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Reconnaissance Survey of Inner Shelton Harbor Sediments

Chemical Screening of Nearshore Sites and Evaluation of Wood Waste Distribution

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Reconnaissance Survey of Inner Shelton Harbor Sediments

Chemical Screening of Nearshore Sites and Evaluation of Wood Waste Distribution

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Washington State Department of Ecology

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Water Body Numbers:

WA-14-0100 (Hammersley Inlet)
WA-14-0110 (Oakland Bay)
WA-14-0050 (Shelton Harbor Inner)

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Abstract

A screening level survey of sediment quality in inner Shelton Harbor was conducted in May 1999. The primary objectives of this investigation were to (1) evaluate contaminant levels (metals and organics) near potential sources and (2) estimate the distribution of wood waste in subtidal sediments.

Ten nearshore stations were sampled for chemical screening analysis. An additional 37 subtidal stations were sampled to evaluate and quantify the distribution of wood debris. Field observations, digital photos, and towed underwater video were used to qualitatively assess the distribution of wood in the inner harbor.

Concentrations of both metals and organics were relatively low at the nearshore sites evaluated for chemical contamination. Most of the contamination appears to be associated with specific sources. Nineteen violations of the sediment quality standards (marine criteria) were noted. Tributyltin concentrations at two locations exceeded the Puget Sound Dredge Disposal Analysis/ Sediment Management Standards interim screening level of 73ugTBT/kg. PCBs were low at all sites tested.

The highest wood levels (measured by total volatile solids) were present in the southwest portion of the harbor. Four strata had significantly higher levels of wood than the reference site. Three organic compounds (benzoic acid, phenol, and 4-methylphenol) commonly associated with wood debris were measured at concentrations above the SMS cleanup screening levels in four of the wood characterization areas.

Underwater video indicated a patchy distribution of wood debris, ranging from a clean bottom to bark accumulations that completely covered the sediment surface. The predominant wood debris was bark. Sulfur reducing bacteria mats were abundant on the sediment surface in the inner harbor, indicating anoxic conditions. It is recommended that best management practices be implemented immediately at the Simpson Mill to minimize the loss of wood chips during barge loading operations.

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A number of individuals made significant contributions to this project. The authors are grateful to all and would like to extend special thanks to the following:

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Introduction

The city of Shelton is located in Mason County 20 miles northwest of Olympia on the shores of Oakland Bay in southern Puget Sound (Figure 1). Shelton was incorporated in 1890 and has a current population of approximately 7,800. The forest products industry has played a major role in the history and economy of the area.

Log rafting and storage has occurred for many years in Oakland Bay, especially in the inner harbor along the Shelton waterfront. Recently, concerns have arisen throughout Puget Sound about the potential adverse effects of wood waste in sediments. Several studies have indicated that wood waste can have a variety of physical and chemical adverse impacts on aquatic life. Common adverse effects include:

- Organic enrichment of sediments
- Oxygen depletion in the water column
- Alteration of benthic communities to more pollution tolerant species
- Leaching of toxic chemicals such as phenols, methylated phenols, benzoic acid, benzyl alcohol, terpenes, and tropolones
- Physical alteration of the benthic substrate (Kendall and Michelsen, 1997)

As a result of concerns over excess accumulations of wood waste in sediments, Hylebos Waterway in Tacoma and Port Angeles Harbor in Port Angeles have undergone evaluations to determine the distribution and impacts of wood debris in sediments (HDG, 1999; SAIC, 1999). In both these studies adverse environmental impacts were indicated in areas that had heavy accumulations of wood waste. No information was available on the extent of wood debris in inner Shelton Harbor.

In addition to wood waste issues, the Washington State Department of Ecology (Ecology) collected sediments in 1989 from several storm drain systems that discharge to Oakland Bay. Concentrations of several metals and organics, while being typical of urban drainage, were present at concentrations above Ecology's Marine Sediment Quality Standards (Ecology, 1995a). Collection of sediments in the receiving environment was recommended, to determine if concentrations of metals and organics were at problem levels in Oakland Bay (Dickes, 1990).

The lack of sediment data from inner Shelton Harbor was identified as an important data gap during the Eastern Olympic Water Quality Management Area Needs Assessment conducted in 1998 (Ecology, 1998a). Consequently, Ecology's Southwest Regional Office requested a sediment study in Oakland Bay to address these data gaps. Ecology's Environmental Assessment Program Watershed Ecology Section was contracted to conduct this survey.

