following benefits to the cleanup and source control programs:

- Identify areas that require cleanup and provide some indication of their relative priority. In addition, identify chemicals of concern to better focus source control efforts.

- Streamline dredging, construction, and NPDES permit processing for areas that are identified as clean. Provide justification for discharge and baseline sediment monitoring as part of the NPDES permitting program for areas that are identified as contaminated.

- Begin identifying areas that require additional stormwater or CSO control to prevent recontamination of areas targeted for dredging or cleanup.

- Contribute synoptic chemistry and bioassay data to help evaluate the toxicity of butyltin compounds.

These objectives are being addressed in three phases:

1. Phase I reconnaissance sampling was completed during April 1995, and consisted of visual examination of sediments from 81 stations evenly distributed throughout Salmon Bay and the Ship Canal. Samples were inspected for grain size (sand, silt, clay, etc.), evidence of contamination (oil, wood debris, paint chips), and biological organisms. Results (shown in Appendix A) were used to identify the more contaminated areas.

2. Detailed chemical analyses of potentially contaminated areas were conducted during Phase II, and are the subject of the present report.

3. Phase III will likely include both chemistry and biological testing to evaluate the toxicity of areas identified as contaminated during Phase II.

Methods

Sampling Strategy

The study area extends from the locks on the west to the western end of the Ship Canal. Results of the reconnaissance (Phase I) study indicated that most sediments in the vicinity of the eastern Ship Canal are coarse-grained which suggests little deposition of fine material. Little visible oil or other evidence of contamination was seen in this area as well. Based on these observations, this area was excluded from further investigation during Phase II.

Phase II focused on areas where visual contamination or depositional areas were observed during the reconnaissance study. Because the SMS requires at least three stations for any regulatory decisions, three or more stations were grouped in each major zone of concern and/or natural geographical feature (Figure 2). Sample stations were generally placed nearshore to CSOs, marinas, and shipyards. One sample zone was placed in the center channel to provide a sense of the ambient chemical concentrations in sediments. A description of each sampling station is included in Appendix B.

Sampling Methods

Sampling methods were consistent with the Puget Sound Estuary Program (PSEP) protocols (EPA, 1986a) as modified by the SMS (Ecology, 1991) and sampling methods used in previous Lake Union and Lake Washington studies conducted by EILS. However, to support evaluation of historical contamination and the cleanup program, the top 10 cm of sediment was sampled. This layer includes most of the biologically active zone in fresh water.

Samples were collected from Ecology's 20-foot skiff equipped with a 0.1 m^2 stainless steel Van Veen grab sampler. Stations were recorded using a Magellan® GPS (Global Positioning System) receiver with differential correction as well as from sightings on nearby landmarks. A grab was considered adequate if it was filled with sediment and both the grab as well as access doors on top of the grab were closed tightly (see PSEP protocols for full description). For each grab, the overlying water was siphoned off and the top 10 cm of sediment not touching the walls of the grab was scooped out of the top doors and placed in a stainless steel beaker.

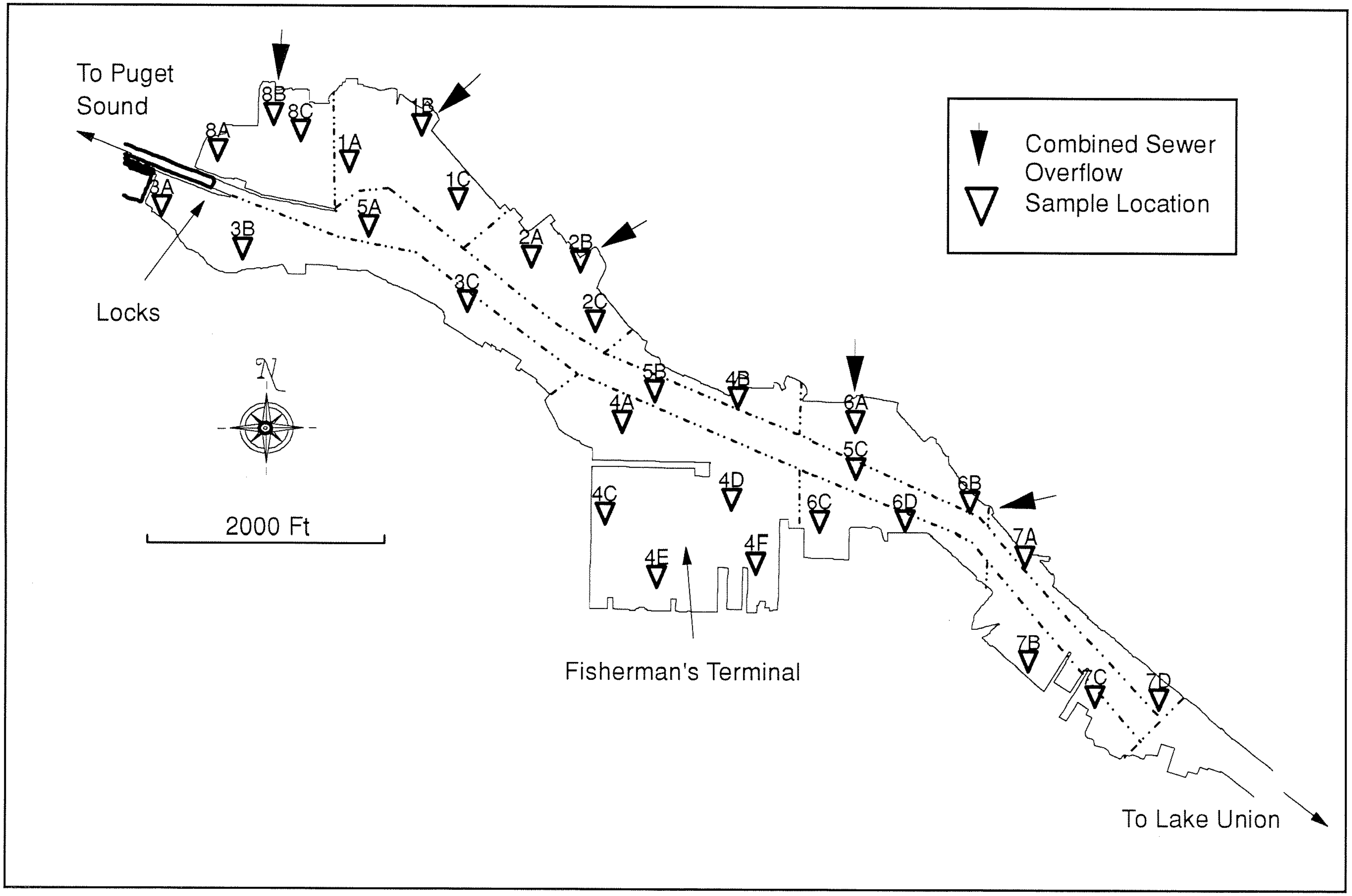

Figure 2. Sample stations and sample zones.

Prior to sampling, all stainless steel tools (grab, beakers, and spoons) were decontaminated with the following procedure:

- wash in hot water and Liquinox® detergent
- rinse in tap water
- rinse in 10% nitric acid
- rinse with deionized water
- rinse with pesticide analysis grade acetone
- air dry
- wrap in aluminum foil

The beaker contents were homogenized, and subsamples for metals and organics analysis were dispensed into separate 8-oz priority pollutant-clean jars capped with teflon lid liners. Samples for organic carbon analysis were placed in 4-oz jars. Grain size samples were placed in Whirl-Pak® bags. If oil was visible in the sample, the sampler was washed with detergent and the sample was disposed into a drum onboard. Between samples, the grab sampler was thoroughly brushed and rinsed with on-site water.

Chemical Analysis

Samples were analyzed for the following parameters:

- Grain size
- Total Organic Carbon (TOC)
- Percent Solids
- Metals, including mercury
- Semivolatile Organics (targeting PAHs, phthalates, and phenols)
- PCBs
- Butyltins

Grain size analysis was done by Soil Technology, Inc. on Bainbridge Island, WA. TOC analysis was done by Weyerhaeuser Analytical and Testing Services, Tacoma, WA. Analysis for metals, organics, and percent solids was conducted at the Ecology/EPA Manchester Environmental Laboratory in Manchester, WA. Analytical methods and target detection limits are shown in Appendix C.

Care was taken to achieve the SMS detection limits for "difficult" chemicals such as methylated phenols, since these are common constituents of plywood manufacturing facilities, and waste piles of glue are known to be present along the shoreline in some areas.

Data Quality

Quality of the data was determined by the analysis of laboratory QA/QC samples. Bias was evaluated through the analysis of check standards (metals), certified reference materials (PAHs and PCBs), uncertified reference sediment (butyltins), and matrix spikes. Precision was assessed through blind field splits, as well as duplicate analysis of reference materials and laboratory spikes. Method blanks were also analyzed to determine the effects of laboratory contamination. Appendix D includes complete results of these analyses as well as narrative quality assurance reviews by Manchester staff.

Table 1 shows a summary of the data quality for the project. Quality assurance results are compared to the data quality objectives outlined in the project plan (Cubbage and Michelsen, 1995). These quality requirements (termed QA1) are to be met in order for the data to be validated for use in sediment management decisions based on Puget Sound Dredged Disposal Analysis (PSDDA) conventions (Ecology, 1991), and are in most cases consistent with EPA Contract Laboratory Program (CLP) requirements.

Overall, quality of the data obtained for this project could be characterized as good. Quality of the metals data was generally better than the organics data, with a few exceptions. Spike recoveries for some of the lead and chromium results were slightly lower than acceptance limits, and were therefore given "N" qualifiers. Results for mercury are considered estimates ("J") because of poor spike recoveries. However, check standard recoveries for all metals averaged 92%, indicating a low level of bias for sample analysis.

Analysis of standard reference materials for PAHs and PCBs gave the best measure of bias for analysis of these compounds. Only slightly more than half of the compounds in NRCC HS6 (PAH in marine sediment) were within certified values. Aside from acenaphthylene, however, most compounds were not substantially outside of the certified ranges. The average recovery for acenaphthylene was approximately 300%.

Matrix spike recoveries for semivolatile organics analysis also indicated low bias overall. Only 5% of the spiked samples were outside of the 50-150% recovery window, although the average spike recovery was somewhat low (83%). For PCBs, recoveries for both the standard reference material (NRCC HS2, PCBs in marine sediment) and matrix spikes were very good.

It was somewhat difficult to assess bias of the butyltin data. Analysis of a reference material (Sequim Bay sediment) yielded poor recoveries for tributyltin (average of 39%). However, no value or range of values has been established for tributyltin concentration in this material. Matrix spike recovery data did not contribute much to determining bias since one of the spiked samples contained high native concentrations of butyltins. Fortunately, an additional spiked sample yielded good recovery data.

Table 1. Functional quality assurance elements required for QA1 review and acceptance under Sediment Management Standards[1].

	Conventionals		Metals		Organics: semivolatiles, PCBs, butyltins	
Parameter	Target	% Achieved	Target	% Achieved	Target	% Achieved
Matrix Spikes (*5% of samples*)	NA	NA	75-125% recovery	75%	50-150% recovery	SVOs - 95% PCBs - 100% Butyltins - 58%
Certified Reference Materials (*CRM; 2/ study*)	NA	NA	80-120% recovery	88%	95% confidence interval	PAHs - 62% Other SVOs - NA PCBs - 100% Butyltins - NA
Surrogate Spikes[2] (*added to each sample*)	NA	NA	NA	NA	>50% recovery; PCBs >60%	SVOs - >99% PCBs - 14% Butyltins - 84%[3]
Analytical Replicates (*5% of samples; spike duplicates for conventionals, CRMs for others*)	20% RPD	100%	20% RPD	100%	35% RPD or Coefficient of Variation	PAHs - 100% Other SVOs - NA PCBs - 100% Butyltins - 100%
Blanks (*1/extraction batch or in a 12 hour period*)	NA	NA	< detection limit	62%	Phthalates: 5 µg, others 2.5 µg or <5% of analyte concentration	Phthalates -100% Other SVOs->99%; PCBs - 100%; Butyltins - 97%
Holding Times (*until extraction*)	TOC 14 days @ 4°C	0%	6 months @ 4°C	100%	14 days @ 4°C Butyltins - freeze within 24 hrs of collection	SVOs - 0% PCBs - 0% Butyltins - 100%

[1] Source: Ecology, 1995

[2] EPA (SW 846; EPA, 1986b) control limit criteria are considered acceptable where reported.

[3] Only 68% of surrogate spikes had recoveries between 50% and 200%.

RPD=Relative Percent Difference

NA=Not Analyzed

Duplicate analysis of matrix spikes and reference materials yielded results which indicated fairly good precision for the lab work. In addition, two samples were split in the field to assess overall precision, a measure of sampling plus laboratory precision. Overall precision for all but butyltin data was generally less than 30% relative percent difference.

Precision for butyltins was poor and it is impossible to determine the source(s) of error with the available data. If paint chips were present, the sample would likely have been non-homogeneous which could account for poor agreement between split samples. However, since the factors affecting butyltin precision are not known, the butyltin data should be viewed with caution.

As for laboratory contamination, copper and zinc were detected at low levels (0.6-1.3 mg/Kg) in blank samples. Since these levels were less than 20% of sample results in all cases (and <1% in most cases), they do not compromise the reported values. Phthalates were the most common class of organic compounds detected in laboratory blanks, as is commonly the case due to their use as plasticizers. Butyltins were also frequently detected in lab blanks at levels generally <5% of associated sample results. However, none of the sample results were void due to blank contamination.

None of the samples for TOC, semivolatiles, or PCB analysis met the holding time requirement of 14 days from collection until extraction. Samples designated for TOC analysis were held unfrozen for 42 days which may have resulted in the loss of some components. TOC data and TOC-normalized data were therefore flagged with an "H" for holding time exceedance. Semivolatile organics and PCBs were extracted 21 days after collection. Considering the relatively stable nature of these compounds, exceeding the holding time requirements probably did not affect the results. Butyltins were kept frozen following PSEP guidelines and extracted seven weeks after collection.

Results and Discussion

Conventional Characteristics of Sediments

The general characteristics of Salmon Bay sediments (TOC, solids, and grain size) are presented in Table 2. TOC, which has been known to correlate well with non-polar organic compounds, ranged from 0.1% to 13.9%. Grain size analysis showed that sediments from all stations were made up of mostly sand or silt (Figure 3). Sediments from Stations 5B and 2B were the sandiest with 93% and 90% sand, respectively. Clay-sized particles were found at substantial proportion at one station only (7B with 46%). Percent fines, the fraction of sediment less than 63 µm (*i.e.*, silt + clay) varied from 0% to 88%. Contaminant concentrations in sediments are often correlated with percent fines since fine material provides more surface area for binding. Eighty percent of the stations had 5% or less gravel, and only one station had more than 10% gravel (Station 3A).

Chemical Concentrations in Sediments

Metals

Concentrations of metals are presented in Figures 4 through 11, and in Appendix E. The eight metals analyzed were detected at all sample stations, except for cadmium which was below detectable levels at five stations. Median concentrations of copper and zinc were highest among metals, followed in decreasing order by lead, chromium, nickel, arsenic, mercury, and cadmium. The correlation matrix shown in Table 3 indicates a pattern of significant positive correlations among all metals except nickel and chromium. A strong correlation exists between nickel and chromium concentrations, and both have a moderately strong correlation with copper. Copper is significantly correlated with every other metal except mercury and lead. All metals demonstrated a weak positive link to percent fines and a weak negative relationship to percent sand.

Stations were ranked according to metals concentrations in order to determine which areas were most contaminated (Table 4). Station 1B, where arsenic, mercury, lead, cadmium, and zinc were all found at the highest concentrations, had the greatest overall metals contamination. The second most metals-contaminated station was 4F where all but nickel and chromium concentrations were high. Nickel, chromium, and copper were the highest in sediments from Station 6B, yet this station was only ranked tenth overall due to relatively low concentrations of mercury, lead, and zinc.

Table 2. Conventional characteristics of Salmon Bay sediments.

			Grain Size				
Site:	% TOC (dry)	% Solids	% Gravel (>2000µm)	% Sand (2000-63µm)	% Silt (62-4µm)	% Clay (<4µm)	Total % Fines (<63µm)
1A	8.4 H	32.2	2	36	44	18	62
1B	6.7 H	26.8	0	40	54	5	59
1C	5.8 H	23.0	0	24	61	15	76
2A	5.8 H	32.7	0	60	36	4	40
2B	1.1 H	75.8	8	90	2	0	2
2C	6.2 H	30.6	9	42	35	14	49
3A	1.9 H	51.6	12	75	9	4	13
3B	6.0 H	30.8	4	30	47	19	66
3C	5.4 H	26.5	0	17	75	8	83
4A	4.8 H	17.5	0	12	76	12	88
4B	7.0 H	28.0	0	24	65	11	76
4C	1.6 H	58.3	1	74	19	6	25
4D	5.3 H	38.6	1	53	37	9	46
4E	5.9 H	23.1	1	32	52	15	67
4F	6.7 H	29.2	1	49	42	8	50
5A	3.4 H	42.3	0	46	47	7	54
5B	0.1 H	80.3	7	93	0	0	0
5C	13.7 H	29.2	4	50	37	9	46
6A	13.9 H	26.8	7	53	33	7	40
6B	2.3 H	51.8	0	67	31	2	33
6C	8.6 H	27.8	2	36	51	11	62
6D	10.8 H	23.1	5	47	39	9	48
7A	5.2 H	37.6	1	67	29	3	32
7B	1.2 H	73.2	1	13	40	46	86
7C	0.7 H	65.1	3	71	17	9	26
7D	0.8 H	68.5	3	87	8	2	10
8A	3.9 H	40.0	0	44	46	10	56
8B	1.3 H	49.8	6	78	12	4	16
8C	6.6 H	26.0	1	19	62	18	80

H=Result may be biased due to excessive holding time prior to analysis.

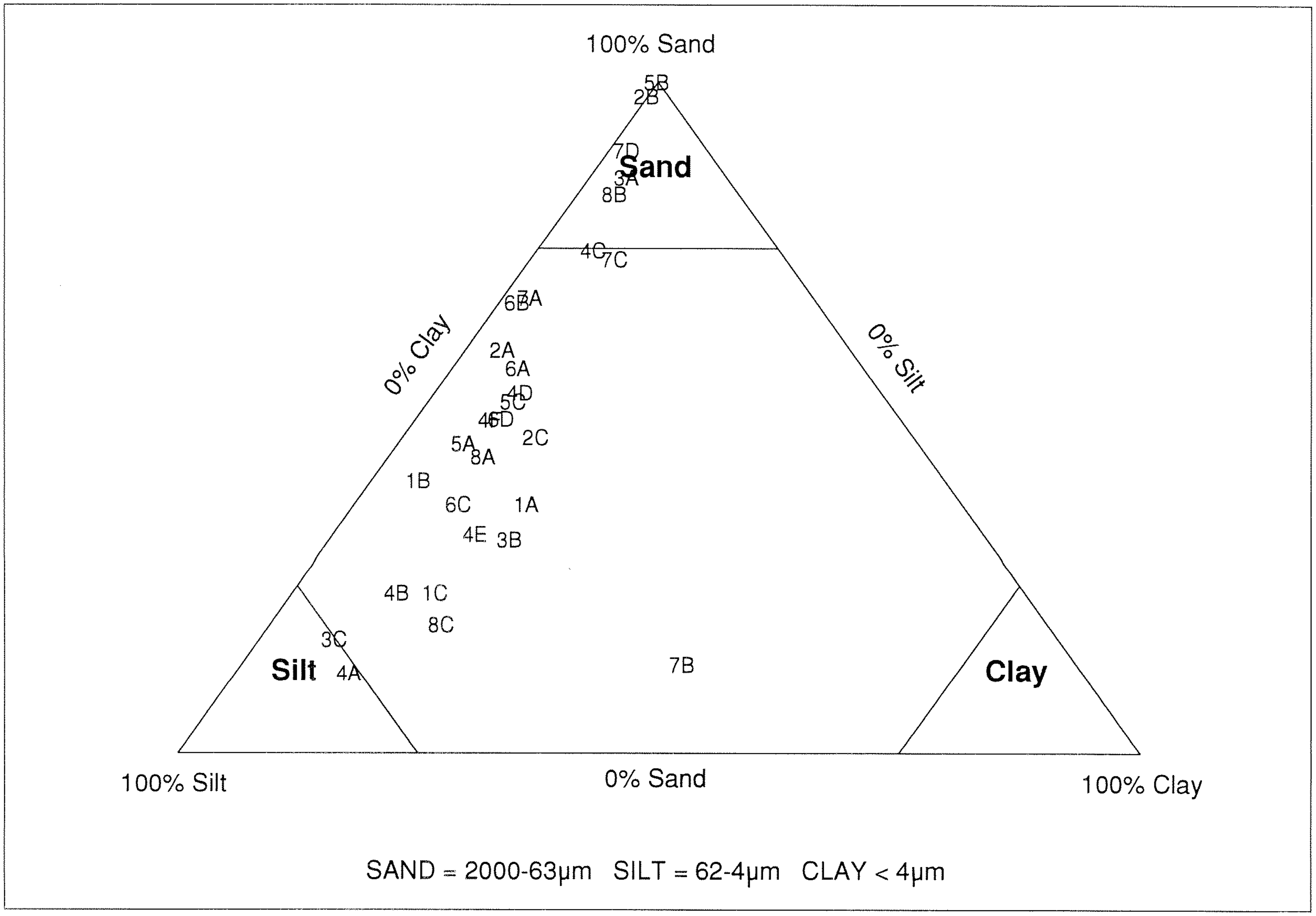

Figure 3. Relative grain size composition of Salmon Bay sediments.

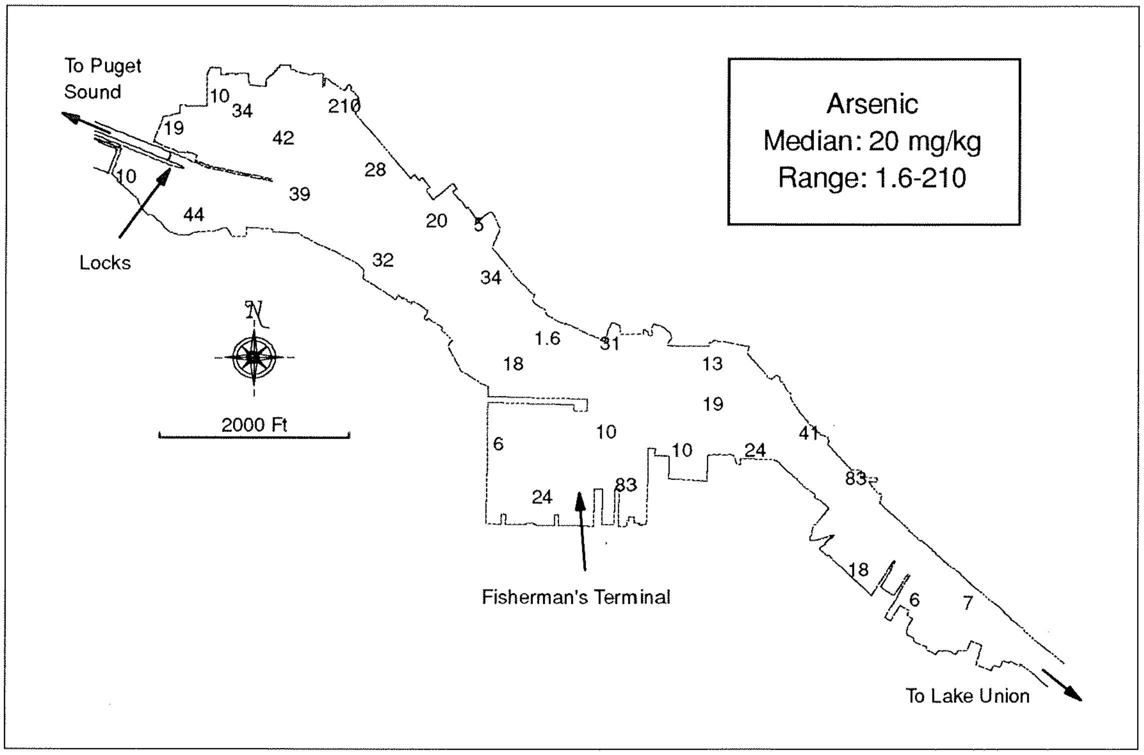

Figure 4. Arsenic concentrations at sample stations. All values mg/kg dry weight.

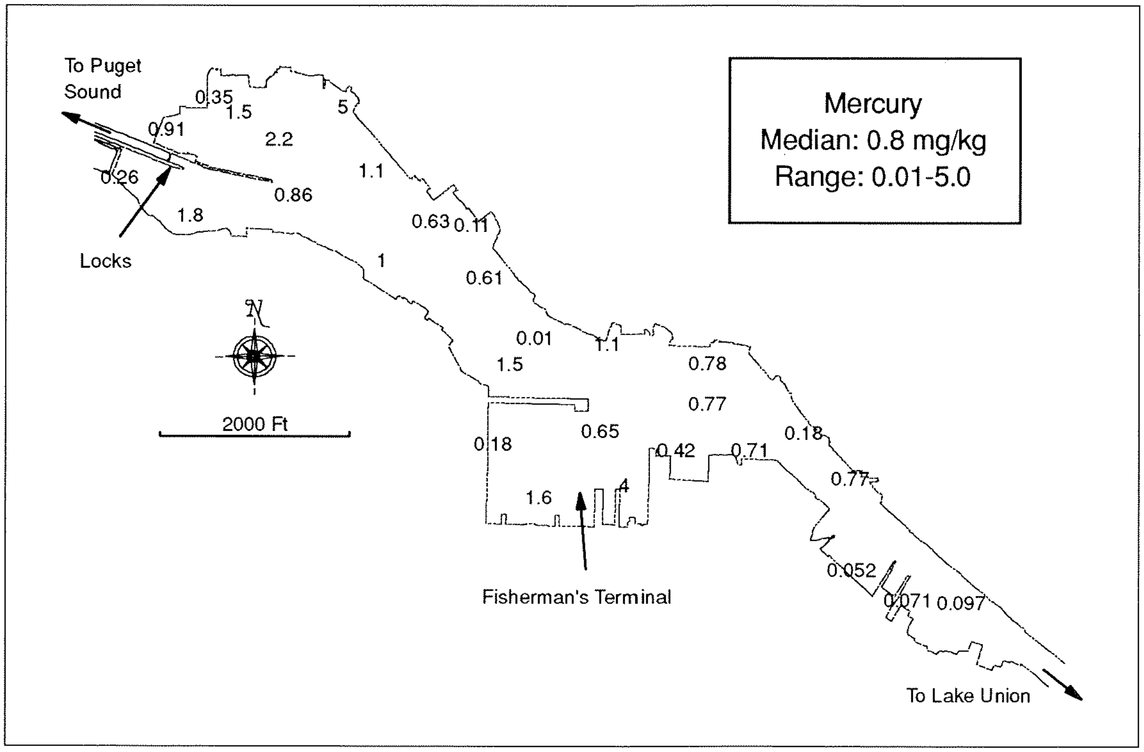

Figure 5. Mercury concentrations at sample stations. All values mg/kg dry weight.

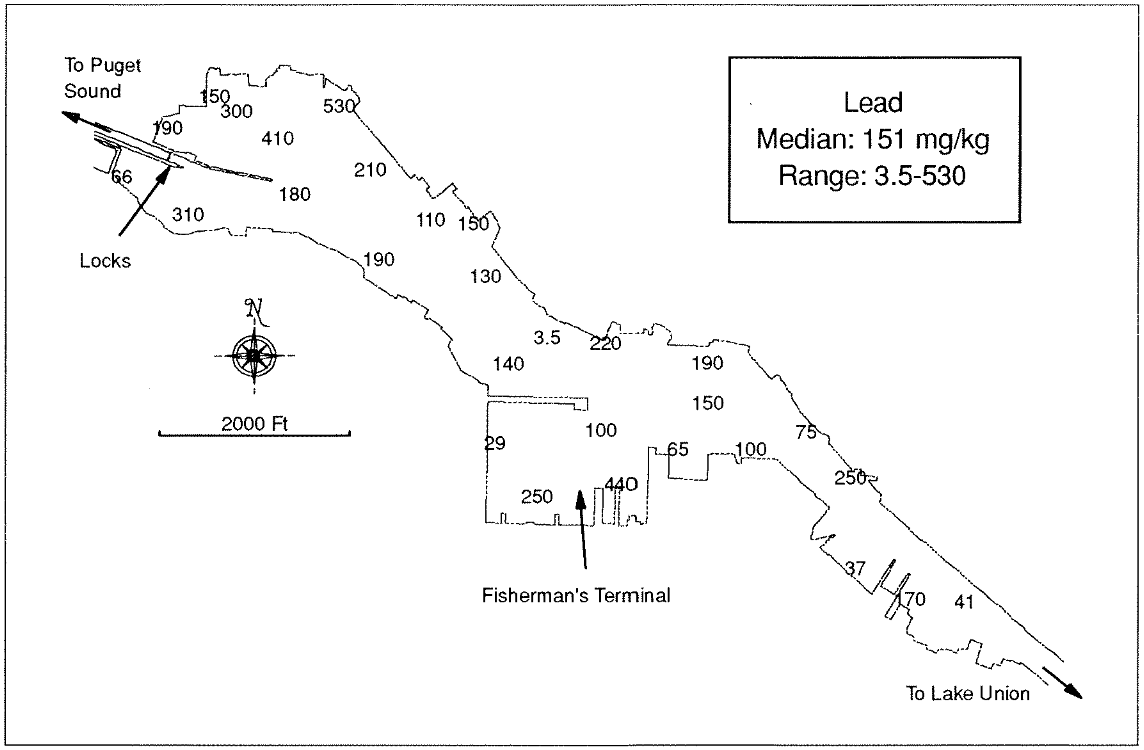

Figure 6. Lead concentrations at sample stations. All values mg/kg dry weight.

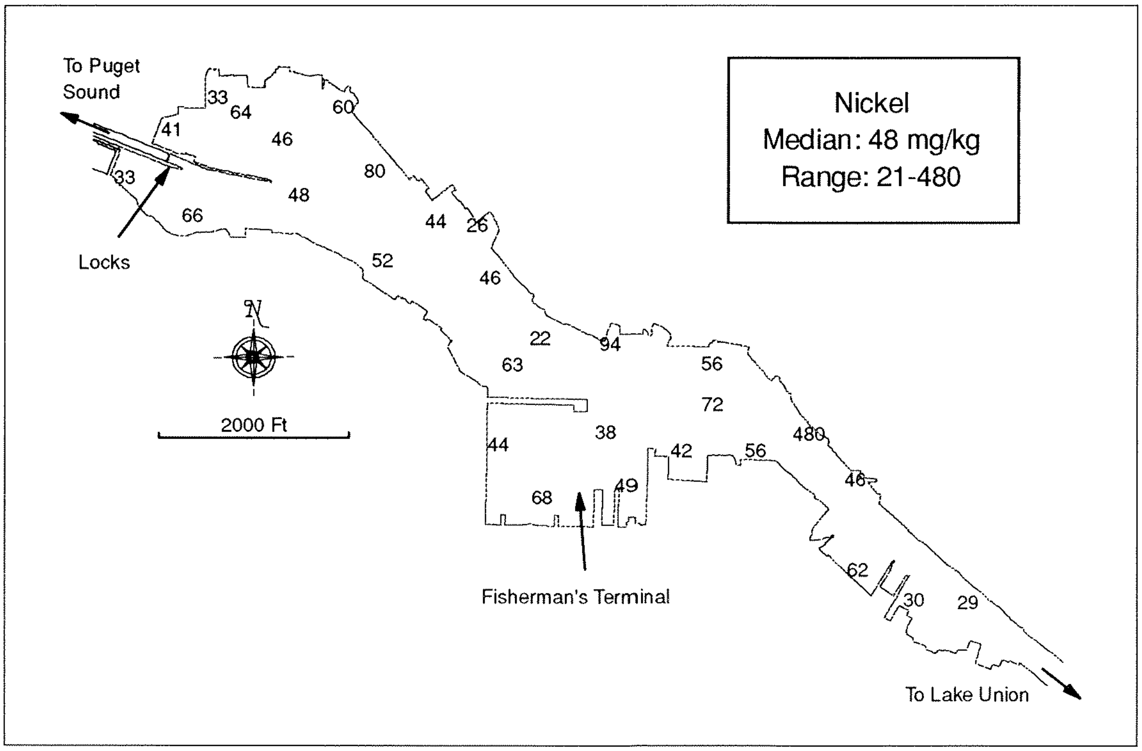

Figure 7. Nickel concentrations at sample stations. All values mg/kg dry weight.

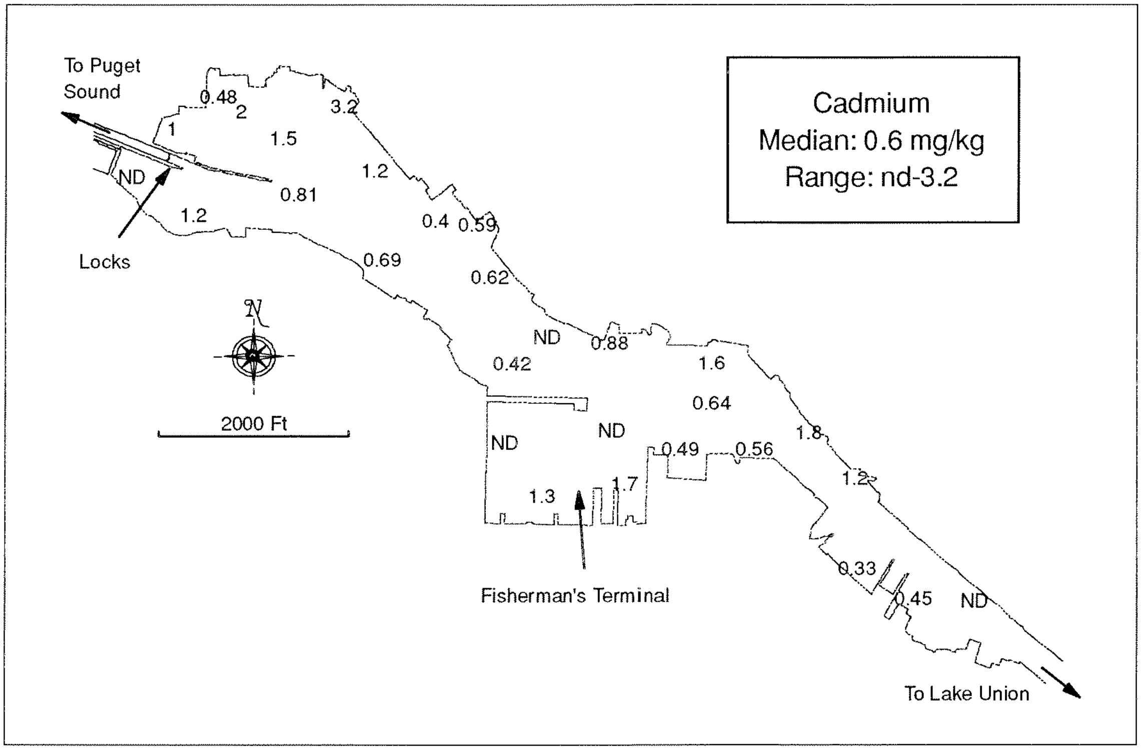

Figure 8. Cadmium concentrations at sample stations. All values mg/kg dry weight.

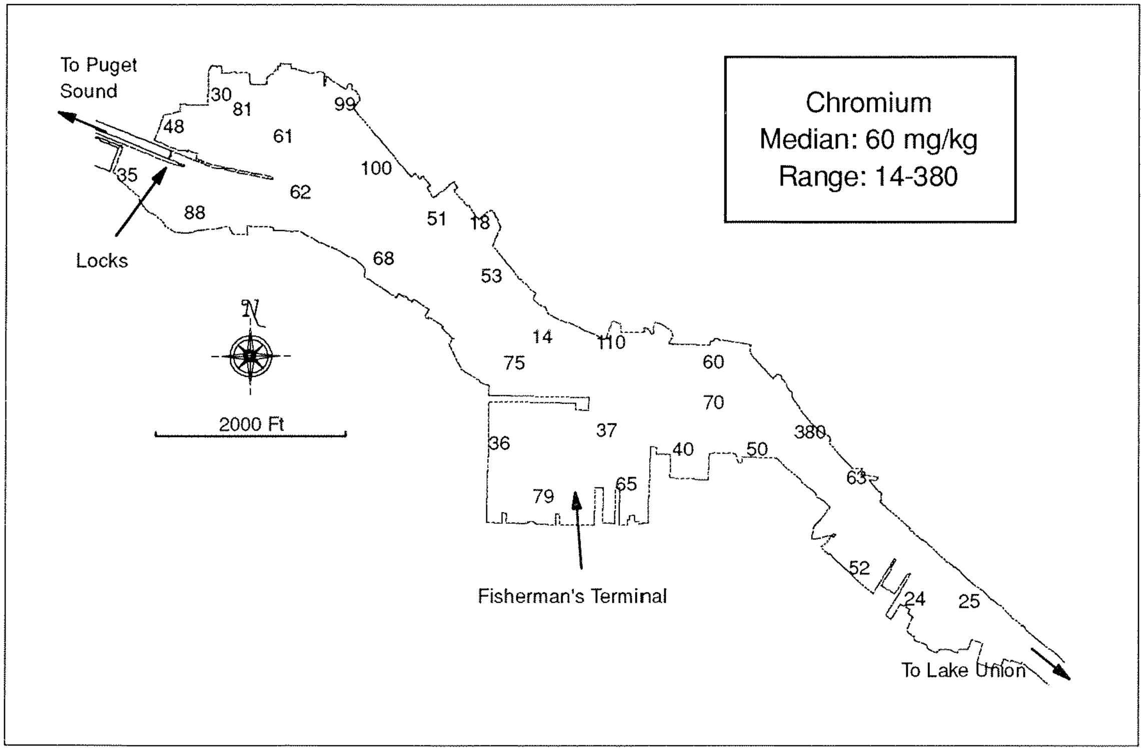

Figure 9. Chromium concentrations at sample stations. All values mg/kg dry weight.

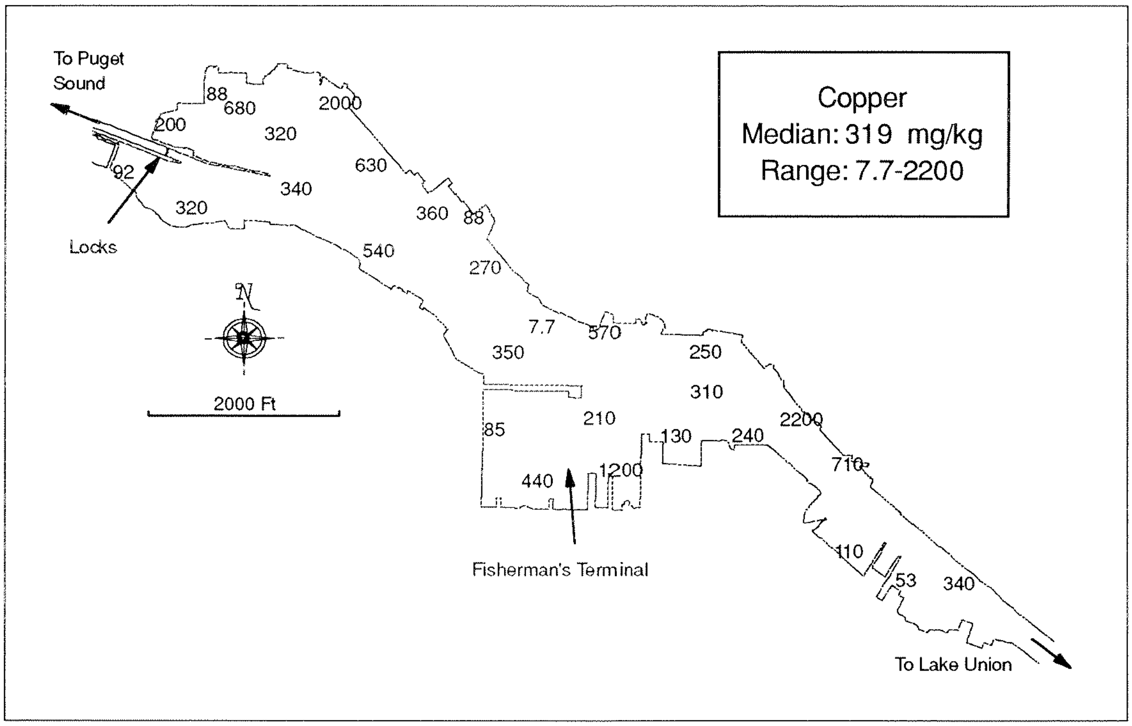

Figure 10. Copper concentrations at sample stations. All values mg/kg dry weight.

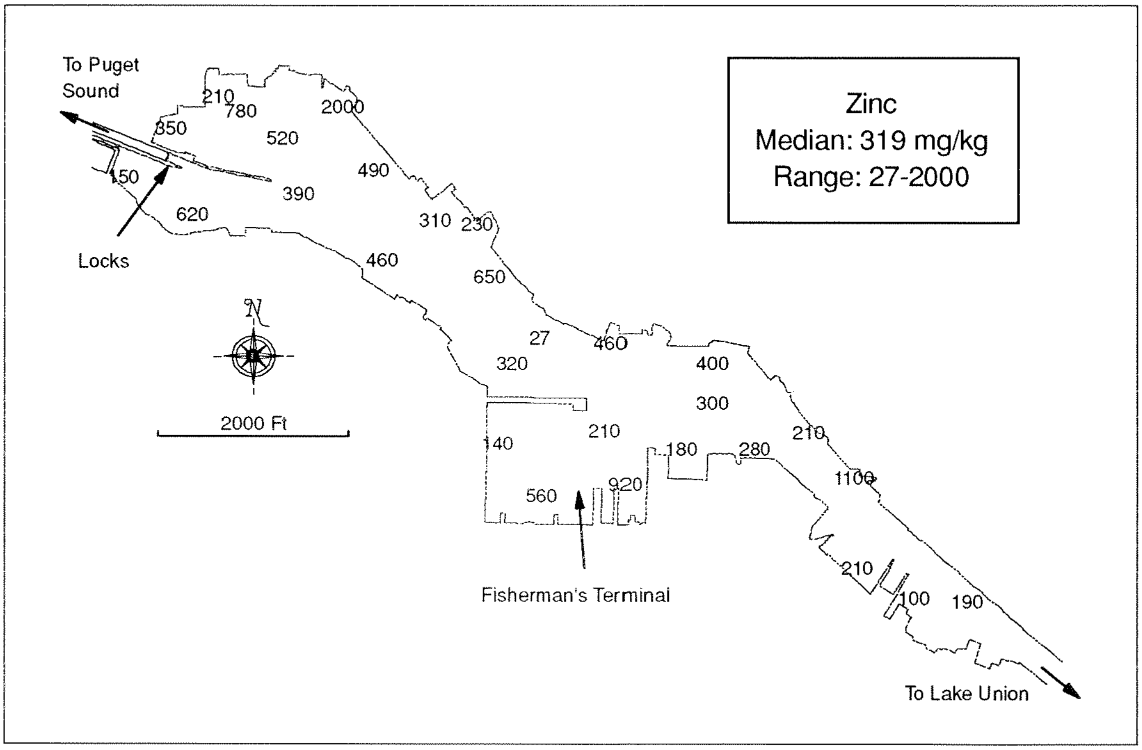

Figure 11. Zinc concentrations at sample stations. All values mg/kg dry weight.

Table 3. Correlations between major parameters in Salmon Bay sediments (Pearson correlation coefficient, n=29).

	As	Hg	Pb	Ni	Cd	Cr	Cu	Zn	totPAH	totPCB	totBT	% Fines	% Sand
Hg	0.84												
Pb	0.77	0.91											
Ni	0.10	-0.07	-0.08										
Cd	0.79	0.77	0.83	0.33									
Cr	0.25	0.11	0.10	0.97	0.48								
Cu	0.74	0.59	0.50	0.69	0.77	0.78							
Zn	0.95	0.84	0.83	-0.04	0.81	0.13	0.63						
totPAH	0.71	0.87	0.85	-0.09	0.71	0.07	0.46	0.73					
totPCB	0.44	0.21	0.34	-0.05	0.30	0.03	0.26	0.55	0.27				
totBT	0.84	0.82	0.72	-0.04	0.76	0.11	0.61	0.83	0.70	0.19			
% Fines	0.23	0.40	0.38	0.04	0.36	0.19	0.17	0.31	0.43	0.02	0.29		
% Sand	-0.21	-0.39	-0.37	-0.01	-0.35	-0.16	-0.13	-0.30	-0.42	0.01	-0.27	-0.99	
TOC	0.19	0.35	0.36	-0.04	0.38	0.05	0.09	0.29	0.54	0.09	0.20	0.41	-0.43

☐ Significant at p<0.01 (Bonferroni probability)

☐ Significant at p<0.05 (Bonferroni probability)

Table 4. Stations ranked according to metals concentrations (lower rank = higher concentration).

Rank	As	Hg	Pb	Ni	Cd	Cr	Cu	Zn	Overall Rank
1	1B	1B	1B	6B	1B	6B	6B	1B	1B
2	4F	4F	4F	4B	8C	4B	1B	7A	4F
3	7A	1A	1A	1C	6B	1C	4F	4F	8C
4	3B	3B	3B	5C	4F	1B	7A	8C	3B
5	1A	4E	8C	4E	6A	3B	8C	2C	1C
6	6B	4A	7A	3B	1A	8C	1C	3B	4E
7	5A	8C	4E	8C	4E	4E	4B	4E	4B
8	2C	1C	4B	4A	1C	4A	3C	1A	7A
9	8C	4B	1C	7B	3B	5C	4E	1C	1A
10	3C	3C	3C	1B	7A	3C	2A	3C	6B
11	4B	5A	6A	6D	8A	4F	4A	4B	3C
12	1C	8A	8A	6A	4B	7A	5A	6A	5A
13	4E	6A	5A	3C	5A	5A	7D	5A	6A
14	6D	5C	7C	4F	3C	1A	1A	8A	5C
15	2A	7A	2B	5A	5C	6A	3B	4A	4A
16	5C	4D	5C	2C	2C	2C	5C	2A	2C
17	8A	6D	8B	1A	2B	7B	2C	5C	8A
18	7B	2A	4A	7A	6D	2A	6A	6D	6D
19	4A	2C	2C	4C	6C	6D	6D	2B	2A
20	6A	6C	2A	2A	8B	8A	4D	7B	7B
21	4D	3A	6D	6C	7C	6C	8A	6B	4D
22	6C	8B	4D	8A	4A	4D	6C	4D	6C
23	8B	4C	6B	4D	2A	4C	7B	8B	8B
24	3A	6B	3A	8B	7B	3A	3A	7D	2B
25	7D	2B	6C	3A	3A	8B	2B	6C	7D
26	7C	7B	7D	7C	4C	7D	8B	3A	3A
27	4C	7C	7B	7D	4D	7C	4C	4C	7C
28	2B	7D	4C	2B	5B	2B	7C	7C	4C
29	5B	5B	5B	5B	7D	5B	5B	5B	5B

Semivolatile Organics

Sediments were analyzed for 74 semivolatile organic compounds of which less than half were detected (Appendix E). Polycyclic aromatic hydrocarbons (PAHs) were the most frequently detected class of semivolatiles. Figure 12 depicts the detection frequency for all organic compounds found. With few exceptions, all ten high molecular weight PAHs (HPAHs) and seven low molecular weight PAHs (LPAHs) were detected at all stations. Incomplete combustion of fossil fuels is probably the major source of environmental PAHs, yet some of these compounds, especially LPAHs, may be present in uncombusted petroleum products (PTI Environmental Services, 1991).

Total dry weight PAH concentrations (Appendix E; the sum of HPAH and LPAH), were greatest at Station 4F (84,200 μg/Kg), followed in decreasing order by Stations 1B (77,700 μg/Kg) and 1A (56,900 μg/Kg). Total PAHs were lowest at Stations 5B (100 μg/Kg), 7C (2,800 μg/Kg), and 3A (3,400 μg/Kg).

PAHs have a high affinity to carbon-containing sediments (Callahan *et al.*, 1979), although concentrations of HPAH were not significantly correlated with TOC. To examine factors influencing PAH levels other than sediment TOC, HPAH and LPAH concentrations were normalized to organic carbon (Figures 13 and 14). Station 2B had the highest organic carbon-normalized concentration of total PAH in sediment (2,280 mg PAH/Kg OC), followed by Station 7B (1,930 mg PAH/Kg OC). Station 5B had the lowest OC-normalized PAH level (107 mg PAH/Kg OC) despite its low TOC content (0.1%).

In addition to PAHs, dibenzofuran and retene were detected at all stations, followed in frequency by 4-methylphenol, 3β-coprostanol, and butylbenzylphthalate. All other semivolatile organics were detected at fewer than 60% of stations, and at dry weight concentrations generally less than 1,000 μg/Kg.

PCBs

PCB concentrations normalized to organic carbon are shown in Figure 15. PCBs were detected at 26 of the 29 sample stations. Of the seven PCB mixtures analyzed, only PCB-1242,-1254, and -1260 were detected; PCB-1242 was detected at one station only (Appendix E). Other PCB mixtures were not detected at quantitation limits of 48-160 μg/Kg.

Total PCBs, the sum of all PCB mixtures, ranged from non-detectable levels at Stations 3A, 5B, and 7C to a dry weight concentration of 7,600 μg/Kg at Station 7A. The median total PCB concentration was comparatively low on both a dry weight (260 μg/Kg) and organic carbon basis (4.8 mg PCB/Kg OC).