Sampling for this study occurred May 17-20, 1999. The primary objectives were to:

- Conduct chemical screening of sediments from selected locations near potential sources in inner Shelton Harbor to determine if further investigation is warranted. This determination was made based on comparison with Ecology's Sediment Management Standards (SMS) Chemical Criteria.

- Evaluate the distribution and significance of wood waste in sediments from inner Shelton Harbor.

Data collected during this study will be used to evaluate the need for further sediment investigations and source control actions in inner Shelton Harbor.

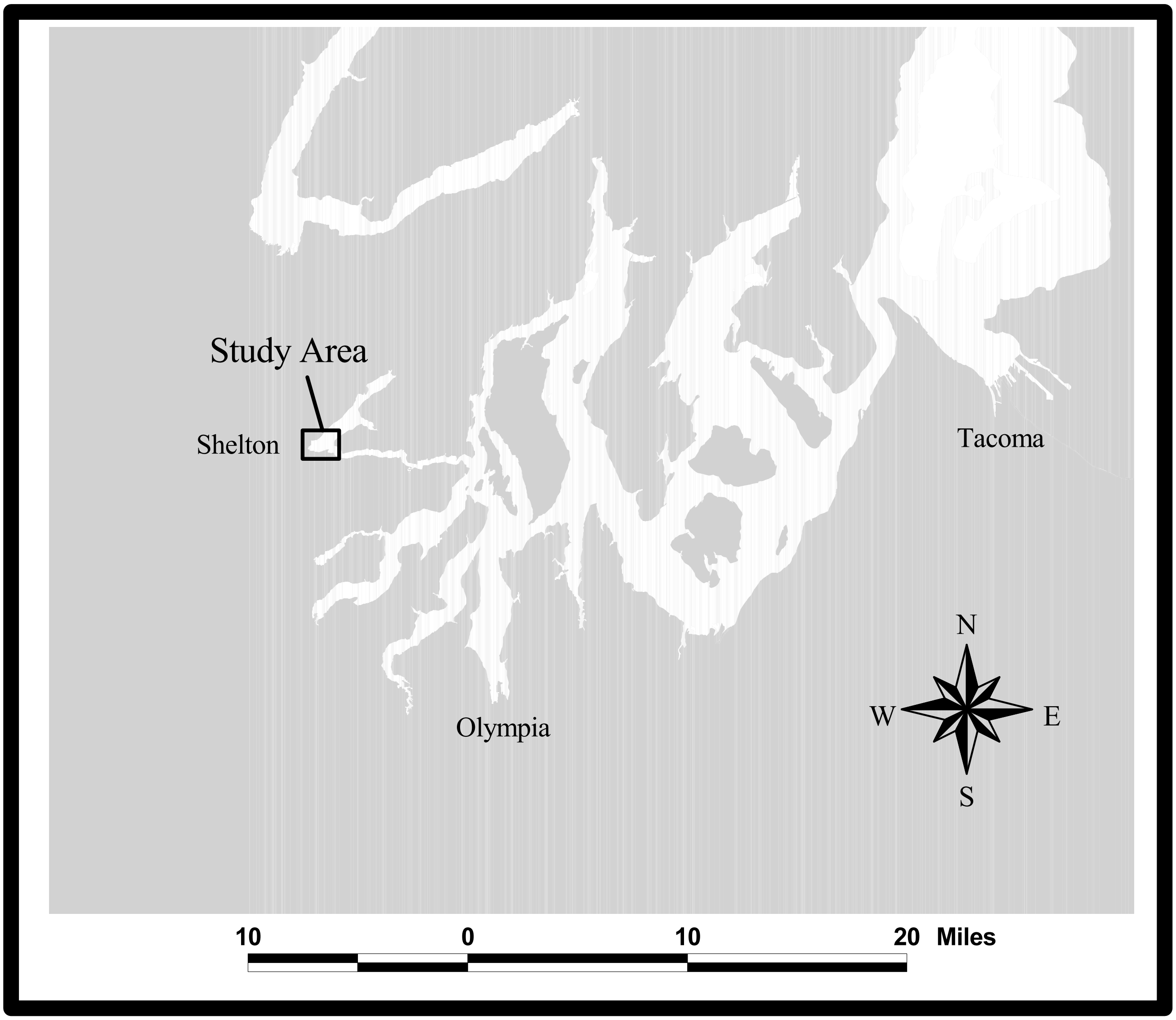

Figure 1: Inner Shelton Harbor Sediment Study Area

Methods

Study Design

A detailed discussion of the study design used for the Inner Shelton Harbor Sediment Investigation is contained in the *Inner Shelton Harbor Sediment Study Quality Assurance Project Plan* (Norton and Coots, 1999).