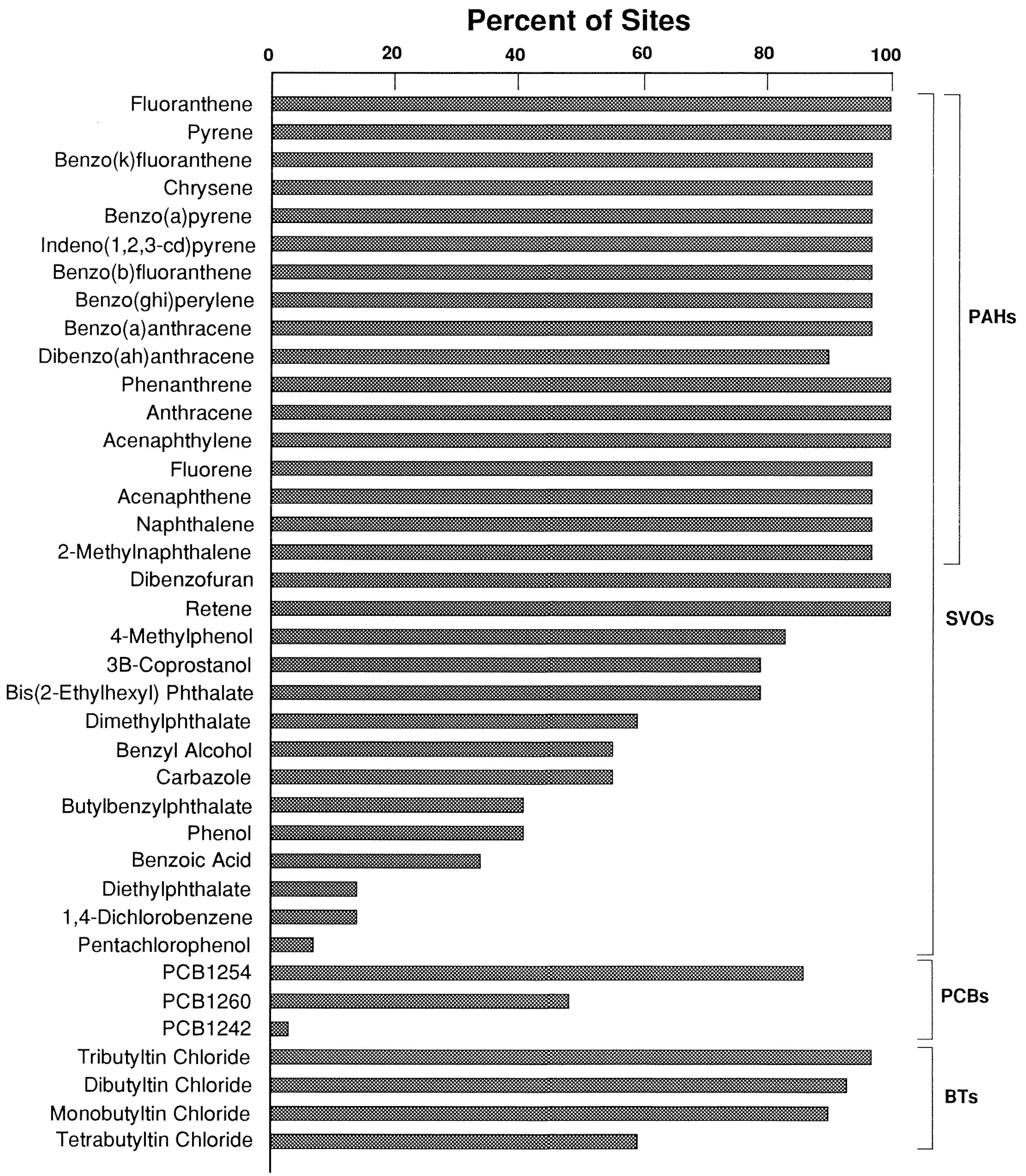

Figure 12. Frequency of detection for organic compounds in sediment.

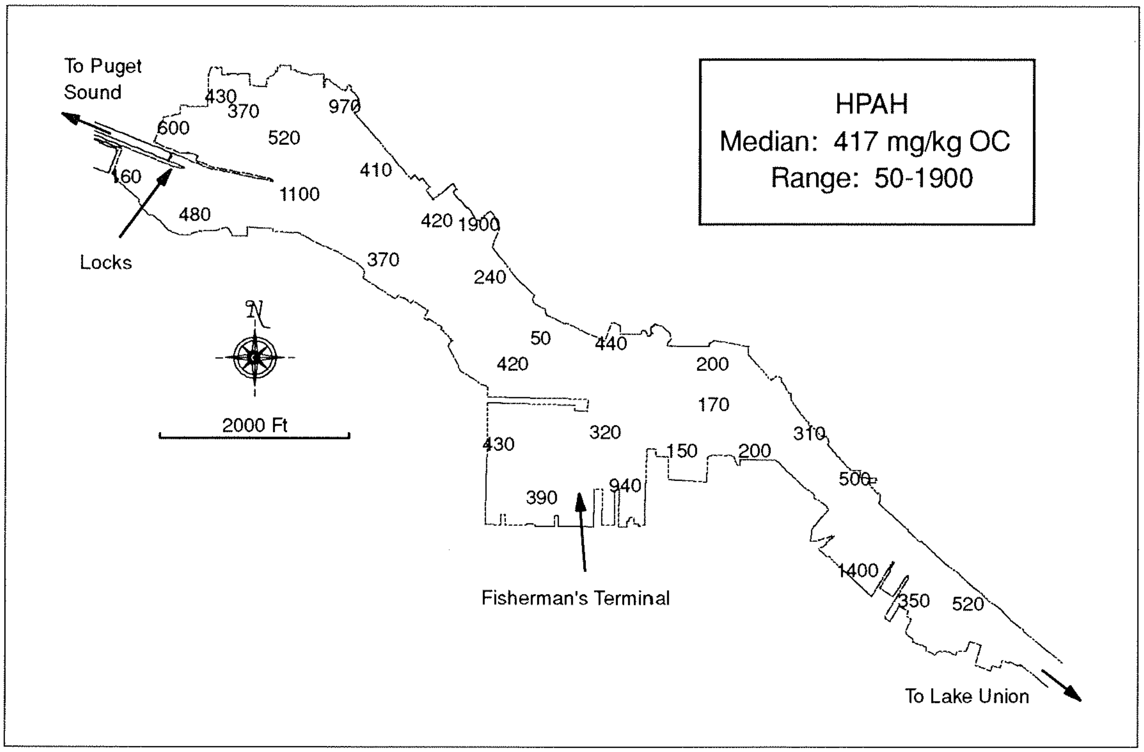

Figure 13. HPAH concentrations at sample stations. All values mg/kg organic carbon.

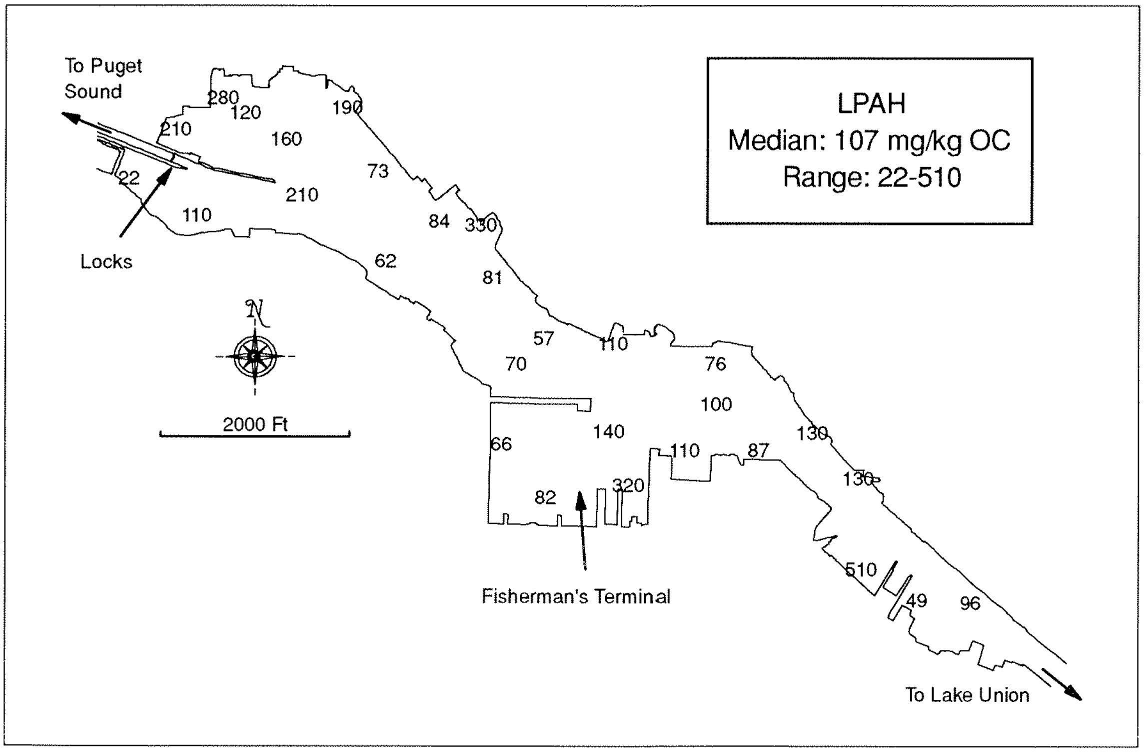

Figure 14. LPAH concentrations at sample stations. All values mg/kg organic carbon.

Butyltins

Butyltin chlorides were detected at all stations except 5B, ranging in concentration from less than 6 µg/Kg to more than 9,000 µg/Kg total butyltins chlorides at Station 1B (Appendix E). Tributyltin chloride (TBT-Cl) was the most frequently detected butyltin congener and accounted for 63% of overall butyltin chloride concentrations on average. The median concentrations of total butyltin chlorides and TBT-Cl were 671 and 366 µg/Kg, respectively. As mentioned previously, the butyltin data should be viewed with caution due to a low degree of precision.

Butyltin chloride concentrations were significantly correlated to PAH concentrations and, like PAHs, they were also significantly correlated to arsenic, mercury, lead, cadmium, and zinc. They were generally associated with fine-grained organic carbon containing sediments, although less so than PAHs. Butyltins were also positively correlated to copper concentrations, although this correlation was not strong.

Figure 16 shows TBT concentrations throughout the study area. These concentrations are expressed as the TBT ion rather than TBT-Cl to maintain consistency with current PSDDA and SMS reporting conventions. TBT is an active ingredient in anti-fouling paint applied to boat and ship hulls. Although the use of TBT for most pleasure boat and ship applications was outlawed in the U.S. in 1988, it may yet be present on hulls with aged paint, on foreign-flagged vessels, and still has limited legal uses in the U.S. (on aluminum hulls for instance). TBT is by far the most toxic among the four congeners analyzed. Mono- and dibutyltin are metabolites formed during the progressive debutylation of TBT to inorganic tin, while tetrabutyltin may be an impurity during TBT manufacturing or possibly formed photolytically or microbially from lesser butylated congeners.

Areal Distribution of Contaminants

Figures 4 through 11 and 13 through 16 indicate there are no clear areal gradients for any of the chemicals analyzed. This is to be somewhat expected since the study area contains numerous potential sources of contamination rather than one or two large sources.

Figures 17 and 18 show how metals and organics co-occur, respectively. The stations most contaminated with arsenic, mercury, lead, cadmium, zinc, and TBT can be found at Station 1B in the northernmost section of the study area, and at Station 4F located in the eastern portion of Fisherman's Terminal. Station 6B stands out as the most contaminated with nickel, chromium, and copper. Station 7A, which is near 6B, also has relatively high concentrations of metals, although the pattern of contamination is different suggesting two distinct sources of metals.

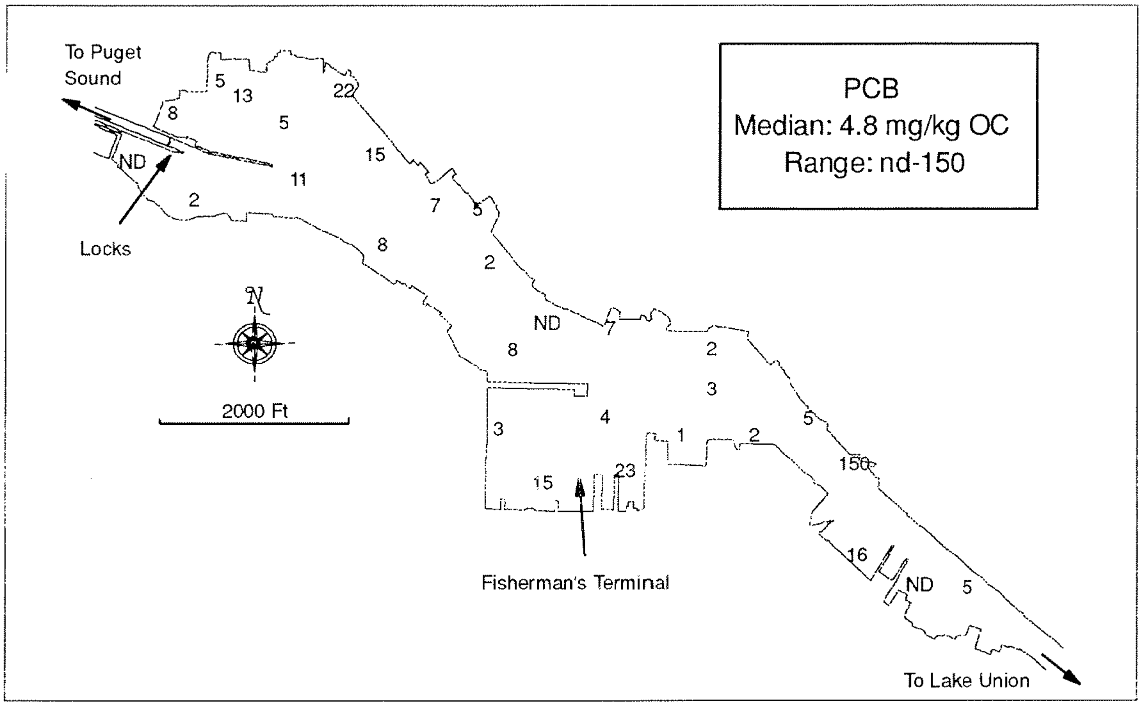

Figure 15. PCB concentrations at sample stations. All values mg/kg organic carbon.

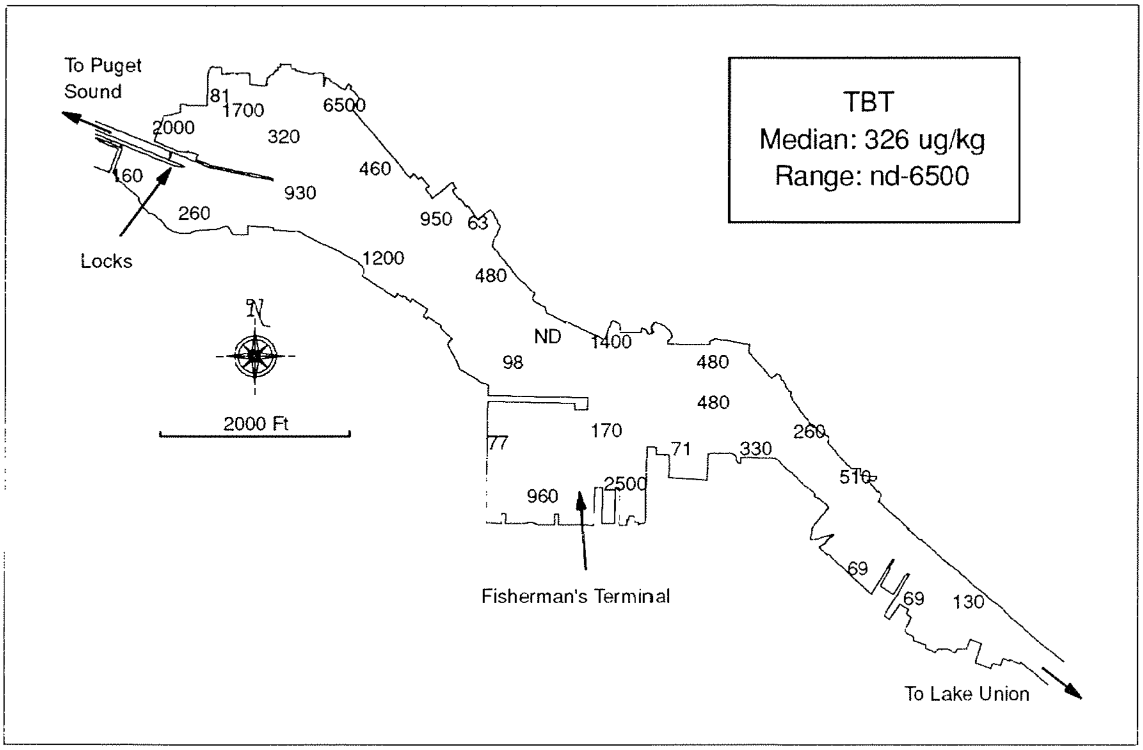

Figure 16. TBT concentrations at sample stations. All values ug/kg dry weight.

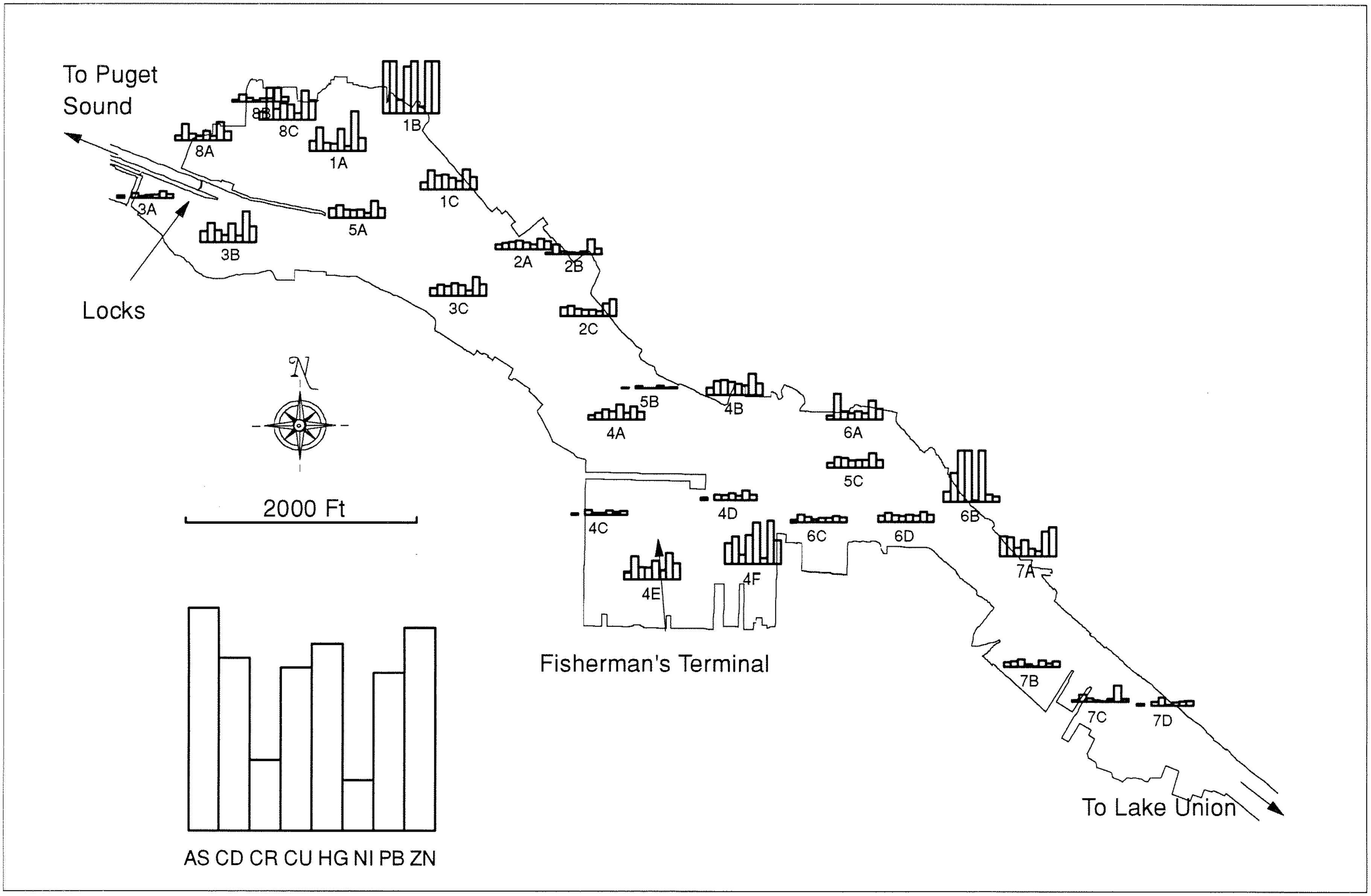

Figure 17. Comparison among metals concentrations at all sites. Concentrations of metals are standardized as a percent of the highest concentration for each metal.

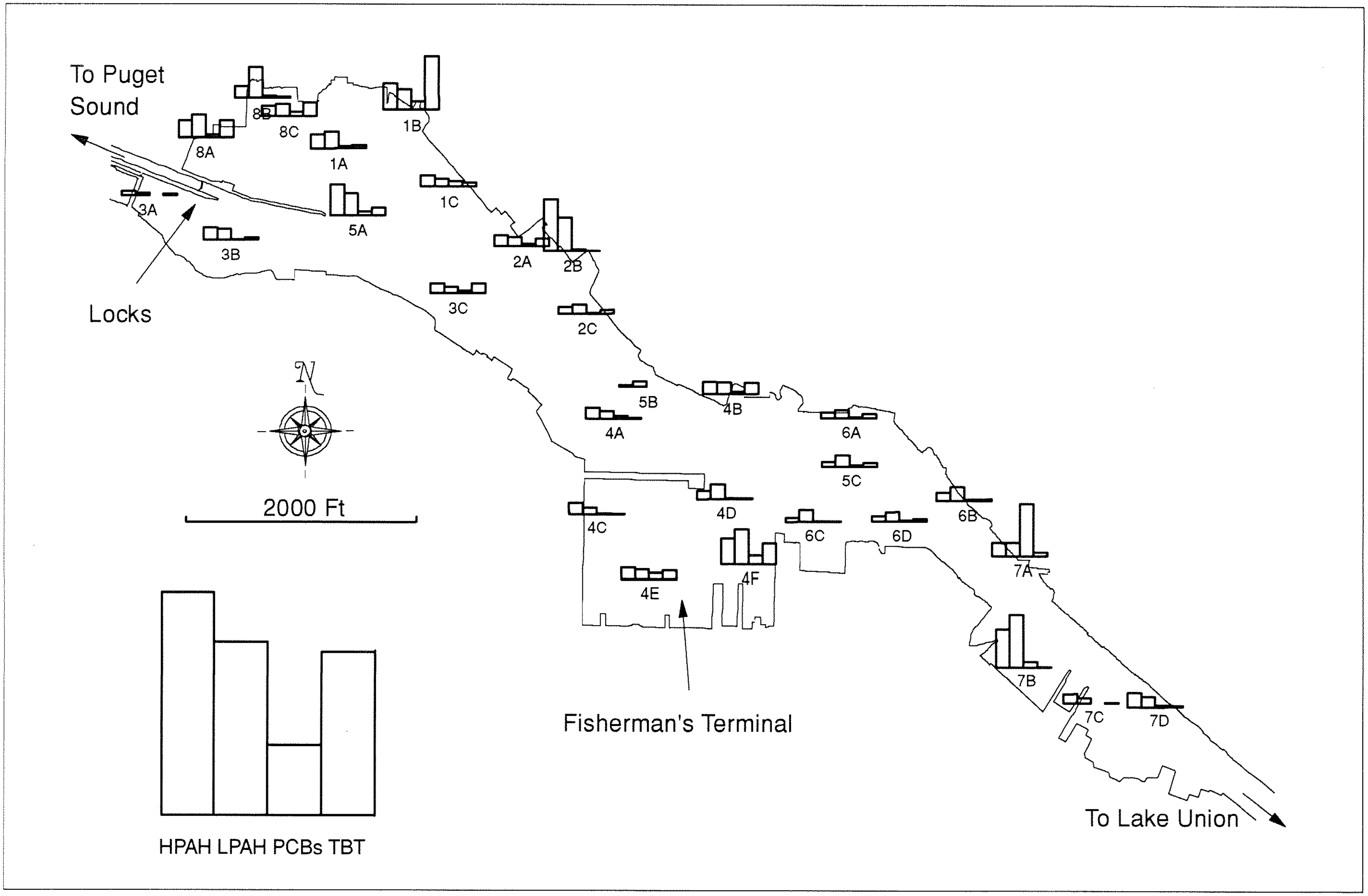

Figure 18. Comparison among groups of organics concentrations at all sites. Concentrations of organics are standardized as a percent of the highest concentration for each group. HPAH, LPAH, and PCBs are on organic carbon basis. TBT is on dry weight basis.

With one possible exception, there is also a lack of gradation or geographical pattern with respect to clean sediments. The cleanest area appears to be at the terminus of the Ship Canal in the easternmost section of Salmon Bay. Station 5B, located near the longitudinal center of the study area, has the lowest overall contamination.

Aside from the northernmost area of Salmon Bay, PAH concentrations normalized to organic carbon tend to show a "patchy" distribution, suggesting localized sources. Three of the four stations with the highest PAH concentrations -- 2B, 7B, and 4F -- have neighboring stations with relatively low PAH levels.

This independent nature of station-to-station contaminant distribution appears to hold true for all chemicals analyzed. It is perhaps best illustrated for PCBs, where a very high concentration at Station 7A apparently has no effect on concentrations at nearby stations. Sediments at 7A were collected just off of the Union Bay Ship Building and Salmon Bay Steel plants. Another example is in sample zone 8 where sediments from Station 8C, found to have some of the worst overall contamination, were collected within 300 feet of one of the cleanest sample stations (8B).

As mentioned under the description of sampling strategy, stations were grouped in each major area of concern and/or natural geographical feature. These zones were chosen to represent groups of industries and combined sewer overflows (CSOs) or areas that were thought to possibly have similar contaminant levels.