Surface sediment (top 10 cm) for chemical screening analysis was collected from the ten nearshore locations shown in Figure 2. These sites were chosen based on information collected during a reconnaissance survey to identify potential sources of sediment contamination in the study area.

To evaluate the distribution of wood waste in the inner harbor a stratified random design was used. This design has been used successfully in other sediment studies to evaluate the aerial extent of contamination (Long et al., 1996 and 1999). Nine strata were defined in inner Shelton Harbor based on various log handling practices (e.g., rafting, storage, dumping) and water depths. Information on wood handling practices in the area was obtained from aerial photos and observed operations.

The total area encompassed by the nine strata is slightly larger than 0.25 mile^2. The limits of each strata, and station locations within each stratum, are shown on Figure 2. For comparison, a reference site located near the point where Hammersley Inlet enters Oakland Bay was also sampled for both chemistry and wood content. A description of each sampling location and station coordinates are provided in Appendix A, Tables A1-A2.

For each of the wood waste strata, three to five stations were assigned to each strata, based on the relative percentage of the total area the strata represented. The area categories selected, and number of stations assigned to each, are summarized in Table 1.

Table 1. Summary of Station Distribution for Wood Waste Strata.

Percentage of Area	No. of Stations	Strata
5	3	2,8
5-15	4	1,5,6,7
≥ 15	5	3,4,9

Positions for each station within a strata were randomly selected from the intersection points of a 10ft x 10ft grid placed over each stratum.

Since larger wood debris would be excluded from grab sampling, underwater video transects were conducted in selected areas. The locations of transects were selected based on visual examination of the grab samples and a review of wood handling practices.

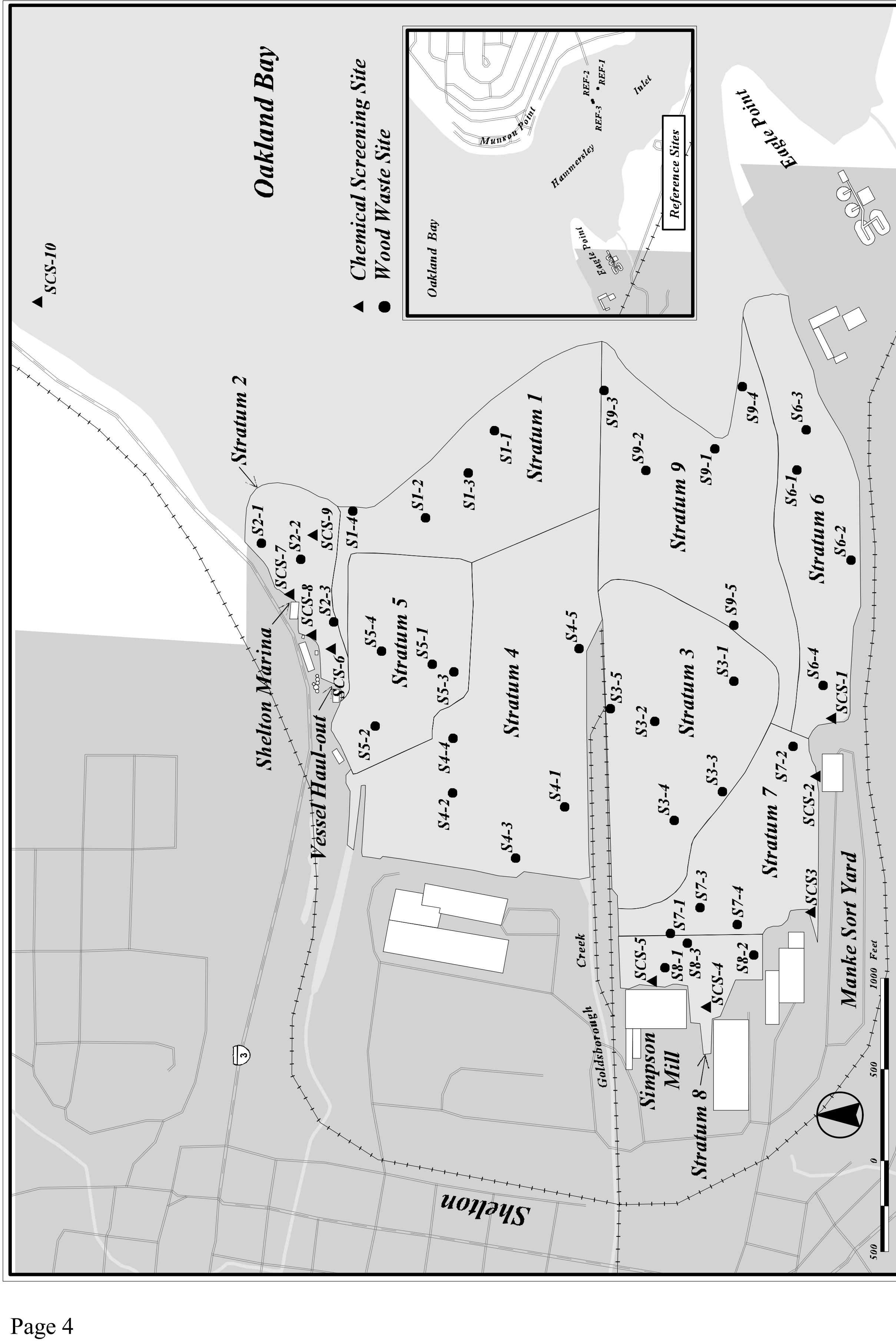

Figure 2. Sediment Station Locations for Inner Shelton Harbor Study

Sampling Methods

Where applicable, sampling methods followed Puget Sound Estuary Protocols (PSEP, 1996) and requirements of the Sediment Management Standards (Ecology, 1995a,b).

At each of the chemical screening sites a composite sample was prepared from three individual grabs. The top 10-cm layer (biologically active zone - Ecology, 1995b) was sampled at each location. A single grab was collected from each of the wood waste characterization stations.

In most instances, samples were collected from Ecology's 20' skiff using a 0.1 m^2 stainless steel van Veen grab. At sites where it was not possible to navigate the vessel, samples were obtained at low tide by hand using stainless steel spoons. All station positions were recorded using a Northstar 941™ differentially corrected global positioning system (GPS) interfaced with Nobeltec Visual Navigation Suite™ software (version 4.1).

A grab was considered acceptable if: (1) it was not over-filled with sediment, (2) overlying water was present and not excessively turbid, (3) the sediment surface was relatively flat, and (4) the desired depth of penetration had been achieved. A field log, which provides a visual description of each sample, was maintained during sampling (see Appendix A, Table A3). Digital photographs were taken of individual grabs for the wood waste portion of the study.

Upon retrieving a successful grab, overlying water was siphoned off and the top 10-cm layer of sediment was removed with stainless steel spoons, placed in a stainless steel bowl, and homogenized by stirring. For all samples, material in contact with the side walls of the grab was not retained for analysis. At the discretion of the project leader, larger debris (i.e., rocks, shells, and pieces of wood) present in the grab that could not be put in the sample container were excluded from the sample. Notes were made in the sample log of all debris originally present in the sample.

Sub-samples of the homogenate were placed in glass jars (Teflon lid liners) cleaned to EPA QA/QC specifications (EPA, 1990). Separate 4-oz jars were used for semivolatile organics, metals, butyltins, and PCBs; 2-oz jars were used for TOC; and 16-oz glass jars were used for total solids (TS), total volatile solids (TVS), and grain size samples.

Stainless steel spoons and bowls used to manipulate the sediments were pre-cleaned by washing with Liquinox detergent, followed by sequential rinses with hot tap water, dilute (10%) nitric acid, de-ionized water, and methanol. The equipment was then air-dried and wrapped in aluminum foil until used in the field. The same procedure was used to pre-clean the grab before going into the field. Between stations, cleaning of the grab consisted of thoroughly brushing with on-site water. If oil or visible contamination was encountered, the grab was cleaned between samples with Liquinox detergent followed by a rinse with on-site water.