Because of the areal variability of contaminant levels, stations within each zone were rarely uniform. To test for differences among zones, chemical concentrations (including OC-normalized organics) in each zone were compared using the Kruskal-Wallis one-way analysis of variance ($p<0.05$). This is a non-parametric test that compares the sum of ranks and assumes the test statistic approximates a chi-square distribution. There was no difference among zones for any of the metals, total PAH, total PCB, or TBT.

Relationship to Sources

The contaminant data were considered in context of their possible sources, *i.e.* potential sources in close proximity to the sample stations. Since the study area is heavily industrialized, not every source was considered. Instead, major groups such as marinas and CSOs were considered.

PAHs, phthalates, lead, and copper are among the most prevalent chemicals in stormwater and CSO discharges (METRO, 1988). In some cases, their concentrations in receiving waters may be useful in estimating the extent to which stormwater and CSO discharges contribute to contamination of a specific area.

In Salmon Bay there is mixed evidence that CSO discharges account for a substantial portion of the contamination. Of the six stations adjacent to CSO outfalls -- 1B, 2B, 6A, 6B, 8B, and 8C -- two stations (1B and 8C) had high overall concentrations of metals, including lead. Station 6B had high concentrations of copper, as did Stations 1B and 8C, yet other stations located near the CSO outfalls had relatively low-to-moderate metals levels. Sediments from Station 2B had the highest organic carbon-normalized PAH concentrations, and Stations 1B, 6A, and 8C had the three highest concentrations of bis(2-ethylhexyl)phthalate. However, organic carbon-normalized PAHs from three stations -- 8C, 6B, and 6A -- were at or below the median PAH concentration. All six stations near CSOs tended to have relatively high levels of 3β-coprostanol, a compound found in the feces of humans and carnivorous animals (Merck, 1976) and therefore a likely indicator of CSO discharge.

Although Stations 1B and 8C had elevated levels of lead, copper, and bis(2-ethylhexyl)phthalate, and were located near CSO outfalls, there remains some question as to the source of these chemicals. Sediments from these stations had elevated TBT levels when compared to other sites, yet CSOs are an unlikely delivery mechanism for TBT unless they receive drainage from upland boatyards. These stations also had some of the highest PCB concentrations. Since high concentrations of TBT and PCBs are not normally associated with CSO discharge, Stations 1B and 8C probably receive contamination from one or more additional source.

Perhaps the best indicators of remarkable PAH and/or PCB contamination were observations made during sample collection. Sediments with a moderate-to-heavy oil sheen, a petroleum odor, or both, were twice as likely to have PAH levels in the top quartile than the middle two quartiles, and were four times less likely to be in the bottom quartile. The same pattern was even more pronounced with regard to PCB concentrations, but oil sheen/odor did not yield a good indication of high TBT or metals concentrations.

Of the 29 stations sampled, 21 were located adjacent to marinas, boat repair facilities, marine terminals (including Fisherman's Terminal), shipyards, or vessel-related facilities. Two of the six stations (8A and 4B) with TBT levels greater than 1,000 µg/Kg were not adjacent to these facilities, while seven of eight sites with TBT less than 100 µg/Kg were adjacent to areas with marinas, etc. Proximity to these facilities alone did not appear to dictate concentrations of TBT. Instead, high TBT concentrations in sediments can probably be traced to individual facilities which do a poor job of containing paints, scrapings, and sand-blast grit on-site. For instance, the station with the highest TBT concentration (Station 1B) is located just offshore of Alaska Pacific Fisheries and Pacific Fisherman, Inc., both with a history of poor "housekeeping." Station 4F, with the second highest TBT concentration, is adjacent to a facility operated by Fishing Vessel Owners Marine Ways. Containment of sand-blast grit from this facility has allegedly been so bad in the past that grit deposition has caused shallowing of the vessel slip, and clouds of airborne particles have drawn complaints from motorists (Dan Cargill, Washington State Department of Ecology Toxics Cleanup Program, personal communication). Stations located near vessel-related facilities were, however, more likely to have high metals concentrations.

Comparison to Criteria

Metals, Semivolatile Organics, and PCBs

To evaluate the biological significance of chemicals in Salmon Bay sediments, concentrations were compared to guidelines for freshwater sediment quality and Ecology's Marine Sediment Management Standards (SMS; Ch. 173-204 WAC) shown in Table 5.

Ecology is currently developing criteria for freshwater sediments. In the interim, Batts and Cubbage (1995) have reviewed guidelines proposed by various government agencies in the U.S. and Canada. These guidelines vary a great deal because of 1) the scientific approaches used to develop them, and 2) their proposed regulatory applications.

The Ontario guidelines were developed using a screening level approach wherein *in situ* impacts are measured along with contaminant concentrations in sediment. The Ontario "severe effects levels" are contaminant concentrations which are tolerated by only 5% of the benthic infaunal species examined (10% for PCBs).

The Environment Canada (EC) guidelines have been proposed as a tool for screening sediments throughout Canada and, by design, are somewhat conservative. EC guidelines were derived using existing studies from a variety of sources and using different scientific approaches. "No effects" and "effects" data sets were subsequently used to derive the intermediate EC "probable effects levels" (see Batts and Cubbage, 1995 for more details concerning the EC approach). As implied, adverse biological effects are expected to occur above the probable effects levels.

Table 5 contains two sets of chemical criteria from the SMS. The "no adverse effects levels" are the marine sediment quality standards -- chemical concentrations that have no adverse impacts on biological resources and no significant health risks to humans. The "minor adverse effects levels" correspond to the cleanup screening levels and the minimum cleanup levels. These are chemical concentrations used to identify "station clusters" of potential concern (Ch. 173-204-510 WAC defines a station cluster as "any number of stations ... that are determined to be spatially and chemically similar"). Stations clusters which are found to be of potential concern may subsequently undergo a hazard assessment to determine whether they should be listed on the contaminated sediment site list and to develop the site rank.

Table 5. Freshwater guidelines and marine standards for sediment quality.

	FRESHWATER		MARINE	
	Ontario Provincial Guidelines Severe Effect Levels	Environment Canada Probable Effect Levels	Ecology SMS No Adverse Effect Levels[1]	Ecology SMS Minor Adverse Effect Levels[2]
METALS	mg/Kg, dry	mg/Kg, dry	mg/Kg, dry	mg/Kg, dry
Arsenic	33	17.0	57	93
Mercury	2	0.486	0.41	0.59
Lead	250	91.3	450	530
Nickel	75	35.9	ne	ne
Cadmium	10	3.53	5.1	6.7
Chromium	110	90.0	260	270
Copper	110	196.6	390	390
Zinc	820	314.8	410	960
PAHs	mg/Kg OC[3]	µg/Kg, dry	mg/Kg OC	mg/Kg OC
Anthracene	370	ne	220	1200
Acenaphthylene	ne	ne	66	66
Acenaphthene	ne	ne	16	57
Phenanthrene	950	514.9	100	480
Fluorene	160	ne	23	79
Naphthalene	ne	ne	99	170
2-Methylnaphthalene	ne	ne	38	64
LPAH[4]	ne	ne	370	780
Pyrene	850	875.0	1,000	1400
Benzo(g,h,i)perylene	320	ne	31	78
Indeno(1,2,3-c,d)pyrene	320	ne	34	88
Benzo(b)fluoranthene	ne	ne	ne	ne
Benzo(k)fluoranthene	1,340	ne	ne	ne
Benzofluoranthene(s)	ne	ne	230	450
Fluoranthene	1,020	2354.9	160	1200
Chrysene	460	861.7	110	460
Benzo(a)pyrene	1,440	782.0	99	210
Dibenzo(a,h)anthracene	130	ne	12	33
Benzo(a)anthracene	1,480	384.7	110	270
HPAH[5]	ne	ne	960	5300
PAH (Total)	10,000	ne	ne	ne
PHTHALATES AND OTHER SEMIVOLATILE ORGANICS			mg/Kg OC	mg/Kg OC
Bis(2-Ethylhexyl) phthalate	ne	ne	47	78
Dimethylphthalate	ne	ne	53	53
Diethylphthalate	ne	ne	61	110
Butylbenzylphthalate	ne	ne	4.9	64
1,4-Dichlorobenzene	ne	ne	3.1	9
Dibenzofuran	ne	ne	15	58
			µg/Kg, dry	µg/Kg, dry
Benzyl Alcohol	ne	ne	57	73
4-Methylphenol	ne	ne	670	670
Phenol	ne	ne	420	1200
Benzoic Acid	ne	ne	650	650
Pentachlorophenol	ne	ne	360	690
PCBs	mg/Kg OC[3]	µg/Kg, dry	mg/Kg OC	mg/Kg OC
PCB-1254	34	ne	ne	ne
PCB-1260	24	ne	ne	ne
PCBs (total)	530	277.2	12	65

ne=not established

[1] These levels are also the SMS marine sediment quality standards

[2] These levels are also the SMS cleanup screening levels and minimum cleanup levels

[3] To a maximum of 10% OC

[4] Represents the sum of Anthracene, Acenaphylene, Acenaphthene, Phenanthrene, Fluorene, and Naphthalene. The LPAH criterion is not the sum of the criterion values for the individual LPAH as listed.

[5] Represents the sum of Pyrene, Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene, Benzofluoranthene(s), Fluoranthene, Chrysene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, and Benzo(a)anthracene. The HPAH criterion is not the sum of the criterion values for the individual HPAH as listed.

The reader should be aware that the marine standards described above are not directly applicable to Salmon Bay sediments. Chapter 173-204-510 WAC defines marine sediments as those which have pore water salinity greater than 25 parts per thousand (ppt). Freshwater sediments are defined as having less than 0.5 ppt salinity. "Low salinity" sediments, for which standards have also not been established, are those with pore water salinity between 0.5 and 25 ppt. Benthic salinity at the Ballard (15th Ave.) Bridge is less than 0.5 ppt approximately 62% of the time and exceeds 5 ppt only about one day per year (Marian Valentine, U.S. Army Corps of Engineers, written communication).

All 29 stations had at least one chemical exceeding criteria listed in Table 5. Seventy-two percent of the stations had one or more contaminants at concentrations expected to have pronounced effects on benthic organisms based on a comparison to the Ontario severe effects levels. Eighty-six percent of the stations would be expected to have at least minor adverse effects on benthic organisms in a marine environment.

Figure 19 shows stations that exceed either the freshwater severe effects levels or the minor adverse effects levels for marine sediments. Figure 20 compares stations based on the number of chemicals exceeding these criteria. These comparisons suggest that sediments in most areas of Salmon Bay can be expected to have some degree of adverse impact on benthic organisms. Only three stations -- 5B, 7C, and 8B -- are not shown on this list because they do not exceed any of these levels.

Of the chemicals listed in Table 5, copper poses the most serious threat to aquatic life in Salmon Bay. Other chemicals likely to harm aquatic life at a substantial number of stations (*i.e.* more than 25%) include mercury, benzyl alcohol, 4-methylphenol, arsenic, and bis(2-ethylhexyl)phthalate.

TBT

No TBT criteria were included in the freshwater guidelines reviewed by Batts and Cubbage (1995), nor have numerical criteria been promulgated under Ecology's marine standards. However, the high degree of toxicity associated with TBT is well regarded and it is recognized as a chemical of special concern under the PSDDA program. In 1988, an interim PSDDA screening level (SL) of 73 μg/Kg (as TBT, dry) was developed using an equilibrium partitioning approach which predicts the TBT concentrations of interstitial water based upon sediment concentrations.

The PSDDA agencies have recently conducted a review of several TBT-related issues, including the appropriateness of the interim SL for sediments (Michelsen et al., 1996). Although the interim SL for sediments is not unreasonable based on an equilibrium partitioning approach, it has become apparent that this approach does not accurately predict partitioning between TBT in sediments and overlying water. TBT is introduced into the environment in many different forms with differing degrees of bioavailability.

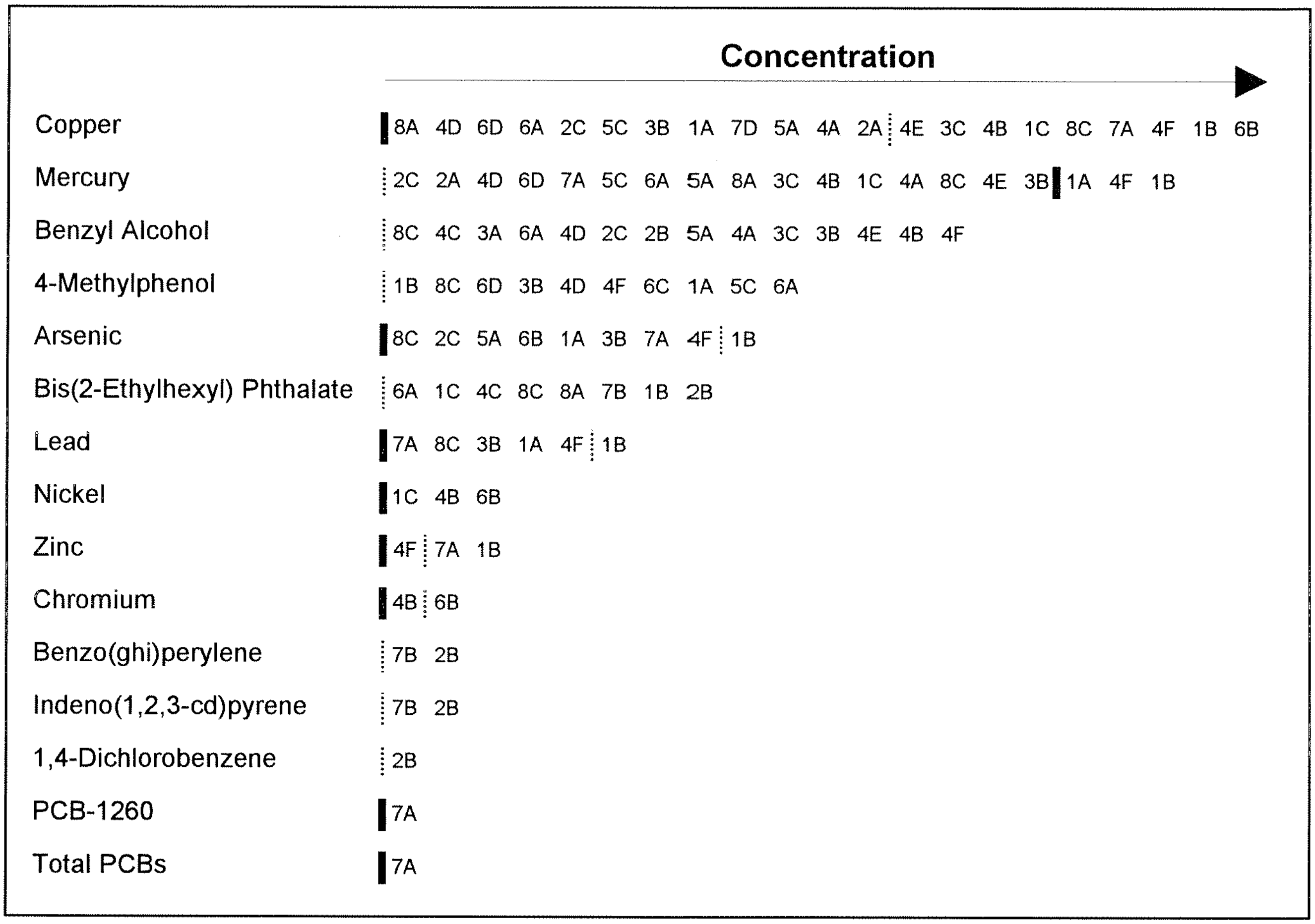

Figure 19. Stations that exceed either Severe Effects Levels for Freshwater Sediments (bold line) or Minor Adverse Effects Levels for Marine Sediments (dotted line). See Table 5 for numerical criteria.

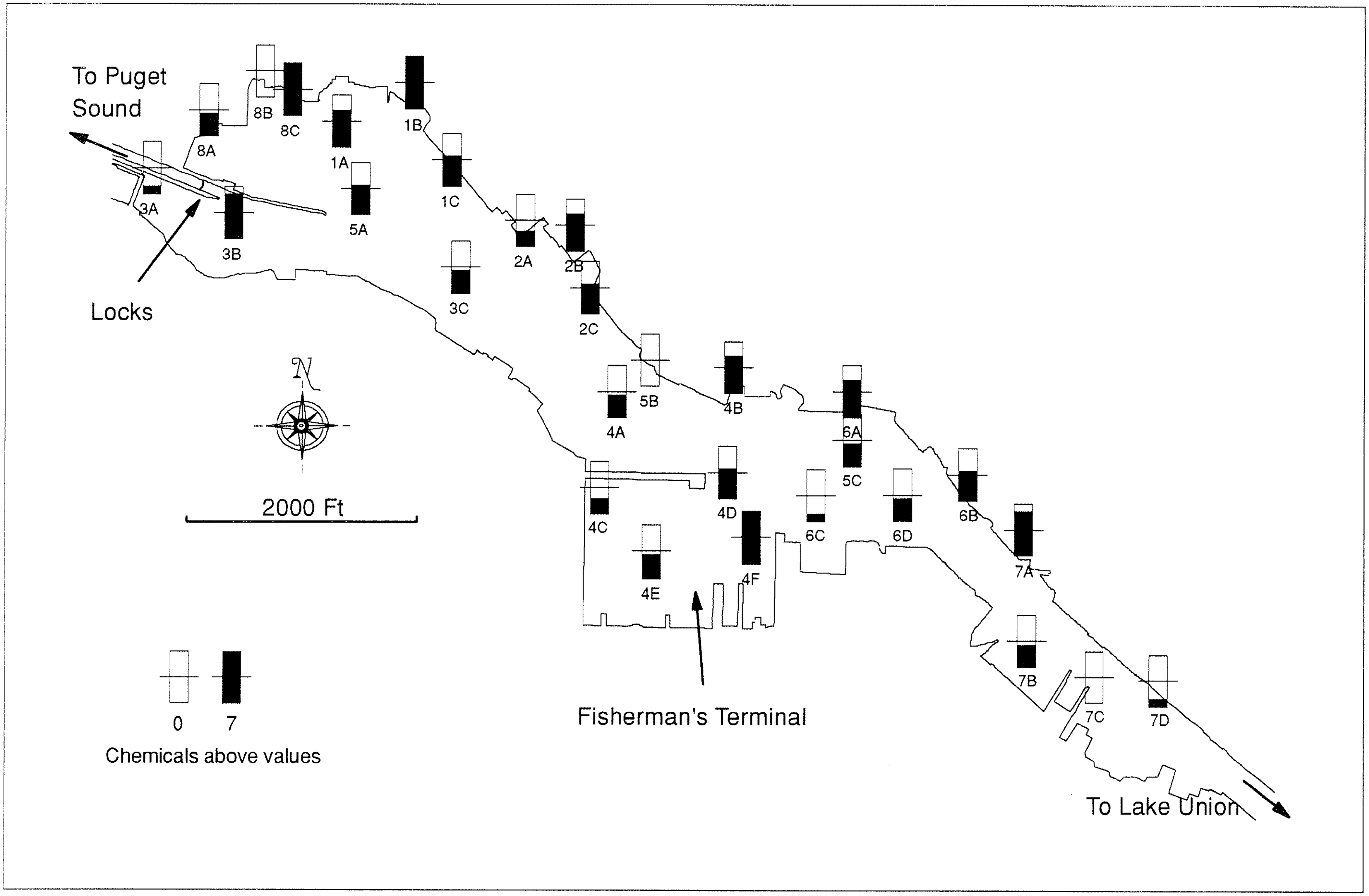

Figure 20. Comparison among sites of number of chemicals that exceed either Severe Effects Levels for Freshwater Sediments or minor Adverse Effects Levels for Marine Sediments.

Its partitioning is also very complex, and is strongly affected by factors such as pH, salinity, and chemical form. The PSDDA agencies have determined that an SL based on concentrations in interstitial water is more appropriate than a sediment SL for use in regulatory decision-making.

No interstitial water or tissue data currently exist for TBT in Salmon Bay. For this report, the sediments SL will be used for comparison. However, Phase III data should include collection of TBT in interstitial water or tissues, to provide a better indication of actual toxicity due to TBT in sediments. In Salmon Bay, all but five stations -- 2B, 5B, 6B, 7B, and 7C -- exceeded the SL. Thirty percent of the stations had TBT concentrations elevated one-to-two orders of magnitude above the SL, with TBT in sediments from 1B the highest by far (6,460 μg/Kg). Median TBT concentrations (326 μg/Kg) were four and one-half times the SL.

Of all chemicals analyzed for the present study, only TBT is elevated to the same degree above one or more associated criteria. This suggests that overall TBT could have a greater impact on aquatic organisms, but this should be confirmed with a more direct measure of toxicity. Consideration should also be given to the variability among criteria due to differing assumptions and approaches used in their development, and the different effects levels at which they are set.

Comparison to Earlier Surveys

Little effort had previously been committed to studying chemicals in Salmon Bay and Lake Washington Ship Canal sediments and, as a result, there are few available data. Cubbage (1992) analyzed metals, PAHs, and PCBs in sediments from 22 locations well-distributed throughout Lake Union and adjoining waters, including five from the Ship Canal. These data are summarized in Tables 6 and 7. Data from the main body of Lake Union are also shown for comparison.

Metals

Median concentrations of all metals in Salmon Bay sediments from the present study are similar to those reported by Cubbage (1992), although the range is greater, probably due to the larger sample size. In contrast, median concentrations of arsenic, mercury, lead, cadmium, and zinc were 2 to 4 times higher in Lake Union sediments. Lead levels were especially high in Lake Union sediments where median concentrations were elevated above all Salmon Bay/Ship Canal samples. The same pattern can be seen to a lesser degree in data reported by Hileman *et al.* (1984), although their sampling was focused primarily in the vicinity of Gas Works Park and therefore less representative of the entire lake.

Table 6. Comparison of metals concentrations in sediments from Salmon Bay/Ship Canal and Lake Union (mg/Kg, dry).

	As	Hg	Pb	Ni	Cd	Cr	Cu	Zn
SALMON BAY AND SHIP CANAL								
This Study (n=29)								
Range	1.6 - 210	0.01 - 5.0	3.5 - 534	22 - 484	<0.3 - 3.2	14 - 376	7.7 - 2210	27 - 2020
85th Percentile	42	1.6	289	68	1.6	86	671	641
75th Percentile	34	1.1	219	62	1.2	75	516	516
Median	20	0.8	151	48	0.6	60	319	319
Cubbage, 1992 (n=5)								
Range	<20 - 52	0.1 - 1.9	33 - 366	45 - 91	<0.5	48 - 124	51 - 638	87 - 685
Median	29	1.4	163	47	<0.5	66	275	368
LAKE UNION								
Cubbage, 1992 (n=13)*								
Range	<20 - 1150	0.5 - 2.9	124 - 831	37 - 133	<0.5 - 2.3	19 - 113	68 - 599	250 - 904
Median	61	1.7	641	57	1.4	58	310	533
Hileman et al., 1984 (n=33)**								
Range	0 - 284	0.03 - 4.3	28 - 962	47 - 291	0.1 - 2.4	14 - 87	23 - 587	51 - 1058
Median	28	1.1	319	92	1.5	54	168	382

*Does not include four sites in Portage Bay area

**Most samples (24 of 33) were collected within 500 feet of Gas Works Park

Table 7. Comparison of PAH and PCB concentrations in sediments from Salmon Bay/Ship Canal and Lake Union.

	Total PAHs (µg/Kg, dry)	mg PAH/Kg OC	Total PCBs (µg/Kg, dry)	mg PCBs/Kg OC
		SALMON BAY AND SHIP CANAL		
This Study (n=29)				
Range	107 - 84200	107 - 2280	nd - 7600	nd - 146
85th Percentile	38600	1090	868	14.8
75th Percentile	35200	677	420	10.6
Median	27800	489	260	4.8
Cubbage, 1992 (n=5)				
Range	540 - 24300	67 - 587	nd - 240	nd - 5.1
Median	11700	238	210	4.5
		LAKE UNION		
Cubbage, 1992 (n=10 for PAH, 8 for PCB)*				
Range	13600 - 135000	138 - 1120	200 - 640	3.8 - 11.2
Median	22800	353	360	5.4
Hileman et al., 1984 (n=8)**				
Range	nd - 198000	nr	nr	nr
Median	8660	nr	nr	nr

OC=Organic Carbon

*Does not include four sites in Portage Bay area and samples collected within 500 feet of Gas Works Park

**Does not include samples collected within 500 feet of Gas Works Park

nd=not detected

nr=not reported

Organics

Previous studies of Lake Union sediments (Hileman *et al.*, 1984; Cubbage, 1992) have centered around Gas Works Park, the site of a former coal gasification plant which has caused extreme PAH contamination of nearby sediments. Data from sediments collected within 500 feet of Gas Works Park were therefore not included in the comparison of organic compounds shown in Table 7.

Median PAH concentrations in the present study are higher than those previously reported for either the Ship Canal or Lake Union. The relative differences remain consistent when PAHs are compared on an organic carbon-normalized basis, suggesting that differences are not solely due to carbon content of the sediments. Median PCB concentrations show more similarities between studies and waterbodies, although the range of PCB concentrations was much broader than those reported by Cubbage (1992).

Elevated concentrations of butyltins in sediments have been reported in several studies of Puget Sound marinas, including portions of Elliott Bay and Fisherman's Terminal in Salmon Bay. Krone *et al.* (1989a) analyzed sediments from seven areas in Puget Sound for the PSDDA Program and found levels to vary widely based on the proximity to boat maintenance and repair facilities. For instance, sediments collected from an area within the Shilshole Bay Marina moorage area had TBT concentrations of 16 µg/Kg (dry) while sediments from the repair area of the same marina had an average concentration of 8,000 µg/Kg. Fisherman's Terminal was an exception to this contamination pattern with concentrations of TBT in the moorage area higher than those in the boat repair area (1,440 vs. 1,200 µg/Kg, respectively). A non-urban reference area had no measurable level of butyltins (<1 µg/Kg).