All samples were placed on ice immediately after collection and transported to the Ecology Manchester Environmental Laboratory (MEL) within two days of collection. Chain-of-custody was maintained.

An underwater video was taken with a FISHEYE™ color underwater video camera in conjunction with a deck monitor and VCR. Video transect locations were logged using the GPS.

To assess general water column conditions, vertical profiles of temperature, salinity, and dissolved oxygen (DO) were collected at six locations. These locations are described in Appendix A, Tables A2 and A4. The intent of the profiles was to evaluate the vertical gradient in DO. These profiles were collected using a calibrated SEABIRD™ CTD. As a check, grab samples of near bottom DO (.3 meters above the bottom) were collected using a Niskin bottle. DO in these samples was determined by the Winkler titration method (APHA, 1995).

Sample Analysis

MEL conducted the majority of laboratory analyses. Analytical methods and laboratories used for sediment analysis in this project are listed in Table 2.

Table 2. Analytical Methods and Laboratories Used for Analysis of Sediment.

Analyte	Method	Reference	Laboratory
Total Solids	Gravimetric (160.3)	PSEP, 1996	Rosa Environmental
Total Volatile Solids	Gravimetric/Ignition (D-2974)	ASTM, 1995	Rosa Environmental
Total Organic Carbon	Combustion/CO2 Measurement @ 70°C and 104°C (9060)	PSEP, 1996	MEL
Grain Size*	Sieve and Pipet	PSEP, 1996	Rosa Environmental
Arsenic	GFAA (7060)	PSEP, 1996	MEL
Cadmium, Chromium, Copper, Lead, Silver, Zinc	ICP (6010)	PSEP,1996	MEL
Mercury	CVAA (245.5)	PSEP, 1996	MEL
Semivolatiles	GC/MS (8270)	EPA, 1995	MEL
Butyltins	GC/AED	PSEP, 1996	MEL
PCBs	GC/ECD (8082)	PSEP, 1996	MEL

*Sample prescreened through a 0.25" mesh screen

TVS measurements were used as a surrogate to estimate the amount of wood debris present in sediments. A larger than normal sample (300-500g) was collected for TS, TVS, and grain size determinations. Collection of a larger than normal sample volume for TVS analysis follows recommendations proposed by the PSDDA and SMS programs, and is described in ASTM D-2974 (Kendall and Michelsen, 1997; ASTM, 1995).

The entire sample was first washed through a 1/4" mesh sieve. The portion retained on the 1/4" sieve was weighed and analyzed for TS and TVS. The portion passing through the 1/4" sieve was analyzed for TS, TVS, and grain size distribution. To estimate the overall wood content of each sample, the TVS results for the two fractions were weighted by the fraction percentages of the total sample and then added together. This procedure is comparable to procedures used in a study of wood waste in Hylebos Waterway, Tacoma, Washington (HDG, 1999). The intent of separating the sample was to evaluate the relative percentage of course and fine wood debris present in each sample.

A composite sample representing all wood waste stations within a strata was prepared and submitted to the laboratory for semivolatile organics analysis. Theses data were used to evaluate organic contamination potentially associated with the presence of wood waste.

Quality Assurance

Quality assurance procedures used in collection and analysis of samples for the Inner Shelton Harbor Study are described in detail in the Inner Shelton Harbor Quality Assurance Project Plan (Norton and Coots, 1999).

Copies of case narratives for analyses are available from the author on request. Overall precision (sampling + laboratory) of the data set was evaluated by calculating the relative percent difference (RPD, range expressed as a percentage of the mean) between blind field duplicates. Precision of the data was good for most analytes. RPDs were as follows:

- Conventionals = <15% for all analytes except TVS (120%) and TS (32%) in the >1/4" size fraction
- Metals = <10% for all metals except Hg (26%)
- Semivolatiles = generally <66%
- Butyltin = 99%
- PCBs = <13%

The high degree of variability associated with the TVS and TS analysis of the >1/4" size fraction most likely reflects the heterogeneous composition of this fraction.

Overall data quality for the project was good, with no major problems encountered in the sample analysis. Therefore, the data are considered acceptable for use as reported and qualified in this document. Unless otherwise specified, all results are reported on a dry weight basis.