Keithly *et al.* (1995) conducted long-term monitoring of TBT in four regions of the country, including Puget Sound. They compared TBT concentrations in sediments representing four site types: commercial harbors, shipyards/drydocks, marinas, and ecologically significant areas. Sample size for each site type ranged from 14 to 18 samples. In Puget Sound, they found shipyard/drydock areas to have the highest mean TBT concentrations in sediments (1,200 µg/Kg, dry), followed by commercial harbors (620 µg/Kg) and marinas (410 µg/Kg). Ecologically significant areas, which were not adjacent to any vessel-related facilities but were within several miles of marinas, had a mean TBT concentration in sediments of 0.4 µg/Kg. These results support the findings of Krone *et al.* (1989a) with respect to TBT levels in relation to the type of activity or facility.

Krone *et al.* (1991) reported a summary of TBT concentrations in fish livers and sediments collected during 1986-1990 as part of the National Benthic Surveillance Project (NBSP), a component of NOAA's National Status and Trends Program. Most of the NBSP samples were collected from urban embayments. Sediments from Elliott

Bay (exact location not specified) had wet weight TBT concentrations of 700 μg/Kg in 1986, declining to 300 μg/Kg in 1990. These were the highest TBT concentrations found in any of the 23 NBSP sample locations nationwide, although the reporting of these concentrations on a wet weight basis limits their comparability among NBSP stations. Wet weight TBT concentrations in the present study ranged from non-detectable levels to 1,730 μg/Kg, with a median value of 106 μg/Kg. Krone *et al.* (1991) also found TBT to be the predominant butyltin, accounting for more than 50% of the total butyltin concentration in most areas. This pattern was also observed by Krone *et al.* (1989) and Keithly e*t al.* (1995), and is consistent with the findings reported here.

Conclusions

- Results of this study indicate there are no clear areal gradients throughout Salmon Bay for any of the chemicals analyzed. Instead, local conditions and sources appeared to be the major determinant with respect to chemical concentrations.

- The most contaminated stations were 1B and 8C, located in the northernmost portion of Salmon Bay, and 4F in the Fisherman's Terminal area. Arsenic, mercury, lead, cadmium, zinc, and tributyltin (TBT) concentrations in sediments from these stations were the highest or among the highest of all 29 stations sampled.

- The cleanest stations were 5B, 7C, and 8B, located in the central, eastern, and western portions of the study area, respectively. With one possible exception, there is also a lack of gradation or geographical pattern with respect to clean sediments. However, the cleanest area appears to be at the terminus of the Ship Canal in the easternmost section of Salmon Bay.

- Dividing the study area into zones based on major areas of concern and/or natural geographical features did not generally yield within-zone samples with similar contaminant concentrations. There was no statistically significant difference among zones for metals, total PAH, total PCB, or TBT concentrations.

- Based on comparisons to freshwater sediment quality guidelines and marine sediment quality standards, contaminated sediments from all but three sample stations in Salmon Bay can be expected to have some degree of adverse impact on benthic organisms. Of the 29 stations sampled, 23 have two or more chemicals expected to cause adverse impacts, and 21 stations have three or more chemicals expected to cause adverse impacts.

- Tributyltin probably poses the most serious threat to aquatic life in Salmon Bay due to its toxicity and high concentrations in sediments. All but five sample stations exceeded the Puget Sound Dredged Disposal Analysis Program sediment screening level (SL) for TBT. Median TBT concentrations (326 µg/Kg) were four and one-half times the SL, and 30% of the sample stations had TBT concentrations elevated one-to-two orders of magnitude above the SL.

- Chemicals other than TBT likely to harm aquatic life at one or more stations include copper, mercury, arsenic, lead, nickel, zinc, chromium, benzyl alcohol, 4-methylphenol, bis(2-ethylhexyl)phthalate, benzo(g,h,i)perylene, indeno(1,2,3-c,d)pyrene, 1,4-dichlorobenzene, and PCB-1260.

- In Salmon Bay there is mixed evidence that combined sewer overflow (CSO) discharges account for a substantial portion of the contamination. Half of the stations adjacent to the five CSO outfalls had high concentrations of metals, PAHs, and bis(2-ethylhexyl)phthalate normally found in stormwater and CSO discharges, yet other stations located near the CSO outfalls had relatively low-to-moderate levels of these compounds.

- Proximity of sample stations to marinas, boat repair facilities, marine terminals (including Fisherman's Terminal), shipyards, or vessel-related facilities alone did not appear to dictate concentrations of TBT. Instead, high TBT concentrations in sediments can probably be traced to individual facilities which do a poor job of containing paints, scrapings, and sand-blast grit on-site. Stations 1B and 4F appear to be two examples. Sediments from these stations had the highest TBT concentrations and the history of nearby facilities indicate they have poor "housekeeping" and containment practices. Stations located near vessel-related facilities were, however, more likely to have high metals concentrations.

- Observations made during sample collection, especially of heavy oil sheen and petroleum odor, may provide the best indicators of noteworthy PAH and/or PCB contamination in sediments.

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Appendices

APPENDIX A

RESULTS OF PHASE I STUDY

Phase 1 Review

1889

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
Northwest Regional Office, 3190 - 160th Ave S.E. • Bellevue, Washington 98008-5452 • (206) 649-7000

July 14, 1995

To Interested Persons:

Provided with this letter are the results from Phase I sampling of Salmon Bay and the Ship Canal area by Ecology in April, 1995. Included is a map of stations, a table of station locations, and station logs describing landmarks, water depth, sediment type, evidence of contamination, and any aquatic life present in the sediments.

These station descriptions were used in narrowing down the study area and in selecting stations for Phase II sampling and laboratory analysis. Phase II sampling was completed during the last week of June, and samples have been sent to the Ecology laboratory. Due to the time required to analyze the samples, perform quality assurance, and write up the results, results from Phase II sampling may not be available until December of 1995. You have been placed on a mailing list for the data and will automatically receive this report once it is available. Phase II results will be used to select stations for Phase III sampling and biological testing to determine the toxicity of sediments. This work will likely take place sometime next spring.

When reviewing the station logs, keep in mind that not all contamination is visible, and only what could be seen was recorded. Metals contamination, in particular, is hard to identify by visual inspection. This is one reason that these areas are being resampled for chemical analysis. However, the presence of paint chips and metal debris is one indicator that metals contamination may be present.

Oily contamination of the samples was recorded as high/heavy, medium/moderate, light/low, and very light. Very light oil means that very small droplets of oil could be seen. Most sediment from urban areas would meet this description. Light oil means that larger droplets were present, mainly on the surface of the sample. Medium oil means that oil patches were present throughout the sample and that a sheen could be seen on water from the sample. Heavy oil means the the sample was thoroughly contaminated with oil or free product was present. A notation that "organic matter" was present may be an indication that sewage or other organic wastes are present, but it is usually not possible to identify specifically without analysis.

In general, areas along the shorelines were more heavily contaminated than areas in the center channel. Areas west of Ballard Bridge were typically more contaminated than areas east of Ballard Bridge, with some exceptions. The southern shoreline near the locks appeared relatively clean, as did areas east of Ballard Bridge along the main channel of the Ship Canal. Sediments high in silt and organic matter generally also had the most oil.

Thank you for your interest in the Salmon Bay Study. If you have any questions on the information provided, please contact me at 649-7257.

Sincerely,

Dr. Teresa Michelsen
Sediment Cleanup Specialist

STATION LOCATIONS

Station	Water Depth (feet)	Latitude (degrees/minutes)	Longitude (degrees/minutes)
0	25	47° 39.510	122° 22.596
1	24	47° 40.014	122° 23.357
2	18	47° 39.959	122° 23.601
3	18	47° 39.991	122° 23.448
4	24	47° 39.958	122° 23.379
5	21	47° 39.985	122° 23.239
6	19	47° 39.910	122° 23.698
7	52	47° 39.899	122° 23.559
8	30	47° 39.910	122° 23.483
9	31	47° 39.897	122° 23.361
10	26	47° 39.891	122° 23.250
11	19	47° 39.909	122° 23.137
12	18	47° 39.843	122° 23.568
13	16	47° 39.858	122° 23.359
14	44	47° 39.827	122° 23.242
15	35	47° 39.831	122° 23.144
16	15	47° 39.825	122° 23.036
17	35	47° 39.739	122° 23.122
18	41	47° 39.766	122° 23.029
19	36	47° 39.753	122° 22.898
20	26	47° 39.685	122° 22.913
21	20	47° 39.714	122° 22.807
22	33	47° 39.604	122° 22.810
23	29	47° 39.621	122° 22.657
24	28	47° 39.637	122° 22.588
25	10	47° 39.632	122° 22.451
26	17	47° 39.622	122° 22.367
27	19	47° 39.601	122° 22.257
28	31	47° 39.542	122° 22.812
29	26	47° 39.565	122° 22.701
30	17	47° 39.557	122° 22.570
31	14	47° 39.546	122° 22.481
32	30	47° 39.551	122° 22.323
33	30	47° 39.546	122° 22.251
34	17	47° 39.534	122° 22.138
35	21	47° 39.468	122° 22.807
36	16	47° 39.455	122° 22.689
37	24	47° 39.460	122° 22.528
38	23	47° 39.473	122° 22.353
39	32	47° 39.476	122° 22.145

Station	Water Depth (feet)	Latitude (degrees/minutes)	Longitude (degrees/minutes)
40	17	47° 39.448	122° 22.003
41	15	47° 39.389	122° 22.809
42	15	47° 39.372	122° 22.683
43	16	47° 39.375	122° 22.565
44	29	47° 39.435	122° 22.005
45	6	47° 39.372	122° 22.121
46	16	47° 39.365	122° 22.012
47	33	47° 39.352	122° 21.899
48	22	47° 39.281	122° 21.806
49	26	47° 39.247	122° 21.700
50	9.5	47° 39.216	122° 21.835
51	12	47° 39.187	122° 21.656
52	30	47° 39.210	122° 21.618
53	33	47° 39.123	122° 21.463
54	36	47° 39.028	122° 21.266
55	36	47° 38.967	122° 21.154
56	36	47° 38.908	122° 21.007
57	38	47° 38.841	122° 20.858
58A	24	47° 39.284	122° 21.844
58B	24	47° 39.278	122° 21.861
59	25	47° 39.310	122° 22.007
60	23	47° 39.289	122° 21.958
61	22	47° 39.364	122° 21.868
62	10	47° 39.427	122° 21.940
63	20	47° 39.456	122° 22.423
64	16	47° 39.363	122° 22.532
65	------	------	------
66	16	47° 39.664	122° 22.574
67	20	47° 39.572	122° 22.847
68	8	47° 39.673	122° 22.962
69	36	47° 39.727	122° 23.046
70	15	47° 39.809	122° 22.874
71	13	47° 39.879	122° 22.955
72	17	47° 39.881	122° 23.050
73	16	47° 39.798	122° 23.270
74	18	47° 39.843	122° 23.465
75	------	------	------
76	16	47° 40.042	122° 23.293
77	8	47° 40.025	122° 23.505
78	18	47° 39.963	122° 23.653
79	8.5	47° 39.835	122° 23.648
80	14	47° 39.436	122° 22.869

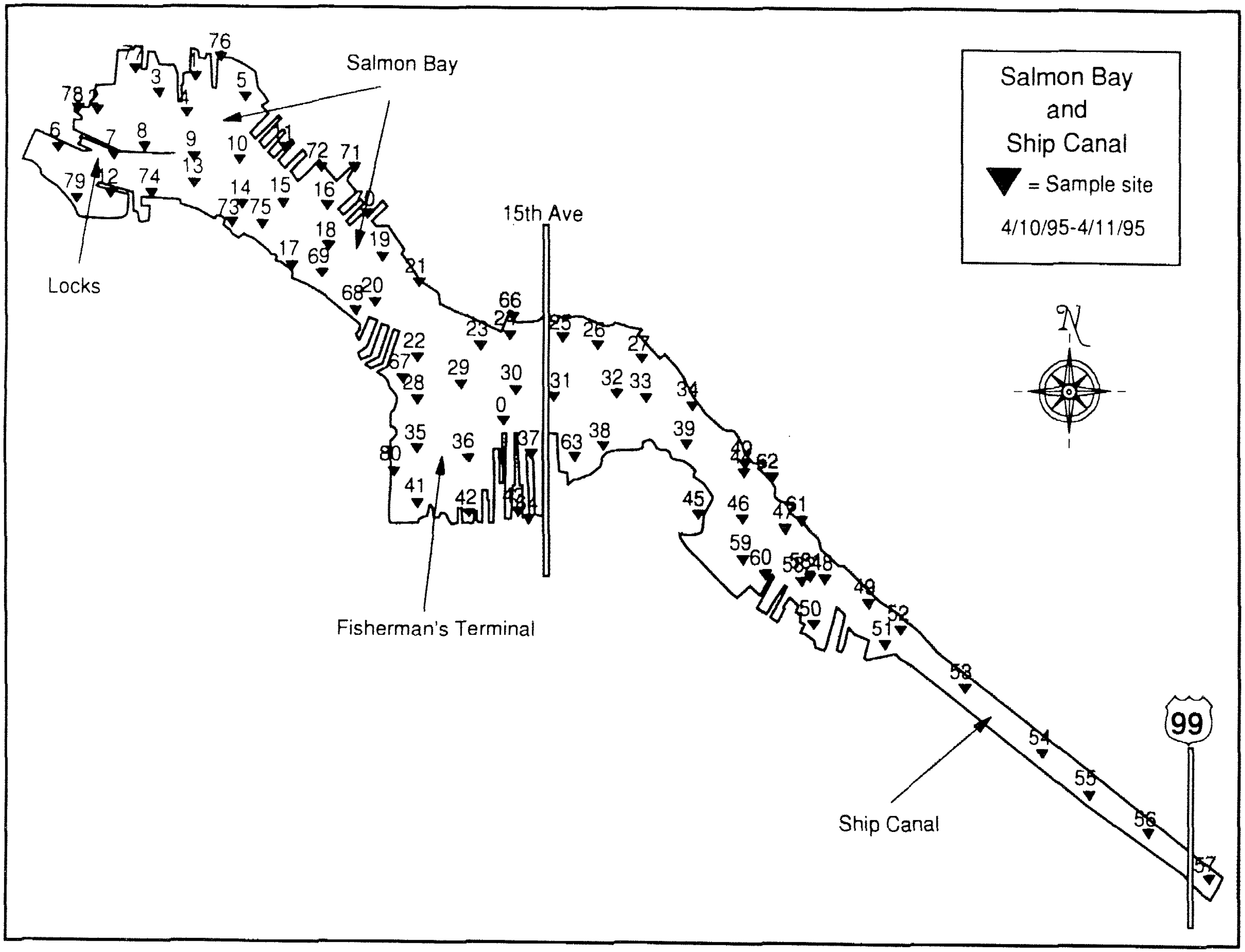

Figure 1. Sample sites for preliminary examination of sediments.

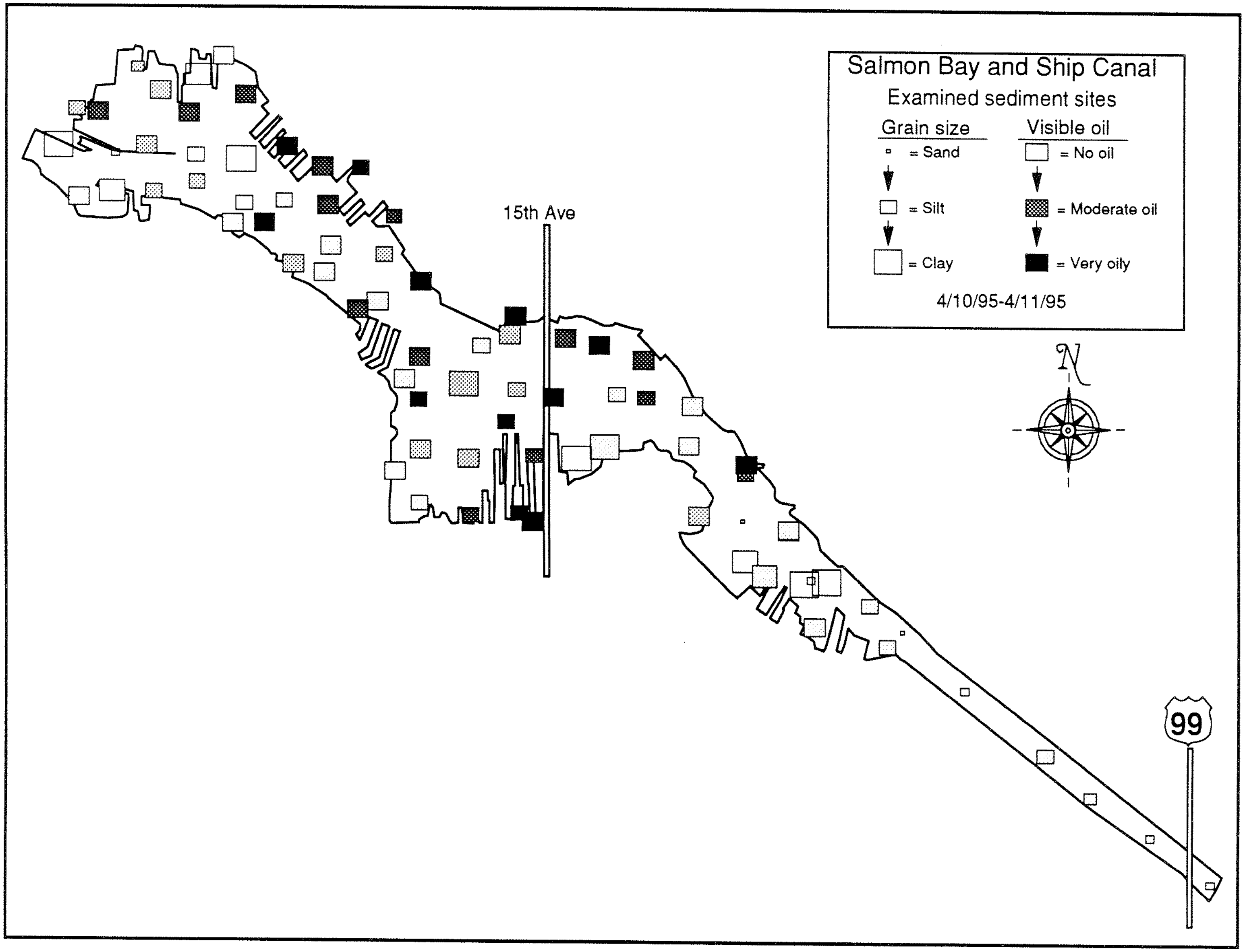

Figure 2. Results of visual inspection of sediment condition during Phase I

STATION LOG - SALMON BAY STUDY, PHASE I

STATION 0

Landmarks Near end of fuel dock at Fisherman's Terminal

Water Depth (feet) 25

Sediment Description 2 cm brown silty sand over black oily silt

Evidence of Contamination Moderate/high oil, some paint chips

Aquatic life. Tubeworms

STATION 1

Landmarks: At end of Mobile fuel dock

Water Depth: 24

Sediment Description: Thin oxidized layer on grey sandy clay

Evidence of Contamination: Metal and wood debris, no visible oil

STATION 2

Landmarks: N of locks, near west shore

Water Depth: 18

Sediment Description: Grey/black silt over grey clay

Evidence of Contamination: Moderate oil

STATION 3

Landmarks: In marina north of barge (5320 28th NW)

Water Depth: 18

Sediment Description. Brown silt over black silt

Evidence of Contamination Low/medium oil, slight petroleum odor

STATION 4

Landmarks W end of Pacific Fishermen

Water Depth 24

Sediment Description Brown/green silt over black sandy silt

Evidence of Contamination Moderate oil

STATION 5

Landmarks Just S of 24th Ave landing dock near Yankee Diner

Water Depth 21

Sediment Description. Brown silt over black sandy silt

Evidence of Contamination Moderate oil, slight petroleum odor

STATION 6

Landmarks: Near yellow end of concrete wall at locks

Water Depth: 19

Sediment Description: Grey-brown clay

Evidence of Contamination: None

STATION 7

Landmarks: S of locks wing wall, E of blue sign

Water Depth: 52

Sediment Description: Brown sand

Evidence of Contamination: None

Aquatic Life Large clumps of saltwater mussels, aquatic plants

STATION 8

Landmarks N of Army Corps barges at lock wall

Water Depth 30

Sediment Description Brown silt over black silt

Evidence of Contamination Rocks, wood

STATION 9

Landmarks: NE of end of lock wall

Water Depth: 31

Sediment Description: Grey/brown silty sand

Evidence of Contamination: Wood chips

STATION 10

Landmarks: S of Stimson Marina

Water Depth: 26

Sediment Description: Grey clay

Evidence of Contamination: None

STATION 11

Landmarks: Stimson Marina between rows C&D, halfway in

Water Depth: 19

Sediment Description: Brown sandy silt over black sandy silt

Evidence of Contamination: Low/moderate oil

STATION 12

Landmarks Inside Time Oil dock near manifold

Water Depth 18

Sediment Description Brown clayey silt

Evidence of Contamination Very little oil

STATION 13

Landmarks: E of Maritime Industrial Center, nearshore

Water Depth 16

Sediment Description Brown silt over black silty sand

Evidence of Contamination Low/moderate oil, lots of paint chips, wood

STATION 14

Landmarks: Between Anderson dry dock and Stimson Marina

Water Depth: 44

Sediment Description: Brown silt over black silty sand, some gravel

Evidence of Contamination: Low oil

STATION 15

Landmarks: Between Maney Seafoods (?) and Stimson Marina, mid-channel

Water Depth: 35

Sediment Description: Brown silt over black sandy silt

Evidence of Contamination: Low oil, wood chunks

Aquatic Life: Tube worms

STATION 16

Landmarks: Just E of gravel dock

Water Depth: 15

Sediment Description: Thin brown layer over black silt

Evidence of Contamination: Moderate oil, paint flecks, organic matter

STATION 17

Landmarks: W of Marco along shoreline

Water Depth: 35

Sediment Description: Brown silt over black sandy silt

Evidence of Contamination: low/moderate oil, plastic, algae

STATION 18

Landmarks: Mid-channel between Marco and Canal Marina

Water Depth: 41

Sediment Description: Brown silt over black sandy silt

Evidence of Contamination: Droplets of oil, organic matter

STATION 19

Landmarks: Just W of Seaview Marina, center of large moored ships

Water Depth: 36

Sediment Description: Green/black silty sand

Evidence of Contamination: Low/moderate oil, lots of wood debris, paint chips

STATION 20

Landmarks: Just N of Salmon Bay Marina

Water Depth: 26

Sediment Description: Brown silt over black silt

Evidence of Contamination: Low oil

STATION 21

Landmarks: Seaview Marina entrance

Water Depth: 20

Sediment Description: Brown silt over black sandy silt

Evidence of Contamination: Moderate oil, paint chips, wood fragments, rocks

STATION 22

Landmarks: Between NWII North Pier and leased dock, halfway in

Water Depth: 33

Sediment Description: Thin brown silt over black silt

Evidence of Contamination: Moderate oil

STATION 23

Landmarks: S of pallet storage, center channel

Water Depth: 29

Sediment Description: Brown layer over black silty sand

Evidence of Contamination: Low oil, wood debris

Aquatic Life: Tube worms

STATION 24

Landmarks Northshore north of E end of Fisherman's Terminal

Water Depth 28

Sediment Description Brown silt over black silt

Evidence of Contamination. Low/moderate oil, organic debris

STATION 25

Landmarks: S of Maritime Training Center, E of Ballard Bridge

Water Depth: 10

Sediment Description. Grey/black silt

Evidence of Contamination: Moderate oil, lots of wood debris, high organic content

STATION 26

Landmarks: S of Community College

Water Depth: 17

Sediment Description: Grey-green silt

Evidence of Contamination: Low/moderate oil, lots of organic matter, wood

STATION 27

Landmarks: S of Duncan Engine Co.