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Results and Discussion

Chemical Screening Sites

Ten nearshore locations were sampled (primarily intertidal) in inner Shelton Harbor to evaluate contaminant levels near potential sources. The results of physical and chemical analysis of these samples are summarized in Appendix B, Tables B1-B4. Total organic carbon (TOC) levels were variable, ranging from 1.1% to 10.6%, with a mean of 4.6%. The highest levels were present along the south shore of the harbor below the Manke log sort yard. TOC levels at the reference site were low, with a mean of 0.51%.

The grain size distribution of sediments from the chemical screening sites is shown in Figure 3.

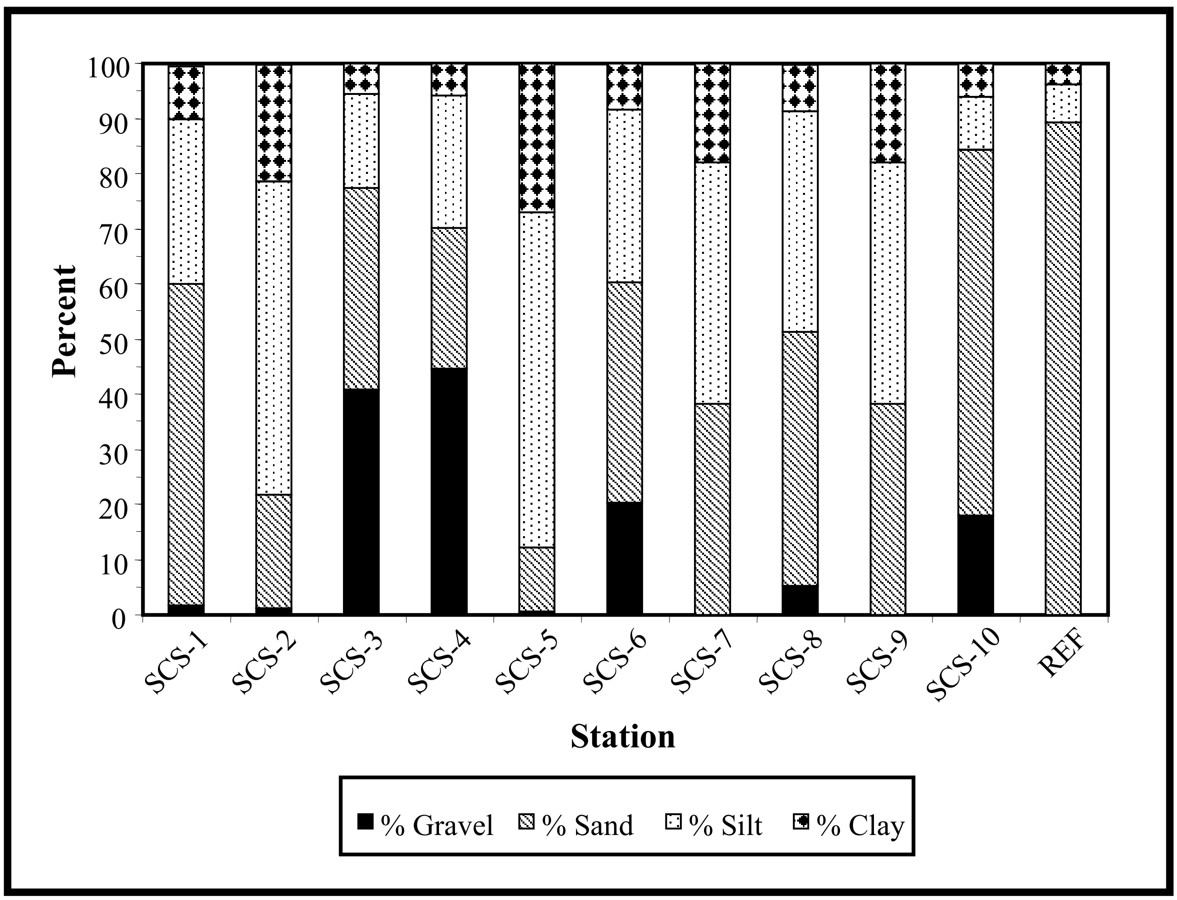

Figure 3. Grain Size Distribution of Sediments from Chemical Screening Stations

Sediments from stations SCS-2,5,7,9 were composed primarily of fine grain material (silt and clay). The remainder of the stations were primarily coarse material (gravel + sand). The reference site was 89.2% sand.