Water Depth: 19

Sediment Description: Grey/brown silt over dark grey silt

Evidence of Contamination: Medium oil, organic matter

STATION 28

Landmarks Just S of E/W Pier, Fisherman's Terminal

Water Depth 31

Sediment Description Brown sand over black silty sand

Evidence of Contamination: Medium/high oil, metals debris

STATION 29

Landmarks: N of 325' marker on E/W Pier, Fisherman's Terminal

Water Depth: 26

Sediment Description: Light grey clay

Evidence of Contamination: Low/moderate sheen

STATION 30

Landmarks: Mid-channel W of Ballard Bridge

Water Depth: 17

Sediment Description: Brown silty sand over grey clay

Evidence of Contamination: Low oil, wood debris

STATION 31

Landmarks: E of Ballard Bridge near S shore

Water Depth: 14

Sediment Description: Brownish-black silty sand

Evidence of Contamination: Medium oil

STATION 32

Landmarks Mid-channel N of Salmon Bay Terminal

Water Depth 30

Sediment Description Black/brown silty sand

Evidence of Contamination Light oil, lots of wood debris, organic matter

STATION 33

Landmarks: S of Canal Boatyard in channel

Water Depth: 30

Sediment Description Black/brown sandy silt

Evidence of Contamination: Light/medium oil

STATION 34

Landmarks: E end of Canal Boatyard

Water Depth: 17

Sediment Description: Green-black silt

Evidence of Contamination: Light oil, paint chips, wood chunks

STATION 35

Landmarks: Between end of Piers 9&10 Fisherman's Terminal

Water Depth: 21

Sediment Description: Brown silt over black silt, some brown clay

Evidence of Contamination: Light/moderate oil, metal debris, organic matter, wood

STATION 36

Landmarks At ends of docks 7&8, Fisherman's Terminal

Water Depth 16

Sediment Description Brown sandy silt over black sandy silt

Evidence of Contamination Light/moderate oil

STATION 37

Landmarks Fisherman's Terminal E side

Water Depth 24

Sediment Description Brown/grey silt

Evidence of Contamination: Moderate oil, organic matter

STATION 38

Landmarks: E end of Salmon Bay Terminal

Water Depth: 23

Sediment Description: Brown clay

Evidence of Contamination: Light oil, wood debris

STATION 39

Landmarks: N of WA Fish & Oyster

Water Depth: 32

Sediment Description: Brown sandy silt over black sandy silt

Evidence of Contamination: Light oil, wood chips, organic matter

STATION 40

Landmarks: Off Union Bay Shipbuilding pier

Water Depth: 17

Sediment Description: Grey/black silt

Evidence of Contamination: Heavy oil, organic matter

STATION 41

Landmarks: Nearshore between Piers 9&10, Fisherman's Terminal

Water Depth: 15

Sediment Description: Brown silty sand

Evidence of Contamination: Light oil, some organic matter

STATION 42

Landmarks: Between docks 7&8 nearshore

Water Depth: 15

Sediment Description: Brown sandy silt over black silt and grey clay

Evidence of Contamination: Moderate oil

STATION 43

Landmarks: Fishing Vessel Owner's Marine Ways Inc, near bulkhead

Water Depth: 16

Sediment Description: Grey/black silt, some brown clay

Evidence of Contamination: Heavy oil, paint chips

STATION 44

Landmarks S of Union Bay Shipbuilding in channel

Water Depth 29

Sediment Description Light brown sand over organic black silt

Evidence of Contamination Medium oil, wood debris

STATION 45

Landmarks Just E of LeClerq Marina near shoreline

Water Depth 6

Sediment Description Brownish black silt

Evidence of Contamination: Medium oil, hydrogen sulfide odor, lots of organic matter

STATION 46

Landmarks: S of Trident, NW of Foss, near dolphins

Water Depth: 16

Sediment Description: Gravel

Evidence of Contamination: Wood chips

STATION 47

Landmarks: S of Trident, N of Foss

Water Depth: 33

Sediment Description: Gravel over silty black sand w/light grey clay

Evidence of Contamination: Light oil

STATION 48

Landmarks: Between Foss Tug and Empire Alaska Seafoods

Water Depth: 22

Sediment Description: Light grey clay

Evidence of Contamination: None

STATION 49

Landmarks: S of Flohr Metal Fabricators

Water Depth: 26

Sediment Description: Brown sand and gravel over black silty sand

Evidence of Contamination: Light oil

STATION 50

Landmarks: Foss near S shoreline

Water Depth: 9.5

Sediment Description: Brown silty sand over black silt

Evidence of Contamination: Light oil

STATION 51

Landmarks: Just inside marina

Water Depth: 12

Sediment Description: Brown sand over black sandy silt

Evidence of Contamination: Light oil

STATION 52

Landmarks: S of gravel plant, N of W end of Metro lab

Water Depth: 30

Sediment Description: Gravel

Evidence of Contamination: None

STATION 53

Landmarks: S of Prolab, N of E end of park

Water Depth: 33

Sediment Description: Brown sand, shell, gravel

Evidence of Contamination: None

STATION 54

Landmarks: S of grey building, N of office buildings

Water Depth: 36

Sediment Description: Brown sand over black silt

Evidence of Contamination: Very light oil

STATION 55

Landmarks: Between electric towers near Red Hook Brewery

Water Depth: 36

Sediment Description: Brown sand over grey silt

Evidence of Contamination: very light oil, some wood debris

Aquatic Life: Small freshwater mussels and clams

STATION 56

Landmarks: S of center of brown warehouse. N of cinderblock wall

Water Depth: 36

Sediment Description: Brown and grey sand w/pebbles

Evidence of Contamination: Very light oil

STATION 57

Landmarks: Just E of Fremont bridge, center channel

Water Depth: 38

Sediment Description: Brown and grey sand, some gravel

Evidence of Contamination: Very light oil

STATION 58A

Landmarks: E of Foss drydocks nearshore

Water Depth: 24

Sediment Description: Grey and brown sand and gravel

Evidence of Contamination: Paint chips and metal debris

STATION 58B

Landmarks: Offshore of 58A near moored tugs

Water Depth: 24

Sediment Description: grey and brown gravel over light grey clay

Evidence of Contamination: Paint chips and metal debris

STATION 59

Landmarks Between Foss drydocks 1&2

Water Depth 25

Sediment Description Medium grey clay w/gravel

Evidence of Contamination: None

STATION 60

Landmarks W of Foss drydocks near shoreline

Water Depth 23

Sediment Description. Brown sand over light grey clay

Evidence of Contamination Very light oil

STATION 61

Landmarks: Just off Trident Seafoods, W end of grey bulkhead

Water Depth: 22

Sediment Description: Gravel and cobble

Evidence of Contamination: Wood and metal debris

STATION 62

Landmarks: Just W of Trident along shoreline

Water Depth: 10

Sediment Description: Riprap and gravel

Evidence of Contamination: Couldn't get a sample

STATION 63

Landmarks: Salmon Bay Terminal near center of bulkhead

Water Depth: 20

Sediment Description: Grey clay, shells

Evidence of Contamination: Blackened wood

STATION 64

Landmarks: Under Ballard Bridge near S shore

Water Depth: 16

Sediment Description: Brown/black silty clay

Evidence of Contamination: High oil, organic matter

STATION 65

Not Collected

STATION 66

Landmarks: W end of Ballard Bridge near marina on N shore

Water Depth: 16

Sediment Description: Brown/black silt

Evidence of Contamination: Heavy oil

STATION 67

Landmarks: Salmon Bay Boatyard just N of E/W Pier

Water Depth: 20

Sediment Description: Brown silt over black silt

Evidence of Contamination: Light oil

STATION 68

Landmarks E end of Marco

Water Depth 8

Sediment Description Brown silt over black sandy silt

Evidence of Contamination Moderate oil, organic matter

Aquatic Life. Aquatic plants

STATION 69

Landmarks: Just E of Marco drydocks

Water Depth: 36

Sediment Description Brown silt over black silt

Evidence of Contamination. Light oil

STATION 70

Landmarks: E end of Canal Marina near shoreline

Water Depth: 15

Sediment Description: Brown silt over black sandy silt

Evidence of Contamination: Moderate oil

STATION 71

Landmarks: Near Standard Marina

Water Depth: 13

Sediment Description: Black silty sand

Evidence of Contamination Moderate/high oil, rope, debris, plastic, wood

STATION 72

Landmarks W of gravel dock near shoreline, Stimson Marina

Water Depth 17

Sediment Description Brown silt over black silt

Evidence of Contamination: Moderate oil

STATION 73

Landmarks: W of Anderson drydock nearshore

Water Depth: 16

Sediment Description: Brown/black sandy silt

Evidence of Contamination: Light oil

STATION 74

Landmarks: Offshore of Time Oil, Maple Bay Boat Co.

Water Depth: 18

Sediment Description: Grey silty sand

Evidence of Contamination: Light/moderate oil, wood debris, paint chips

STATION 75

Not Collected

STATION 76

Landmarks: Just E of Yankee Diner at shoreline

Water Depth: 16

Sediment Description: Black silt

Evidence of Contamination: Moderate/heavy oil, petroleum odor, wood chunks, plastic

STATION 77

Landmarks Sea & Shore Construction (5355 28th NW)

Water Depth 8

Sediment Description Black sand

Evidence of Contamination: Light/moderate oil, lots of paint chips

STATION 78

Landmarks: Near Corps carpenter shop at locks

Water Depth: 18

Sediment Description: Black sandy silt

Evidence of Contamination: Light/moderate oil, wood chips, rocks

STATION 79

Landmarks: Lockhaven Marina E side

Water Depth: 8.5

Sediment Description: Thin brown silt over black sandy silt

Evidence of Contamination: Light oil

Aquatic Life: Aquatic plants

STATION 80

Landmarks: W bulkhead of Fisherman's Terminal near 175' mark

Water Depth: 14

Sediment Description: Green sandy silt

Evidence of Contamination: light oil, chunks of wood fibers

APPENDIX B

DESCRIPTION OF SAMPLE STATIONS

Table B-1. Description of sample stations for Phase II.

Station:	Sample No.	Date and Time	Depth (ft)	Latitude (47-)	Longitude (122-)	Remarks
1A	8230	6/26/96 14:25	18	39.958	23.367	
1B	8231	6/26/96 14:47	20	40.010	23.225	west side of Ballard dock near CSO 152
1C	8232	6/26/96 15:11	19	39.911	23.148	between boathouse C&D
2A	8233	6/26/96 15:31	29	39.835	23.000	off Chevron dock
2B	8234	6/26/96 16:08	24	39.830	22.901	off CSO
2C	8235	6/26/96 16:22	20	39.749	22.869	
3A	8236	6/26/96 12:08	16	39.892	23.740	
3B	8237	6/26/96 12:20	17	39.836	23.576	Time Oil dock
3C	8238	6/26/96 12:40	36	39.772	23.125	
4A	8239	6/26/96 16:37	33	39.614	22.811	east of first main dock
4B	8240	6/27/96 10:25	13	39.649	22.580	
4C	8241	6/27/96 9:14	21	39.489	22.841	
4D	8242	6/27/96 10:00	21	39.512	22.588	off fuel dock
4E	8243	6/27/96 9:41	14	39.408	22.735	4th slip from west-halfway down
4F	8244	6/27/96 10:12	24	39.429	22.538	
5A	8245	6/26/96 11:56	45	39.871	23.326	
5B	8246	6/26/96 11:40	28	39.656	22.747	
5C	8247	6/26/96 11:29	30	39.558	22.342	
6A	8248	6/27/96 11:06	14	39.621	22.345	
6B	8249	6/27/96 12:34	16	39.516	22.113	
6C	8250	6/27/96 10:44	18	39.485	22.412	
6D	8251	6/27/96 10:22	20	39.488	22.241	Ocean Beaty Seafoods
7A	8252	6/27/96 13:15	17	39.446	22.001	Union Bay Shipbuilders
7B	8253	6/27/96 13:40	22	39.305	21.990	west side of Foss
7C	8254	6/27/96 14:48	23	39.260	21.855	
7D	8255	6/27/96 14:40	33	39.257	21.728	
8A	8256	6/26/96 13:29	18	39.969	23.630	
8B	8257	6/26/96 13:43	18	40.021	23.520	
8C	8258	6/26/96 14:02	18	39.998	23.466	

APPENDIX C

ANALYTICAL METHODS

Table C-1. Analytical methods used for Phase II.

Analysis	Method	Reference	Target Detection Limit
Total organic carbon (TOC)	PSEP Method	EPA, 1986a	
Grain size	ASTM D-422		
% Solids	Gravimetric - EPA Method 160.3	EPA, 1986b	
Arsenic	GFAA - EPA Method 206.2	EPA, 1986b	1 mg/Kg
Cadmium	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Chromium	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Copper	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Mercury	CVAA - EPA Method 245.5	EPA, 1986b	0.1 mg/Kg
Lead	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Nickel	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Zinc	ICAP - EPA Method 200.7	EPA, 1986b	1 mg/Kg
Semivolatile organics	GC/MS - EPA Method 8270	EPA, 1986b	100 μg/Kg
PCBs	GC/EC - EPA Method 8080	EPA, 1986b	50 μg/Kg
Butyltins	GC/MS - NOAA Method	Krone *et al*., 1989b	20 μg/Kg

APPENDIX D

QA/QC RESULTS

DEPARTMENT OF ECOLOGY

July 18, 1996

TO: Stewart Lombard, QA Section

FROM: Dave Serdar, Toxics Section

SUBJECT: Review of Salmon Bay Data

Stew, thanks for agreeing to take a look at the Salmon Bay data. I've enclosed the entire data package for the project as well as a copy of our draft report. The draft report has a digestion of the QA results in Appendix D and a discussion of data quality on pages 11-13. There is also a comparison to acceptance limits for QA1 review in Table 1.

The major concerns about the data quality are as follows:

- The holding time requirements for TOC were exceeded by 28 days. Semivolatiles and PCBs were extracted seven days after the holding time limit of 14 days. Butyltins were not extracted until seven weeks after collection, although they were held frozen during that time.

- There were some problems with the butyltin analysis. The low precision resulting from analysis of field splits may have been due to the presence of paint chips which would yield non-homogeneous samples (see Table D-3 of the draft report). Recovery of TBT in the Sequim Bay Reference material and matrix spikes were also poor (see Tables D-1 and D-2 in draft report and the Manchester case narrative for butyltins).

- About one-third of the PAH reference material analyses were outside the acceptable recovery windows (see Table D-2).

- Matrix spike recoveries for mercury, lead, and chromium were outside the acceptance windows (see Table D-1 and Manchester case narrative).

- I'm also wondering if the data should have additional flags or qualifiers.

As I mentioned during our phone conversation, I'd like to shoot for a turnaround time of no longer than one month. I know that time has become especially valuable these days so again, I appreciate your help. Let me know if you have any questions. My number is 407-6772.

DS:jl

DEPARTMENT OF ECOLOGY
ENVIRONMENTAL INVESTIGATIONS AND LABORATORY SERVICES PROGRAM

August 30, 1996

TO: Dave Serdar
Toxics Investigations Section

THROUGH: Cliff Kirchmer
QA Section Manager

FROM: Stewart Lombard
QA Section

SUBJECT: Salmon Bay Sediments Data QC

I have reviewed your report and the analytical data reports and case narratives for the Salmon Bay sediments study. I have attempted to address below the concerns which you expressed in your cover memo.

Failure to meet sample preservation and holding time specifications compromises the representativeness, comparability and accuracy of the analytical results. Organic compounds in sediment samples are subject to volatilization, oxidation and biodegredation during storage.

The samples for TOC analysis were not preserved according to the PESP protocol. There is no way to determine whether the results are actually affected by the sample storage procedures. The analytical procedure includes drying the samples at 70°C and treating them with acid. Obviously, the results are not intended to include volatile compounds or those susceptible to acid hydrolysis.

I recommend qualifying the organic carbon and carbon-normalized results because of the non-standard storage procedure. However, I think that the TOC results are suitable for the purpose of comparing carbon-normalized results for organic contaminants to sediment criteria. Obviously, when the results are close to the criteria, you can not determine from these data whether the criteria have been exceeded.

I agree with the conclusion in the report that PCBs and PAHs are among the more stable organic contaminants and the results for these compounds are probably not affected significantly by the extended holding times.

The analytical quality control results for the PAH analyses reflect the inherent variability in this determination. The recoveries for the D10-pyrene surrogate for the 31 samples ranged from 63 to 92% with a mean of 82% and standard deviation of 6.5%. The D10-pyrene surrogate is not included in Method 8270, so there are no specified recovery limits for it. To the extent that this surrogate is representative of the 16 PAH compounds, these data suggest that the analytical system was in good control.

The median values of the matrix spike recoveries for the 16 PAH compounds were 88% (Range = 69% to 120%) and 90.5% (Range = 74% to 130%) for the two spiked samples, respectively. These are good results for organic matrix spikes.

Relative to the certified values, the median value of the "recoveries" for 15 of the 16 PAHs in the reference sediment (calculated from the means of the duplicate results) is 100% with a range of 72% to 155%. These results also suggest that the analytical system was in good control. The results for acenaphthylene are a problem. You may wish to discuss them with the analyst. I hesitate to recommend qualifying any results for the project sediment samples on the basis of this single apparent anomaly in the results for the reference sediment.

The Relative Standard Deviations (RSD) for the PAH results for the two pairs of field split samples range from 0 to 40% with a median value of 7.4%. I consider that to be good precision. I wonder how much variability true field replicates would have exhibited.

The situation with the mercury results is unfortunate. Since the second matrix spike/matrix spike duplicate pair did not produce useable results, we are left with just one pair of spike results, one of which is very high. The other QC results for the mercury analyses indicate that the system was in good control. The recoveries for the laboratory control samples (LCS) are 92% and 93%, the method blanks produced no measurable response and the agreement between the field split results for the two duplicate pairs is excellent, 1.3% and 4.5% RSD, respectively. I do not recommend qualifying your mercury results on the basis of a single matrix spike recovery. The method specifies that, if any results are to be qualified solely on the basis of MS/MSD recoveries, only the results for the sample used for the MS/MSD ought to be qualified.

The QC data for chromium and lead do indicate a negative bias, but there is not sufficient data to quantify that bias. The recoveries for the two laboratory control samples (LCS) are 79% and 81% for chromium and both are 85% for lead. The recoveries for the two MS/MSD pairs for chromium are 79% and 85%, 69% and 74%. The recoveries for lead were not calculated for the first pair and were 65% and 66% for the second. The two method blank results showed no measurable levels of either chromium or lead and the results for the two pairs of field split samples showed good agreement (all less than 10% RSD).

These QC data indicate good precision for chromium and lead results and the possibility of a negative bias of, perhaps, 20% to 40%.

The organo-tin results are certainly of concern. There is a preponderance of evidence that organo-tin compounds are present at significant levels in most of the sediment samples. Your conclusion that organo-tin compounds are the major contaminant of concern in Salmon Bay sediments is justified. However, the QC results indicate that the analytical system was not in good control with these samples and these results should not be used as the basis for any comparisons to criteria or to other data.

I am concerned about some of the entries in Table 1 of your report. The table indicates that the surrogate recovery target of >50% was achieved for 96% of the butyltin results. By my calculations, surrogate recoveries for the original extracts of 21 of the 31 samples were between 50% and 200%. The case narrative states that surrogate recoveries over 200% were due to chromatographic interference. I think it is deceptive to indicate that surrogate recoveries were satisfactory for 96% of the butyltin results.

The PSEP protocols recommend freezing samples for organo-tin analyses within 24 hours of collection and does not specify a holding time. Therefore, I don't think it is justified to indicate in Table 1 that 0% of the butyltin samples met holding time requirements.

I hope these comments are helpful to you. Let me know if you have any questions. I would be happy to discuss any specific issues with these data in more detail.

SML:sml

cc: Larry Goldstein
Bill Kammin

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366

July 261995

Project: Salmon Bay

Samples: 26-8230-8258, 26-8260-61

Laboratory: Soil Technology

By: Pam Covey

Case Summary

The ~~Sound Refining~~ samples required thrirty one (31) Grain Size analyses on sediment using ASTM D-422 modified with wet preparation.

These samples were received at the Manchester Environmental Laboratory on June 28, 1995 and transported to Soil Technology on June 29, 1995 for Grain Size analyses. These analyses were reviewed for qualitative and quantitative accuracy, validity and usefullness.

The results are acceptable for use as reported.

State of Washington Department of Ecology
Manchester Environmental Laboratory
7411 Beach Dr. East Port Orchard WA. 98366
August 8, 1995

Project: **Salmon Bay/Ship Canal**

Samples: 268230 through 268261

Laboratory: Weyerhaeuser Analytical and Testing Services 18303

By: Karin Feddersen KF

These samples were received at the Manchester Environmental Laboratory (MEL) on June 27, 1995, and were sent to Weyerhaeuser Analytical and Testing Services on June 28, 1995, for TOC analysis using PSEP.

HOLDING TIMES

The holding time for frozen sediments is six (6) months. There have been no studies performed to indicate the effect of holding time on samples that have not been stored frozen prior to analysis. Therefore an evaluation of the results with regard to holding time is not feasible. All samples were stored in the proper containers at 4 degrees C until analysis. All analyses were performed within forty-two (42) days of collection.

PROCEDURAL BLANKS

The procedural blanks associated with these samples demonstrated that the processes were free from contamination. For consistency, all non-detect results have been qualified with a "U" to conform to the Manchester Laboratory reporting format.

INITIAL CALIBRATION

The % Relative Standard Deviations (%RSD) were within QC limits of 20%.

CHECK STANDARDS

All Check Standard recoveries are reasonable, acceptable, and within QC limits of 90% to 110% of the expected result.

TRIPLICATE

Sample 268230 was analyzed in triplicate on July 18. The carbon peak areas were higher than that of the highest concentration standard. The triplicate analysis was repeated on July 26. The Relative Percent Difference (RPD) of the triplicate analyses to the original analyses are within QC limits of 10% for both days.

SUMMARY

All non-detect results have been qualified with a "U" (not detected at or above the reporting limit) for consistency with MEL's reporting format. This data is acceptable for use as amended.

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive East • Port Orchard, Washington 98366-8204 • (360) 871-8860 • FAX (360) 871-8850

August 22, 1995

To: Jim Cubbage, Project Officer

From: Myrna McIntosh, Metals Chemist

Subject: Metals Quality Assurance Memo for the Salmon Bay, sediment samples
Sample Numbers: 95268230 - 95268261

QUALITY ASSURANCE SUMMARY

Data quality for this project is generally very good.

The mercury results are qualified with "J" because of negative spike recoveries. This is usually the case when mercury is not homogeneously distributed throughout the subsamples.

The other metal analytes were digested in two batches. The recoveries of lead and chromium in the second digestion batch are low. All lead and chromium results from this digestion are qualified with "N". These low recoveries are probably unique to the sample chosen rather than the whole batch. Although it is lab policy to qualify on the basis of one set of spikes per batch, since the recoveries are in the 60 % - 70 % range the results need not be estimated.

SAMPLE INFORMATION

The samples from the Salmon Bay project were received by the Manchester Laboratory on 6/28/95 in good condition.

HOLDING TIMES

All analysis were performed within the USEPA Contract Laboratory Program (CLP) holding times for metals analysis (28 days for mercury, 180 days for all other metals).

INSTRUMENT CALIBRATION

Instrument calibration was performed before each analytical run and checked by initial calibration verification standards and blanks. Continuing calibration standards and blanks were analyzed at a frequency of 10% during the run and again at the end of the analytical run. All initial and continuing calibration verification standards are within the relevant USEPA (CLP) control limits. AA calibration gave a correlation coefficient (r) of 0.995 or greater, also meeting CLP calibration requirements.

PROCEDURAL BLANKS

The procedural blanks associated with these samples show no significant amounts of contamination.

SPIKED SAMPLE ANALYSIS

Spiked sample analysis were performed on this data set. All spike recoveries, except mercury (all), lead and chromium (digestion batch #2) are within the CLP acceptance limits of +/- 25 %. All lead and chromium results in digestion batch #2 are qualified with "N". All mercury results are qualified with "J".

PRECISION DATA

All precision results except for mercury were within the CLP limits of +/- 20% RSD.

LABORATORY CONTROL SAMPLE (LCS) ANALYSIS

LCS analysis are within the windows established for each parameter.

Please call Bill Kammin at SCAN 360-871-8801 to further discuss this project.

MMM:mmm

MANCHESTER ENVIRONMENTAL LABORATORY
7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

October 11, 1995

Subject: Salmon Bay

Samples: 95 - 268230 to -268258, -268260 and -268261

Case No. 1961-95

Officer: Jim Cubbage

By: Dickey D. Huntamer
Organics Analysis Unit

SEMIVOLATILE ORGANICS

ANALYTICAL METHODS:

The semivolatile soil samples were extracted with acetone following the Manchester modification of the EPA CLP and SW 846 8270 procedure with capillary GC/MS analysis of the sample extracts. Normal QA/QC procedures were performed with the analyses except that only one matrix spike was analyzed with each extraction batch.

HOLDING TIMES:

All sample and extraction holding times were within the recommended limits.

BLANKS:

Low levels of some target compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank.

SURROGATES:

The normal Manchester Laboratory surrogates were added to the sample prior to extraction. All surrogate recoveries were within acceptable limits except for nitrobenzene-d5 in samples -268231 and -268238 and -268249. Samples -268231 and -269238 less than 3% low whereas sample -268249 had less than 10% recovery. Since all of the other surrogates in these samples were acceptable no additional qualifiers were added to the data.

MATRIX SPIKE AND MATRIX SPIKE DUPLICATE:

At the project officers request only one matrix spike (LMX1) was analyzed with each batch of samples extracted. Consequently no duplicate spikes and Relative Percent Differences (RPD) data is available.

Matrix spike recoveries were low for 1,3-dichlorobenzene, N-nitrosodinpropylamine, hexchloroethane, 4-chloroaniline, 3-nitroaniline in sample -268246 (LMX1). For the other matrix spike sample, -268234 (LMX1) hexchloroethane, 2-nitrophenol, 3- and 4-nitroanilines had low recoveries. The "J" qualifier was added to the results for these compounds. Hexachlorocylcopentadiene and 4-chloroaniline recoveries were less than 10% in sample, -268234 (LMX1) and the data for these compounds were rejected, "REJ" in the matrix spike source sample. In sample, -268246 (LMX1) only hexachlorocylcopentadiene was less than 10% and data for this compound was also rejected.

ANALYTICAL COMMENTS:

No special analytical problems were encountered in the semivolatile analyses. The data is acceptable for use as qualified.

One Canadian reference material sample, HS-6, for polynuclear aromatic hydrocarbons was prepared and analyzed with each batch of samples. These are identified as HS652431 and HS652485.

DATA QUALIFIER CODES:

U - The analyte was not detected at or above the reported value.

J - The analyte was positively identified. The associated numerical value is an estimate.

UJ - The analyte was not detected at or above the reported estimated result.

REJ - The data are unusable for all purposes.

EXP - The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3 X 10^6.

NAF - Not analyzed for.

N - For organic analytes there is evidence the analyte is present in this sample.

NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

E - This qualifier is used when the concentration of the associated value exceeds the known calibration range.

bold - The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

Manchester Environmental Laboratory

7411 Beach Dr E
Port Orchard Washington 98366
September 19, 1995

Project: **Salmon Bay**

Samples: 95268230 through 268261

By: Karin Feddersen KF

These samples were analyzed by EPA Method 8080 for Polychlorinated Biphenyls (PCBs) employing the dual column confirmation technique.

Holding Times:

These samples were extracted six days past the method holding time of fourteen days. PCBs are extremely stable. Therefore, extraction beyond the holding time should not affect the results. The samples were analyzed within the method holding time of forty days from extraction.

Method Blanks:

No analytes of interest were detected in the method blanks.

Initial Calibration:

The % Relative Standard Deviations were within the maximum of 30% for all target analytes.

Continuing Calibration:

The Percent Differences between the initial and continuing calibrations were within the maximum of 25% for all target analytes.

Surrogates:

Four surrogates were added to each sample. The recommended range for surrogate recovery is between 60% and 150%. Dibutylchlorendate (DBC) recoveries were low in almost all samples. An acid cleanup was performed on these samples. DBC is very susceptible to degradation by acid. Since PCBs are not susceptible to acid degradation, and because the other surrogates demonstrated acceptable recoveries, qualification of the results is not required. Recoveries were acceptable for three of the surrogates in all samples except the 1:100 dilution of sample 268252. The surrogates were most likely not detected as a result of the dilution performed. Non-detected surrogates have been qualified with "REJ". However, the associated sample results do not need qualification.

Matrix Spikes (MS/MSD):

All matrix spike recoveries were between 75% and 100%. These recoveries are reasonable and acceptable.

Sample Results:

When the RPD between the two columns was greater than 30% for an analyte, the result was qualified with a "J".

The PCB - 1254 and -1260 results for sample 268252 exceeded the calibration curve. Therefore, two dilutions were required. Use the results from the first dilution (DIL1) for PCB - 1260. Use the results from the second dilution (DIL2) for PCB - 1254. Use the undiluted sample results for all non-detects.

This data is acceptable for use with the qualifications mentioned.

DATA QUALIFIER CODES:

U - The analyte was not detected at or above the reported value.

J - The analyte was positively identified. The associated numerical value is an estimate.

UJ - The analyte was not detected at or above the reported estimated result.

NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

NAF - Not analyzed for.

REJ - The data are unusable for all purposes.

MANCHESTER ENVIRONMENTAL LABORATORY

7411 Beach Drive E , Port Orchard Washington 98366

CASE NARRATIVE

December 18, 1995

Subject:	Salmon Bay
Samples:	95 - 268230 to -268258, -268260 and -268261
Case No.	1961 -95
Officer:	Jim Cubbage
By:	Dickey D. Huntamer Organics Analysis Unit

TRIBUTYL TINS

ANALYTICAL METHODS:

The samples were extracted following the methods given in Puget Sound Estuary Program (PSEP) "Recommended Guidelines for Measuring Organic Compounds in Puget Sound Sediment and Tissue Samples" Recommended Methods for Organotin Compounds. The samples were Soxhlet extracted with acetone and tropolone, 0.2% by weight, solvent exchanged to hexane and dried using sodium sulfate. The organotin compounds were hexylated using the Grignard reaction given in Krone et al (1989) including the silica gel/alumina cleanup. Analysis was done by capillary Gas Chromatography using Single Ion Monitoring (SIM) mode GC/MS. All samples are reported on a dry weight basis.

HOLDING TIMES:

The samples were stored frozen following PSEP Guidelines until extraction. After extraction all samples were analyzed within the recommended 40 day extract time.

BLANKS:

Some low levels of organo tin compounds were detected in the laboratory blanks. The EPA five times rule was applied to all target compounds which were found in the blank. Compounds that were found in the sample and in the blank were considered real and not the result of contamination if the levels in the sample are greater than or equal to five times the amount of compounds in the associated method blank.

SURROGATES:

Recovery of the surrogate spike, tripropyltin, ranged from 30% to 125% for most of the samples. Two sample dilutions, -268239 DIL1 and -268249 DIL1 had recoveries less than 20%. Since the surrogate recoveries in the undiluted samples were 48% and 76% respectively no qualifiers were added. Several other samples had recoveries greater than 200% due to chromatographic interference with the tripropyltin quantitation ion. No surrogate recovery QC limits have been established for this method and no qualifiers were added due to high surrogate recoveries.

MATRIX SPIKE AND MATRIX SPIKE :

At the request of the project officer only one matrix spike was run with each extraction batch. Consequently no matrix spike duplicate analysis are available. The sample choice for the first matrix spike, -268231, was unfortunate since this sample was very high in native organotin compounds. Consequently no useful recovery information could be obtained even after correction for the native amounts except for the tetrabutyltin recovery of 67%.

Reprocessing the sample as a duplicate sample instead of a matrix spike gives tetrabutyltin, 221 ug/Kg, tributyltin, 7620 ug/kg, dibutyltin 1680 ug/kg and monobutyltin, 143 ug/kg which is comparable to the results for sample -268231.

The second matrix spike sample, -268246, had lower native amounts and recoveries ranged from 75% to 98%. Chromatographic interference with the monobutyltin peak in the matrix spike sample prevented recovery calculation for the monobutyltin and the data was rejected , "REJ". The interference is also the reason for the higher quantitation limit for monobutyltin in sample -268246.

ANALYTICAL COMMENTS:

Some samples had chromatographic interference's with the organotin peaks, particularly monobutyltin.

Nearly all of the samples required dilution to bring the samples within the linear calibration range of the GC/MS . The sample results which are outside the calibration range are flagged "E". The results for the dilution are also reported and are indicated by "DIL1" or "DIL2" after the sample number. The results for the undiluted analysis should be reported except where the "E" flag is used. The result for the corresponding compound in the diluted sample should then be used in place of the "E" flagged compound result.

Two additional samples were analyzed with the sediment samples. This was a Sequim Bay Reference Sediment which presumably was spiked with 100 ng/gm (100 ug/Kg) wet weight of tributyltin. No value for tributyltin has been established for the Sequim Bay Reference Sediment so the accuracy of the analysis cannot be determined. The amounts reported below, although within the observed range for Sequim Bay Reference Sediments for organo tin, are on the low side of the range. These samples are identified as SBR52794 and SBR53642.

SBR52794	35	ug/Kg (wet weight)	Tributyltin	% solids 66.4
SBR53642	43	ug/Kg (wet weight)	Tributyltin	% solids 61.6

Note that the data sheets report these values as dry weight.

DATA QUALIFIER CODES:

U - The analyte was not detected at or above the reported value.

J - The analyte was positively identified. The associated numerical value is an estimate.

UJ - The analyte was not detected at or above the reported estimated result.

REJ - The data are unusable for all purposes.

EXP - The result is equal to the number before EXP times 10 to the power of the number after EXP. As an example 3EXP6 equals 3 X 10^6.

NAF - Not analyzed for.

N - For organic analytes there is evidence the analyte is present in this sample.

NJ - There is evidence that the analyte is present. The associated numerical result is an estimate.

E - This qualifier is used when the concentration of the associated value exceeds the known calibration range.

bold - The analyte was present in the sample. (Visual Aid to locate detected compound on report sheet.)

CN_SALMT.DOC

Table D-1. Results of spiked sample analysis (% recovery).

1. Metals

Sample No.:	8233	8233	RPD	8244	8244	RPD	8261	8261	RPD
Mercury	84	175	-70%	N/A	N/A		N/A	N/A	
Arsenic	N/A	N/A		NC	N/A		NC	N/A	
Lead	N/A	N/A		NC	NC		65	66	-2%
Nickel	N/A	N/A		89	88	1%	79	81	-3%
Cadmium	N/A	N/A		107	85	23%	95	81	16%
Chromium	N/A	N/A		76	77	-1%	69	74	-7%
Copper	N/A	N/A		NC	NC		NC	NC	
Zinc	N/A	N/A		NC	NC		NC	NC	

2. Semivolatile Organics

Sample No.:	8234	8246
4-Nitroaniline	37	52
4-Nitrophenol	99	99
Benzyl Alcohol	73	79
4-Bromophenyl-Phenylether	98	90
2,4-Dimethylphenol	96	86
4-Methylphenol	84	83
1,4-Dichlorobenzene	67	55
4-Chloroaniline	REJ	21
Phenol	84	82
Pyridine	N/A	N/A
Bis(2-Chloroethyl)Ether	76	79
Bis(2-Chloroethoxy)Methane	80	79
Bis(2-Ethylhexyl) Phthalate	75	77
Di-N-Octyl Phthalate	130	120
Hexachlorobenzene	92	87
Anthracene	88	88
1,2,4-Trichlorobenzene	73	69
2,4-Dichlorophenol	81	80
2,4-Dinitrotoluene	74	85
Hydrazine, 1.2-Diphenyl-	N/A	N/A
Pyrene	81	81
Dimethylphthalate	96	92
Dibenzofuran	100	92
Benzo(ghi)perylene	70	110
Indeno(1,2,3-cd)pyrene	100	120
Benzo(b)fluoranthene	69	120
Fluoranthene	88	93
Benzo(k)fluoranthene	110	130
Acenaphthylene	91	87
Chrysene	79	81
3B-Coprostanol	N/A	N/A
Bis(2-Chloroisopropyl)Ether	79	78
Retene	N/A	N/A
Benzo(a)pyrene	74	120
2,4-Dinitrophenol	51	69
4,6-Dinitro-2-Methylphenol	54	75
Dibenzo(a,h)anthracene	120	120
1,3-Dichlorobenzene	63	48
Benzo(a)anthracene	84	85
Caffeine	N/A	N/A
4-Chloro-3-Methylphenol	82	79
2,6-Dinitrotoluene	79	87
N-Nitroso-Di-N-Propylamine	91	250

Sample No.:	8234	8246
Aniline	N/A	N/A
N-Nitrosodimethylamine	N/A	N/A
Benzoic Acid	60	58
Hexachloroethane	26	22
4-Chlorophenyl-Phenylether	97	88
Hexachlorocyclopentadiene	REJ	REJ
Isophorone	76	75
Acenaphthene	97	90
Diethylphthalate	95	87
Di-N-Butylphthalate	96	91
Phenanthrene	87	89
Butylbenzylphthalate	80	81
N-Nitrosodiphenylamine	92	87
Fluorene	96	91
Carbazole	N/A	N/A
Hexachlorobutadiene	73	59
Pentachlorophenol	78	78
2,4,6-Trichlorophenol	98	90
2-Nitroaniline	93	89
2-Nitrophenol	50	73
Naphthalene	76	74
2-Methylnaphthalene	80	75
2-Chloronaphthalene	96	86
3,3'-Dichlorobenzidine	N/A	N/A
Benzidine	N/A	N/A
2-Methylphenol	84	83
1,2-Dichlorobenzene	60	50
2-Chlorophenol	84	84
2,4,5-Trichlorophenol	95	90
Nitrobenzene	68	74
3-Nitroaniline	20	43
Semivolatile Organic Surrogate Recoveries (%)		
D14-Terphenyl	94	77
D10-Pyrene	95	79
1,2-Dichlorobenzene-D4	68	50
2-Fluorobiphenyl	100	87
2-Fluorophenol	80	79
D5-Nitrobenzene	73	73
D5-Phenol	87	82
D4-2-Chlorophenol	84	80

Table D-1 (Cont'd). Results of spiked sample analysis (% recovery).

3. PCBs

Sample No.:	8234	8246
PCB - 1260	89	91
PCB - 1254	N/A	N/A
PCB - 1221	N/A	N/A
PCB - 1232	N/A	N/A
PCB - 1248	N/A	N/A
PCB - 1016	N/A	N/A
PCB - 1242	92	83
PCB Surrogate Recoveries (%)		
4,4-Dibromooctafluorobiphenyl	102	80
Dibutylchlorendate	56	64
Decachlorobiphenyl	90	90
Tetrachloro-m-xylene	100	85

4. Butyltins

Sample No.:	8231	8246
Monobutyltin Chloride	$\boxed{231}$	REJ
Tributyltin Chloride	$\boxed{595}$	75.8
Tetrabutyltin Chloride	67.3	75.7
Dibutyltin Chloride	$\boxed{538}$	97.5
Butyltin Surrogate Recoveries (%)		
Tripopropyltin Chloride	NC	87

RPD=Relative Percent Difference of duplicate analysis
N/A=Not Analyzed
NC=Not Calculated
REJ=Rejected, data are unusable
☐ Outside of acceptable recovery window

Table D-2. Results of check standard and reference material analysis.

1. Metals (% Recovery of Check Standards)

Sample No.:	27052400	27052401	RPD	ERA52387	ERA52389	RPD
Mercury	92	93	-1%	N/A	N/A	
Arsenic	N/A	N/A		122	109	11%
Lead	N/A	N/A		85	85	0%
Nickel	N/A	N/A		91	93	-2%
Cadmium	N/A	N/A		93	93	0%
Chromium	N/A	N/A		81	79	3%
Copper	N/A	N/A		92	91	1%
Zinc	N/A	N/A		85	85	0%

2. Semivolatile Organics (PAH Standard Reference Material NRCC HS-6; µg/Kg, dry)

Sample No.:	HS652431		HS652485		RPD	NRCC HS-6 Certified Values
Anthracene	1000		1100		-10%	1100 ± 400
Pyrene	$\boxed{2300}$		2400		-4%	3000 ± 600
Benzo(ghi)perylene	2100		2200		-5%	1780 ± 720
Indeno(1,2,3-cd)pyrene	2400		2500		-4%	1950 ± 580
Benzo(b)fluoranthene	$\boxed{4100}$		$\boxed{4600}$		-11%	2800 ± 600
Fluoranthene	3400		3600		-6%	3540 ± 650
Benzo(k)fluoranthene	$\boxed{1900}$		$\boxed{1900}$		0%	1430 ± 150
Acenaphthylene	$\boxed{550}$		$\boxed{580}$		-5%	190 ± 50
Chrysene	2000		2100		-5%	2000 ± 300
Benzo(a)pyrene	2100		2200		-5%	2200 ± 400
Dibenzo(a,h)anthracene	650	J	$\boxed{660}$	J	-2%	490 ± 160
Benzo(a)anthracene	$\boxed{1400}$		$\boxed{1400}$		0%	1800 ± 300
Acenaphthene	160	J	170	J	-6%	230 ± 70
Phenanthrene	3000		3200		-6%	3000 ± 600
Fluorene	470		460		2%	470 ± 120
Naphthalene	3400		3600		-6%	4100 ± 1100
Semivolatile Surrogate Recoveries (%)						
D14-Terphenyl	83		80		4%	
D10-Pyrene	82		83		-1%	
1,2-Dichlorobenzene-D4	68		64		6%	
2-Fluorobiphenyl	93		97		-4%	
2-Fluorophenol	82		87		-6%	
D5-Nitrobenzene	75		80		-6%	
D5-Phenol	85		90		-6%	
D4-2-Chlorophenol	83		87		-5%	

3. PCBs (Standard Reference Material NRCC HS-2; µg/Kg, dry)

Sample No.:	HS252430	HS252484	RPD	NRCC HS-6 Certified Values
PCB - 1254	110	113	-3%	111.8 ± 2.5
PCB Surrogate recoveries (%)				
4,4-Dibromooctafluorobiphenyl	123	105	16%	
Dibutylchlorendate	44	70	-46%	
Decachlorobiphenyl	129	101	24%	
Tetrachloro-m-xylene	102	100	2%	

4. Butyltins (Sequim Bay Reference Sediment [SBRS]; µg/Kg, wet)

Sample No.:	SBR52794	SBR53642	RPD	SBRS Reported Value*
Tributyltin Chloride	35	43	-21%	100
Butyltin Surrogate Recoveries (%)				
Tripropyltin Chloride	152	62	84%	

RPD=Relative Percent Difference of duplicate analysis

N/A=Not Analyzed

J=Estimated concentration

☐ Outside certified range of values

*No value for tributyltin has been established for this material

Table D-3. Analytical results of split field samples.

Station:	1A					8C				
Sample No.:	8230		8260		RPD	8258		8261		RPD
1. Conventionals										
% TOC (dry)	8.1		8.7		-7%	6.7		6.4		5%
% Solids	31.6		32.8		-4%	28.5		23.6		19%
% Gravel (>2000µm)	1		2		-67%	2		0		200%
% Sand (2000-63µm)	34		37		-8%	19		19		0%
% Silt (62-4µm)	45		44		2%	60		63		-5%
% Clay (<4µm)	20		17		16%	19		18		5%
2. Metals (mg/Kg, dry)										
Arsenic	38.5		44.9		-15%	34.5		33.2		4%
Mercury	2.3	J	2.2	J	2%	1.3	J	1.7	J	-25%
Lead	441		385	N	14%	298	N	297	N	0%
Nickel	44.6		46.6		-4%	64.8		63.5		2%
Cadmium	1.3	P	1.7	P	-27%	2.2	P	1.7	P	26%
Chromium	60.7		61.8	N	-2%	80.8	N	80.4	N	0%
Copper	317		330		-4%	702		663		6%
Zinc	530		501		6%	778		776		0%
3. Semivolatile Organics (µg/Kg, dry)										
4-Methylphenol	1700		1800		-6%	820		930		-13%
Phenol	250	UJ	340		-31%	270		240	J	12%
Bis(2-Ethylhexyl) Phthalate	340	UJ	480	UJ		6700		6800		-1%
Anthracene	1200		1400		-15%	1100		990		11%
Pyrene	9100		11000		-19%	4200		4300		-2%
Dimethylphthalate	190	U	200	U		170	J	190	J	-11%
Dibenzofuran	570		720		-23%	400		590		-38%
Benzo(ghi)perylene	3400		3300		3%	1900		2100		-10%
Indeno(1,2,3-cd)pyrene	2800		2700		4%	1800		1900		-5%
Benzo(b)fluoranthene	4700		4500		4%	3300		3500		-6%
Fluoranthene	11000		13000		-17%	5400		5600		-4%
Benzo(k)fluoranthene	1600		1800		-12%	1400		1300		7%
Acenaphthylene	740		850		-14%	270		330		-20%
Chrysene	2700		2900		-7%	2200		2200		0%
3B-Coprostanol	3700	UJ	4000	UJ		11000	J	12000	J	-9%
Retene	1100		1500		-31%	960		960		0%
Benzo(a)pyrene	3700		3800		-3%	2200		2300		-4%
Dibenzo(a,h)anthracene	550	J	520	J	6%	450	J	420	J	7%
Benzo(a)anthracene	2000		2100		-5%	1400		1400		0%
Benzoic Acid	3700	UJ	410	J		480	J	600	J	-22%
Acenaphthene	1200		1700		-34%	510		580		-13%
Phenanthrene	4800		6400		-29%	3600		4600		-24%
Butylbenzylphthalate	930	U	990	U		190	J	330	J	-54%
Fluorene	1200		1600		-29%	690		910		-28%
Carbazole	190	U	200	U		340		250	U	31%
Naphthalene	2500		3000		-18%	620		1100		-56%
2-Methylnaphthalene	650		890		-31%	300		450		-40%
Semivolatile Surrogate Recoveries (%)										
D14-Terphenyl	72		79		-9%	75		78		-4%
D10-Pyrene	77		80		-4%	76		80		-5%
1,2-Dichlorobenzene-D4	53		61		-14%	39		59		-41%
2-Fluorobiphenyl	94		100		-6%	88		95		-8%
2-Fluorophenol	86		81		6%	77		79		-3%
D5-Nitrobenzene	54		58		-7%	32		35		-9%
D5-Phenol	90		82		9%	81		82		-1%
D4-2-Chlorophenol	88		83		6%	81		85		-5%

Table D-3 (Cont'd). Analytical results of split field samples.

Station:	1A					8C			
Sample No.:	8230		8260		RPD	8258		8261	RPD
4. PCBs (µg/Kg, dry)									
PCB - 1260	200		300		-40%	420		370	13%
PCB - 1254	250		250		0%	480		500	-4%
PCB Surrogate Recoveries (%)									
4,4-Dibromooctafluorobiphenyl	95		107		-12%	123		124	-1%
Dibutylchlorendate	65		53		20%	35		34	3%
Decachlorobiphenyl	112		119		-6%	123		127	-3%
Tetrachloro-m-xylene	94		105		-11%	124		124	0%
5. Butyltins (µg/Kg, dry)									
Monobutyltin Chloride	9	U	168		-180%	2030		1040	64%
Tributyltin Chloride	324		404		-22%	656		3130	-131%
Tetrabutyltin Chloride	9.4	U	9.3	U		15	U	46	-102%
Dibutyltin Chloride	9.1	U	20		-75%	77		827	-166%
Butyltin Surrogate Recoveries (%)									
Tripropyltin Chloride	56		89		-46%	248		101	84%

RPD=Relative Percent Difference
J=Estimated concentration
N=Low matrix spike recoveries associated with this result
P=The analyte was detected below the minimum quantitation limit
U=The analyte was not detected at or above the value shown

Table D-4 Results of laboratory blank analysis.

1. Metals (mg/Kg, dry)

Sample No.:	BLN52402	BLN52403	BLN52386	BLN52388
Mercury	0.005	0.005	N/A	N/A
Arsenic	N/A	N/A	0.3 U	0.3 U
Lead	N/A	N/A	2 U	2 U
Nickel	N/A	N/A	1 U	1 U
Cadmium	N/A	N/A	0.3 U	0.3 U
Chromium	N/A	N/A	0.5 U	0.5 U
Copper	N/A	N/A	0.62 P	1.3 P
Zinc	N/A	N/A	0.66 P	0.49 P

2. Semivolatile Organics (µg/Kg, dry)

Sample No.:	BLN52428	BLN52429	BLN52482	BLN52483
4-Nitroaniline	840 U	840 U	840 U	840 U
4-Nitrophenol	840 U	840 U	840 U	840 U
Benzyl Alcohol	170 U	170 U	170 U	170 U
4-Bromophenyl-Phenylether	170 U	170 U	170 U	170 U
2,4-Dimethylphenol	170 U	170 U	170 U	170 U
4-Methylphenol	170 U	170 U	170 U	170 U
1,4-Dichlorobenzene	170 U	170 U	170 U	170 U
4-Chloroaniline	170 U	170 U	170 U	170 U
Phenol	100 J	82 J	170 U	170 U
Pyridine	840 U	840 U	840 U	840 U
Bis(2-Chloroethyl)Ether	170 U	170 U	170 U	170 U
Bis(2-Chloroethoxy)Methane	170 U	170 U	170 U	170 U
Bis(2-Ethylhexyl) Phthalate	63 J	140 J	59 J	40 J
Di-N-Octyl Phthalate	840 U	840 U	840 U	840 U
Hexachlorobenzene	170 U	170 U	170 U	170 U
Anthracene	170 U	170 U	170 U	170 U
1,2,4-Trichlorobenzene	170 U	170 U	170 U	170 U
2,4-Dichlorophenol	170 U	170 U	170 U	170 U
2,4-Dinitrotoluene	840 U	840 U	840 U	840 U
Hydrazine, 1,2-Diphenyl-	170 U	170 U	170 U	170 U
Pyrene	170 U	170 U	170 U	170 U
Dimethylphthalate	170 U	170 U	170 U	170 U
Dibenzofuran	170 U	170 U	170 U	170 U
Benzo(ghi)perylene	170 U	170 U	170 U	170 U
Indeno(1,2,3-cd)pyrene	170 U	170 U	170 U	170 U
Benzo(b)fluoranthene	170 U	170 U	170 U	170 U
Fluoranthene	170 U	170 U	170 U	170 U
Benzo(k)fluoranthene	170 U	170 U	170 U	170 U
Acenaphthylene	170 U	170 U	170 U	170 U
Chrysene	170 U	170 U	170 U	170 U
3B-Coprostanol	3400 UJ	3400 UJ	3400 UJ	3400 UJ
Bis(2-Chloroisopropyl)Ether	170 U	170 U	170 U	170 U
Retene	170 U	170 U	170 U	170 U
Benzo(a)pyrene	170 U	170 U	170 U	170 U
2,4-Dinitrophenol	6700 UJ	6700 UJ	6700 UJ	6700 UJ
4,6-Dinitro-2-Methylphenol	3400 U	3400 U	3400 U	3400 U
Dibenzo(a,h)anthracene	170 UJ	170 UJ	170 UJ	170 UJ
1,3-Dichlorobenzene	170 U	170 U	170 U	170 U
Benzo(a)anthracene	170 U	170 U	170 U	170 U
Caffeine	170 U	170 U	170 U	170 U
4-Chloro-3-Methylphenol	170 U	170 U	170 U	170 U
2,6-Dinitrotoluene	840 U	840 U	840 U	840 U
N-Nitroso-Di-N-Propylamine	170 U	170 U	170 U	170 U
Aniline	170 U	170 U	170 U	170 U
N-Nitrosodimethylamine	840 UJ	840 UJ	840 UJ	840 UJ
Benzoic Acid	120 J	3400 UJ	3400 UJ	3400 UJ
Hexachloroethane	170 U	170 U	170 U	170 U
4-Chlorophenyl-Phenylether	170 U	170 U	170 U	170 U
Hexachlorocyclopentadiene	3400 UJ	3400 UJ	3400 UJ	3400 UJ
Isophorone	170 U	170 U	170 U	170 U
Acenaphthene	170 U	170 U	170 U	170 U
Diethylphthalate	140 J	42 J	170 U	170 U
Di-N-Butylphthalate	1200	160 J	87 J	170 U

Table D-4 (Cont'd). Results of laboratory blank analysis.