Metals analysis included all eight elements specified in Ecology's Sediment Management Standards (SMS). Metals concentrations were generally low in most samples, being only slightly elevated compared to the reference site (Appendix B, Table B3). Notable exceptions were observed for copper (SCS-6,7) and mercury (SCS-4,5). Stations SCS-6,7 are both located along the north shore of the harbor adjacent to a vessel haul-out railway and a boat crib at the Shelton Marina, respectively. The presence of copper at these sites is most likely related to the use of antifouling paints on vessels. Stations SCS-4,5 are adjacent to the Simpson Mill. It is unclear what the source of mercury might be in this portion of the harbor. Silver was not detected at any of the sites sampled.

Organics analyses included semivolatiles, butyltins, and PCBs (Aroclors). Results of these analyses are summarized in Appendix B, Table B4. Thirty-eight semivolatile compounds were detected in sediments from the chemical screening sites. The majority of compounds detected were polynuclear aromatic hydrocarbons (PAHs). The highest PAH concentrations were present along the north shore of the harbor at two locations: adjacent to a boat crib at the Shelton Marina (SCS-7) and below a small tank farm (SCS-8). Elevated PAH concentrations were also noted adjacent to the Simpson Mill (SCS-5).

At all sites except SCS-4, the sum of high molecular weight PAH (HPAH) exceeded the sum of low molecular weight PAH (LPAH). This enrichment of HPAH relative to LPAH is commonly observed in environmental samples since weathering processes (e.g., evaporation, photochemical oxidation, dissolution, microbial degradation) can preferentially remove PAHs with molecular weights less than that of fluoranthene (Merrill and Wade, 1985). The distribution of PAHs observed indicates that the sediments sampled have undergone some weathering. This finding implies that historical PAH sources are primarily responsible for the PAH contamination observed. In contrast, the relative enrichment of LPAHs at SCS-4 suggests that an ongoing source of these compounds might be present in this area of the harbor. This station is located in the middle of the chip barge loading area, one of the most active parts of the harbor with respect to vessel traffic. This area of the harbor also has stormwater discharges.

Other than the PAHs, concentrations of all target semivolatile organics were generally below 1000 ug/kg. Semivolatile organics (excluding PAHs) exceeding 1,000 ug/kg in sediments from the chemical screening sites are summarized in Table 3.

Table 3. Semivolatile Organics (excluding PAHs) Present at Concentrations Above 1,000ug/kg in Inner Shelton Harbor Sediments.

Chemical	Station SCS	Location of Maximum
Retene	1,4,5	4
4-Methylphenol	4	4
Di-n-butylphthalate	5,6,9	6
Benzoic Acid	5	5

Peak concentrations of retene (11,000 ug/kg) and 4-methylphenol (2,600 ug/kg) were present at the chip barge loading area. Retene, 4-methylphenol, and benzoic acid are naturally occurring compounds that are often associated with the presence of wood debris. Di-n-butylphthalate is a commonly used plasticizer in the manufacture of a variety of plastics (Verschueren, 1983). One other chemical of note was pentachlorophenol which was detected at all of the chemical screening sites, except SCS-1. Detected concentrations of pentachlorophenol in the inner harbor ranged from 125 to 400 ug/kg, with a mean of 220 ug/kg. The highest concentration was measured at SCS-5 near the old Simpson Mill sawmill log feed. Pentachlorophenol was also detected at the reference site at a concentration of 87 ug/kg.

Butyltin concentrations were generally low in nearshore sediments with the exception of the area adjacent to the vessel haul-out railway (SCS-6). Individual concentrations of mono-(1,300 ug/kg), di-(4,100 ug/kg), and tri-(1,500 ug/kg)butyltin chloride all exceeded 1,000 ug/kg at this site. The primary source of tributyltin in the marine environment is from the historical use of anti-fouling paints on vessels.

Mono-(MBT) and di-(DBT)butyltin are released into the environment through multiple sources. Most of the time, their occurrence is related to degradation pathways of tributyltin (TBT). However, there is increasing evidence that MBT and DBT may be released directly into the environment via discharge pipes and sewage treatment discharges (Quevauviller et al., 1991). It is thought that the butyltins leach to the water from pipes (such as PVC) and are later discharged to the environment. In addition, MBT and DBT are used as a catalyst in the manufacture of polyurethane foams (EPA, 1996).