2. Semivolatile Organics (µg/Kg, dry)

Sample No.:	BLN52428	BLN52429	BLN52482	BLN52483
Phenanthrene	170 U	170 U	170 U	170 U
Butylbenzylphthalate	840 U	840 U	840 U	840 U
N-Nitrosodiphenylamine	170 U	170 U	170 U	170 U
Fluorene	170 U	170 U	170 U	170 U
Carbazole	170 U	170 U	170 U	170 U
Hexachlorobutadiene	170 U	170 U	170 U	170 U
Pentachlorophenol	840 U	840 U	840 U	840 U
2,4,6-Trichlorophenol	340 U	340 U	340 U	340 U
2-Nitroaniline	340 U	340 U	340 U	340 U
2-Nitrophenol	170 U	170 U	170 U	170 U
Naphthalene	170 U	170 U	170 U	170 U
2-Methylnaphthalene	170 U	170 U	170 U	170 U
2-Chloronaphthalene	170 U	170 U	170 U	170 U
3,3'-Dichlorobenzidine	340 U	340 U	340 U	340 U
Benzidine	340 UJ	340 UJ	340 UJ	340 UJ
2-Methylphenol	170 U	170 U	170 U	170 U
1,2-Dichlorobenzene	170 U	170 U	170 U	170 U
2-Chlorophenol	170 U	170 U	170 U	170 U
2,4,5-Trichlorophenol	170 U	170 U	170 U	170 U
Nitrobenzene	170 U	170 U	170 U	170 U
3-Nitroaniline	840 U	840 U	840 U	840 U
Semivolatile Organic Surrogate Recoveries (%)				
D14-Terphenyl	82	80	80	82
D10-Pyrene	79	77	78	81
1,2-Dichlorobenzene-D4	70	73	71	73
2-Fluorobiphenyl	95	94	93	98
2-Fluorophenol	74	78	80	88
D5-Nitrobenzene	69	65	72	74
D5-Phenol	86	87	87	93
D4-2-Chlorophenol	81	82	85	92

3. PCBs (µg/Kg, dry)

Sample No.:	BLN52428	BLN52429	BLN52482	BLN52483
PCB - 1260	34 U	34 U	34 U	34 U
PCB - 1254	34 U	34 U	34 U	34 U
PCB - 1221	34 U	34 U	34 U	34 U
PCB - 1232	34 U	34 U	34 U	34 U
PCB - 1248	34 U	34 U	34 U	34 U
PCB - 1016	34 U	34 U	34 U	34 U
PCB - 1242	34 U	34 U	34 U	34 U
PCB Surrogate Recoveries (%)				
4,4-Dibromooctafluorobiphenyl	91	92	85	97
Dibutylchlorendate	55	54	52	62
Decachlorobiphenyl	107	101	102	106
Tetrachloro-m-xylene	95	92	85	95

4. Butyltins (µg/Kg, dry)

Sample No.:	BLN52792	BLN52793	BLN53640	BLN53641	BLN54110
Monobutyltin Chloride	7 U	7 U	0.4 J	7 U	0.7 J
Tributyltin Chloride	2.9 J	7.6 U	2.4 J	1.6 J	2.2 J
Tetrabutyltin Chloride	7.4 U	7.4 U	7.4 U	7.4 U	7.4 U
Dibutyltin Chloride	7.1 U	7.1 U	0.49 J	7.1 U	0.98 J
Butyltin Surrogate Recoveries (%)					
Tripropyltin Chloride	36	50	56	60	53

☐ Analyte was detected in laboratory blank

N/A=Not Analyzed

U=The analyte was not detected at or above the value shown

P=Analyte was detected below the numerical quantitation limit

J=Estimated concentration

APPENDIX E

CHEMICAL CONCENTRATIONS IN SEDIMENTS

Table E-1. Concentration of metals in sediments (mg/Kg, dry).

Station	As	Hg	Pb	Ni	Cd	Cr	Cu	Zn
1A	42	2.2 J	413 N	46	1.5 P	61 N	324	516
1B	210	5.0 J	534	60	3.2	99	2000	2020
1C	28	1.1 J	208	80	1.2 P	101	629	492
2A	20	0.63 J	107	44	0.40 P	51	358	311
2B	5.0	0.11 J	151	26	0.59 P	18	88	225
2C	34	0.61 J	131	46	0.62 P	53	268	646
3A	9.5	0.26 J	66	33	0.30 U	35	92	147
3B	44	1.8 J	314	66	1.2 P	88	318	619
3C	32	1.0 J	193	52	0.69 P	68	539	462
4A	18	1.5 J	137	63	0.42 P	75	354	319
4B	31	1.1 J	219	94	0.88 P	114	565	459
4C	5.7	0.18 J	29	44	0.30 U	36	85	136
4D	10	0.65 J	100	38	0.30 U	37	207	206
4E	24	1.6 J	250	68	1.3 P	79	436	562
4F	83	4.0 J	444	49	1.7 P	65	1230	921
5A	39	0.86 J	175 N	48	0.81 P	62 N	340	388
5B	1.6	0.01 J	3.5 J	22	0.30 U	14 N	7.7	27
5C	19	0.77 J	147 N	72	0.64 P	70 N	310	302
6A	13	0.78 J	190 N	56	1.6 P	60 N	246	403
6B	41	0.18 J	75 N	484	1.8 P	376 N	2210	207
6C	10	0.42 J	65 N	42	0.49 P	40 N	128	183
6D	24	0.71 J	101 N	56	0.56 P	50 N	244	283
7A	83	0.77 J	254 N	46	1.2 P	63 N	709	1140
7B	18	0.052 J	37 N	62	0.33 P	52 N	107	210
7C	6.2	0.071 J	169 N	30	0.45 P	24 N	53	100
7D	6.8	0.097 J	41 N	29	0.30 U	25 N	335	185
8A	19	0.91 J	186 N	41	1.0 P	48 N	197	350
8B	9.8	0.35 J	146 N	33	0.48 P	30 N	88	205
8C	34	1.5 J	298 N	64	2.0 P	81 N	682	777

J=Estimated concentration
N=Low matrix spike recoveries associated with this result
P=The analyte was detected below the minimum quantitation limit
U=The analyte was not detected at or above the value shown

Table E-2. Semivolatile organics not detected in sediments.

Compound	Quantitation Limits (µg/Kg)
4-Nitroaniline	490 - 1600
4-Nitrophenol	490 - 1600
4-Bromophenyl-Phenylether	97 - 320
2,4-Dimethylphenol	97 - 320
4-Chloroaniline	97 - 320
Pyridine	490 - 1600
Bis(2-Chloroethyl)Ether	97 - 320
Bis(2-Chloroethoxy)Methane	97 - 320
Di-N-Octyl Phthalate	97 - 1600
Hexachlorobenzene	97 - 320
1,2,4-Trichlorobenzene	97 - 320
2,4-Dichlorophenol	97 - 320
2,4-Dinitrotoluene	490 - 1600
Hydrazine, 1,2-Diphenyl-	97 - 320
Bis(2-Chloroisopropyl)Ether	97 - 320
2,4-Dinitrophenol	3900 - 13000
4,6-Dinitro-2-Methylphenol	1900 - 6400
1,3-Dichlorobenzene	97 - 320
Caffeine	97 - 320
4-Chloro-3-Methylphenol	97 - 320
2,6-Dinitrotoluene	490 - 1600
N-Nitroso-Di-N-Propylamine	97 - 320
Aniline	97 - 320
N-Nitrosodimethylamine	490 - 1600
Hexachloroethane	97 - 320
4-Chlorophenyl-Phenylether	97 - 320
Hexachlorocyclopentadiene	2100 - 6400
Isophorone	97 - 320
Di-N-Butylphthalate	97 - 1200
N-Nitrosodiphenylamine	97 - 320
Hexachlorobutadiene	97 - 320
2,4,6-Trichlorophenol	190 - 640
2-Nitroaniline	190 - 640
2-Nitrophenol	97 - 320
2-Chloronaphthalene	97 - 320
3,3'-Dichlorobenzidine	190 - 640
Benzidine	190 - 640
2-Methylphenol	97 - 320
1,2-Dichlorobenzene	97 - 320
2-Chlorophenol	97 - 320
2,4,5-Trichlorophenol	97 - 320
Nitrobenzene	97 - 320
3-Nitroaniline	490 - 1600

Table E-3. Concentration of PAHs and other semivolatile organics detected in sediments (µg/Kg, dry).

Station	Pyrene	Benzo(ghi)perylene	Indeno(1,2,3-cd)pyrene	Benzo(b)fluoranthene	Fluoranthene	Benzo(k)fluoranthene	Chrysene	Benzo(a)pyrene	Dibenzo(a,h)anthracene	Benzo(a)anthracene	Anthracene	Acenaphthylene	Acenaphthene	Phenanthrene	Fluorene	Naphthalene	2-Methylnaphthalene	Benzyl Alcohol
1A	10050	3350	2750	4600	12000	1700	2800	3750	535 J	2050	1300	795	1450	5600	1400	2750	770	190 U
1B	11000	4500	4800	8900	14000	3700	5900	6200	1100 J	4800	2100	300	1000	7200	1300	880	650	240 U
1C	3500	2600	2300	3700	3800	1300	1900	2700	490 J	1300	650	320	280	1800	440	740	260	240 U
2A	4700	1600	1600	3200	6000	1100	1700	2300	350 J	1700	760	270	560	1900	560	810	350	180 U
2B	3400	1500	1700	3200	4300	1200	1900	2300	350 J	1500	600	44 J	190	2500	280	64 J	64 J	300
2C	2600	1300	1200	2000	3000	750	1200	1500	250 J	830	660	330	320	2200	540	1000	310	240
3A	370	370	330	510	360	190	220	390	71 J	170	77 J	44 J	24 J	170	40 J	72 J	25 J	130
3B	4600	2800	2600	4400	4600	1400	2400	3500	540 J	1900	900	710	320	2600	510	1400	370	420
3C	2800	1900	1800	3400	3200	1100	1700	2300	350 J	1300	600	240	220 J	1500	290	510	170 J	420
4A	2800	2400	2100	3000	3100	1100	1500	2400	400 J	1200	610	280	240	1300	320	590	240	410
4B	5300	2000	2000	4200	6900	1400	3600	2800	430 J	2100	1100	420	510	3600	870	1200	510	680
4C	1500	320	310	740	2200	270	550	490	67 J	490	180	56 J	92 J	430	170	130	55 J	120
4D	3800	1200	1000 J	1900	4000	750	1300	1600	200 J	970	780	460	540	3000	740	1800	760	180
4E	3400	2500	2200 J	3500	3700	1400	2000	2600	460 J	1300	860	430	300 J	1800	500	950	340	470
4F	11000	4900	4600 J	8800	13000	3000	5800	6300	1000 J	4500	3100	1100	2000	9300	2700	3100	1800	1000
5A	6700	2500	2500 J	5700	8600	2500	3300	3800	640 J	2700	770	300	490	3700	560	1200	390	410
5B	25 J	97 U	97 U	97 U	25 J	97 U	97 U	97 U	97 U	97	8.1 J	9.6 J	97 U	39 J	97 U	97 U	97 U	24 J
5C	5600	1200	1000 J	2400	6000	800	2000	1800	250 U	1900	1300	1000	1300	4800	1400	3900	1600	250 U
6A	5600	2000	1700 J	3700	6500	1300	2800	2500	370 J	1600	1100	620	700	4600	950	2600	1200	150 J
6B	1500	510	420 J	830	1600	290	720	630	130 U	470	340	110 J	290	1600	390	320	180	130 U
6C	3200	870	640 J	1300	3500	460	1100	1100	91 J	660	820	500	1000	3500	1000	2600	1000	210 U
6D	3900	1400	1200 J	2800	4900	1100	2000	2100	270 J	1600	970	440	1000	3700	1300	2000	800	300 U
7A	4500	1600	1600 J	3400	5700	1500	2600	2700	370 J	2000	990	180	520	3700	650	590	270	180 U
7B	2800	990	1100 J	2200	4300	900	1500	1700	290 J	1200	720	39 J	460	4200	600	140	150	120 U
7C	350	180	190 J	360	390	130	250	320	54 J	210	64 J	26 J	26 J	160	31 J	39 J	22 J	110 U
7D	670	330	300 J	560	820	220	390	470	65 J	320	140	50 J	80 J	330	75 J	93 J	56 J	110 U
8A	4400	1500	1300 J	3000	6100	1100	2200	2000	290	1700	1100	320	800	2700	1200	2200	470	170 U
8B	1200	300	270	610	1600	250	490	420	64 J	370	290	120	660	1600	570	420	280	50 J
8C	4250	2000	1850	3400	5500	1350	2200	2250	435 J	1400	1045	300	545	4100	800	860	375	110 J

J=Estimated concentration

U=The analyte was not detected at or above the value shown

Table E-3 (Cont'd). Concentration of PAHs and other semivolatile organics detected in sediments (µg/Kg, dry).

Station	4-Methylphenol	1,4-Dichlorobenzene	Phenol	Bis(2-EH) Phthalate	Dimethylphthalate	Dibenzofuran	3B-Coprostanol	Retene	Benzoic Acid	Diethylphthalate	Butylbenzylphthalate	Carbazole	Pentachlorophenol
1A	1750	150 J	232 J	340 UJ	190 U	645	3700 UJ	1300	410 J	190 U	930 U	190 U	930 U
1B	830	420	243 UJ	14000	240 U	840	51000 J	3500	1220 UJ	240 U	390 J	620	1200 U
1C	340	16 J	240 UJ	5100	280	280	6000 J	9700	1200 UJ	240 U	180 J	180 J	1200 U
2A	580	180 U	182 UJ	2700	230	480	3300 J	580	913 UJ	180 U	910 U	170 J	910 U
2B	93 J	110	100 UJ	3300	71 J	130	5700 J	150	500 UJ	100 UJ	290 J	320	500 U
2C	330	200 U	200 UJ	2100	160 J	370	5100 J	1200	1000 UJ	200 U	1000 U	120 J	1000 U
3A	110 U	110 U	108 UJ	538 UJ	110 U	32 J	1100 J	63 J	538 UJ	110 U	540 U	110 U	540 U
3B	900	240 U	241 UJ	1200 UJ	160 J	330	4800 UJ	600	1210 UJ	240 U	1200 U	240 U	1200 U
3C	200 J	220 U	219 UJ	3200	190 J	220	6800 J	720	1100 UJ	220 U	1100 U	220 U	1100 U
4A	190 J	220 U	224 UJ	3200	210 J	260	8200 J	1500	1120 UJ	220 U	1100 U	220 U	1100 U
4B	560	230 U	231 UJ	5100	230	540	8700 J	4200	1150 UJ	230 U	170 J	230 U	340 J
4C	41 J	110 U	109 UJ	1600	42 J	95 J	1300 J	140	2200 UJ	110 U	550 U	110 U	550 U
4D	930	180 U	210 UJ	1200 UJ	60 J	400	4200	2800	3500 UJ	176 UJ	880 U	130 J	880 U
4E	310 J	320 U	319 UJ	4100	340	350	6300 J	720	1590 UJ	320 U	1600 U	320 U	1600 U
4F	1100	190 U	200 UJ	3500	310	1400	5900	5400	960 UJ	190 U	160 J	510	960 U
5A	510	170 U	169 UJ	2100	85 J	380	2800 J	480	846 UJ	170 U	76 J	420	850 U
5B	97 U	97 U	37 J	97 UJ	97 U	6.8 J	1900 U	22 J	26 J	96 J	490 U	97 U	490 U
5C	2600	250 U	290	1800	190 J	700	3000 J	52000	380 J	250 U	1200 U	250	1200 U
6A	2700	280 U	320	12000	280 U	620	7900	11000	450 J	280 U	620 J	400	1400 U
6B	300	130 U	110 J	1700	130 U	240	8900	780	2500 UJ	130 U	130 J	130 U	630 U
6C	1600	210 U	180 J	1400	210 U	790	2700 J	74000 J	190 J	210 U	1100 U	210 U	1100 U
6D	900	300 U	220 J	2000	140 J	790	3300 J	8100	300 J	300 U	1500 U	170 J	1500 U
7A	220	180 U	210	2100	140 J	380	2500 J	650	170 J	77 J	900 U	280	900 U
7B	120 U	120 U	200	1300	120 U	370	2400 U	71 J	68 J	44 J	590 U	400	590 U
7C	110 U	110 U	110 U	210 UJ	110 U	19 J	2100 U	26 J	2100 U	110 U	530 U	110 U	530 U
7D	110 U	110 U	55 J	430 J	110 U	41 J	2100 U	60 J	100 J	110 U	130 J	110 U	530 U
8A	360	170 U	130 J	4100	170 U	710	1900 J	760	220 J	170 U	99 J	180	840 U
8B	430	110 U	79 J	730	110 U	390	2900 J	320	2200 UJ	40 J	35 J	62 J	550 U
8C	875	240 U	240 J	6750	180 J	495	11500 J	960	540 J	240 U	260 J	232 J	220 J

J=Estimated concentration

U=The analyte was not detected at or above the value shown

Table E-4. Concentration of PAHs in sediments.

Station	Total HPAH[1] (µg/Kg, dry)	mg HPAH/Kg OC	Total LPAH[2] (µg/Kg, dry)	mg LPAH/Kg OC	TOTAL PAHs[3] (µg/Kg, dry)	mg TOTAL PAH/Kg OC
1A	43585 J	519 JH	13295	158	56880 J	677 JH
1B	64900 J	969 JH	12780	191	77680 J	1159 JH
1C	23590 J	407 JH	4230	73	27820 J	480 JH
2A	24250 J	418 JH	4860	84	29110 J	502 JH
2B	21350 J	1941 JH	3678 J	334 JH	25028 J	2275 JH
2C	14630 J	236 JH	5050	81	19680 J	317 JH
3A	2981 J	157 JH	427 J	22 JH	3408 J	179 JH
3B	28740 J	479 JH	6440	107	35180 J	586 JH
3C	19850 J	368 JH	3360 J	62 JH	23210 J	430 JH
4A	20000 J	417 JH	3340	70	23340 J	486 JH
4B	30730 J	439 JH	7700	110	38430 J	549 JH
4C	6937 J	434 JH	1058 J	66 JH	7995 J	500 JH
4D	16720 J	315 JH	7320	138	24040 J	454 JH
4E	23060 J	391 JH	4840 J	82 JH	27900 J	473 JH
4F	62900 J	939 JH	21300	318	84200 J	1257 JH
5A	38940 J	1145 JH	7020	206	45960 J	1352 JH
5B	50 J	50 JH	57 J	57 JH	107 J	107 JH
5C	22700 J	166 JH	13700	100	36400 J	266 JH
6A	28070 J	202 JH	10570	76	38640 J	278 JH
6B	6970 J	303 JH	3050 J	133 JH	10020 J	436 JH
6C	12921 J	150 JH	9420	110	22341 J	260 JH
6D	21270 J	197 JH	9410	87	30680 J	284 JH
7A	25970 J	499 JH	6630	128	32600 J	627 JH
7B	16980 J	1415 JH	6159 J	513 JH	23139 J	1928 JH
7C	2434 J	348 JH	346 J	49 JH	2780 J	397 JH
7D	4145 J	518 JH	768 J	96 JH	4913 J	614 JH
8A	23590 J	605 JH	8320	213	31910 J	818 JH
8B	5574 J	429 JH	3660	282	9234 J	710 JH
8C	24635 J	373 JH	7650	116	32285 J	489 JH

[1] Sum of Pyrene, Benzo(g,h,i)perylene, Indeno(1,2,3-c,d)pyrene, Benzo(b)fluoranthene, Fluoranthene, Benzo(k)fluoranthene, Chrysene, Benzo(a)pyrene, Dibenzo(a,h)anthracene, and Benzo(a)anthracene

[2] Sum of Anthracene, Acenaphthylene, Acenaphthene, Phenanthrene, Fluorene, and Naphthalene

[3] Sum of HPAH and LPAH

OC=Organic Carbon

J=Estimated concentration

H=Result may be biased due to excessive holding time for TOC

Table E-5. Concentration of PCBs in sediments (µg/Kg, dry).

Station	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	TOTAL PCBs	mg TOTAL PCB/Kg OC
1A	93 U	93 U	93 U	93 U	93 U	250	150	400	4.8 H
1B	120 U	120 U	120 U	160	120 U	800	500	1460	22 H
1C	120 U	120 U	120 U	120 U	120 U	410 J	450	860 J	15 JH
2A	91 U	91 U	91 U	91 U	91 U	200	190 J	390 J	6.7 JH
2B	50 U	50 U	50 U	50 U	50 U	52	50 U	52	4.7 H
2C	100 U	100 U	100 U	100 U	100 U	140	100 U	140	2.3 H
3A	54 U	54 U	54 U	54 U	54 U	54 U	54 U	nd	nd
3B	120 U	120 U	120 U	120 U	120 U	110 J	120 U	110 J	1.8 JH
3C	110 U	110 U	110 U	110 U	110 U	240	180	420	7.8 H
4A	110 U	110 U	110 U	110 U	110 U	210	150	360	7.5 H
4B	115 U	115 U	115 U	115 U	115 U	280	220 J	500 J	7.1 JH
4C	55 U	55 U	55 U	55 U	55 U	52 J	55 U	52 J	3.3 JH
4D	88 U	88 U	88 U	88 U	88 U	130	100	230	4.3 H
4E	160 U	160 U	160 U	160 U	160 U	490	380	870	15 H
4F	96 U	96 U	96 U	96 U	96 U	630	920	1550	23 H
5A	85 U	85 U	85 U	85 U	85 U	210	150	360	11 H
5B	48 U	48 U	48 U	48 U	48 U	48 U	48 U	nd	nd
5C	120 U	120 U	120 U	120 U	120 U	350	120 U	350	2.6 H
6A	140 U	140 U	140 U	140 U	140 U	260 J	140 U	260 J	1.9 JH
6B	63 U	63 U	63 U	63 U	63 U	110	63 U	110	4.8 H
6C	60 U	60 U	60 U	60 U	60 U	120	60 U	120	1.4 H
6D	150 U	150 U	150 U	150 U	150 U	200	150 U	200	1.9 H
7A	90 U	90 U	90 U	90 U	90 U	9000 U	7600	7600	146 H
7B	59 U	59 U	59 U	59 U	59 U	190	59 U	190	16 H
7C	53 U	53 U	53 U	53 U	53 U	53 U	53 U	nd	nd
7D	53 U	53 U	53 U	53 U	53 U	36 J	53 U	36 J	4.5 JH
8A	84 U	84 U	84 U	84 U	84 U	180	130	310	7.9 H
8B	55 U	55 U	55 U	55 U	55 U	62	55 U	62	4.8 H
8C	120 U	120 U	120 U	120 U	120 U	490	395	885	13 H

OC=Organic Carbon

U=The analyte was not detected at or above the value shown

H=Result may be biased due to excessive holding time for TOC

J=Estimated concentration

nd=not detected

Table E-6. Concentration of butyltins in sediments (μg/Kg, dry).

Station	Monobutyltin Chloride	Dibutyltin Chloride	Tributyltin Chloride	Tetrabutyltin Chloride	TOTAL BUTYLTIN CHLORIDES	Tributyltin Chloride as Sn	Tributyltin Chloride as TBT^{+}
1A	86 J	12 J	364	9.3 U	462 J	133	324
1B	199 J	1380	7260	185 J	9024 J	2648	6461
1C	26	163	516	22	727	188	459
2A	158	455	1070	25	1708	390	952
2B	4.7 U	2.6 J	71	5 U	74 J	26	63
2C	60	225	537	17	839	196	478
3A	166	82	179	1.6 J	429 J	65	159
3B	83	72	295	17	467	108	263
3C	32	283	1390	32	1737	507	1237
4A	19	41	110	20	190	40	98
4B	30	450	1520	37	2037	554	1353
4C	9.5	27	87	7.9 U	124	32	77
4D	24	59	195	9.2 U	278	71	174
4E	428	387	1080	17	1912	394	961
4F	57	1170	2830	71	4128	1032	2519
5A	562	178	1040	9 J	1789 J	379	926
5B	540 UJ	5.7 U	6.1 UJ	5.9 U	nd	nd	nd
5C	57	261	535	23	876	195	476
6A	1180 UJ	250	540	7.2 J	797 J	197	481
6B	31	75	287	8.2 U	393	105	255
6C	69	24	80	13 U	173	29	71
6D	131	174	366	20 U	671	134	326
7A	135	130	577	9.8 J	852 J	210	514
7B	50	7 U	78	7.3 U	128	28	69
7C	17	58	78	6.5 U	153	28	69
7D	285	65	141	6.9 U	491	51	125
8A	734	456	2260	11	3461	824	2011
8B	86	22	91	12	211	33	81
8C	1535	452	1893	27 J	3907 J	690	1685

J=Estimated concentration

U=The analyte was not detected at or above the value shown

nd=not detected