PCB levels were low in all samples analyzed, with total PCB concentrations ranging from <7.2 to 64 ug/kg. The mean total PCB value calculated from detected concentrations was 31 ug/kg. PCB-1254 and PCB-1260 were the primary Aroclors detected.

The lowest concentrations for all organic compounds were typically measured at the reference site. The low level of contamination measured at the reference site is probably related to a number of factors including (1) the area is removed from sources, (2) sediments were primarily sand, and (3) the TOC content was very low.

Comparison with Applicable Sediment Quality Values

In 1991, Ecology adopted the Sediment Management Standards (SMS; Ecology, 1995a). The standards include chemical concentrations criteria, biological effects criteria, and human health criteria. These criteria are used to identify sediments that have no adverse effect on biological resources and pose no significant risks to human health. The *Sediment Quality Standards* (SQS) represent the level below which no adverse effects would be observed in benthic communities. The standards also establish *Cleanup Screening Levels* (CSL) that represent the upper limit of allowable minor adverse effects on biological resources. Contaminant concentrations above the CSL are a high priority for remediation activities. Chemical concentrations in inner Shelton Harbor sediments that exceeded the SMS criteria are summarized in Table 4. A complete comparison of chemicals detected at the chemical screening sites to the SMS can be found in Appendix C, Table C1.

Table 4. Summary of Chemicals Exceeding Ecology's Sediment Management Standards in Nearshore Sediments from Inner Shelton Harbor (Values shown are elevation factors).

Station ID	Chemical	Elevation Factor Above SQS	CSL	Reference Area
SCS-1	Phenol	1.2	-	ND
SCS-2	Benzoic Acid	1.2	1.2	1.8
SCS-3	None			
SCS-4	Mercury	1.1	-	23
	Phenol	1.1	-	ND
	4-Methylphenol	3.9	3.9	ND
	2,4-Dimethylphenol	1.3	1.3	78
SCS-5	Mercury	1.2	-	25
	Pentachlorophenol	1.1	-	4.6
	Benzoic Acid	1.5	1.5	2.4
SCS-6	Copper	1.3	1.3	41
	Bis(2-ethyl hexyl)phthalate	1.0	-	ND
SCS-7	Copper	1.2	1.2	38
	Fluoranthene	1.3	-	20
	Chrysene	1.3	-	48
	Pentachlorophenol	1.1	-	4.4
SCS-8	Fluoranthene	2.4	-	40
	Chrysene	1.2	-	45
	HPAH	1.1	-	30
	Benzoic Acid	1.1	1.1	1.7
SCS-9	None			
SCS-10	None			
REF	None			

SQS = Sediment Quality Standard, Marine Criteria
CSL = Cleanup Screening Level
ND = Chemical was not detected at reference area; unable to calculate elevation factor

Seven of the ten sites sampled had one or more chemicals exceeding the SMS chemical criteria. Stations SCS-4,7,8 had the greatest number of SQS violations (4 each). Six of the sites also had chemical concentrations in excess of the CSL. Chemicals exceeding the CSL level included copper (SCS-6,7), benzoic acid (SCS-2,5,8), 4-methylphenol (SCS-4), and 2,4-dimethylphenol (SCS-4). Areas with chemicals exceeding the CSL should undergo biological toxicity testing to determine the potential for adverse biological effects.

Sediment concentrations of non-ionizable organics and the toxicity of these compounds have been observed to correlate well with the organic content of sediments. Consequently, the SMS criteria for this class of compounds is reported on an organic-carbon normalized basis. However, this relationship is less certain for sediments that have very low (<0.5%) or relatively high (>4.0%) TOC values. It is recommended that in areas with very low or high TOC values, biological testing or the use of dry weight Apparent Effects Threshold (AET) values should be considered along with the organic-carbon normalized criteria (Michelsen, 1992). Non-ionizable organics detected at the chemical screening sites are compared to the dry weight AETs in Appendix C, Table C3. PAHs were the primary group of chemicals measured above the dry weight AETs. A variety of PAHs exceeded the dry weight AETs at four stations, SCS-4,5,7,8. Di-n-butylphthalate levels exceeded the AETs at three stations, SCS-5,6,9. Di-methylphthalate at SCS-8 also exceeded the AETs.

The toxicity and bioaccumulation of TBT is a complex process that is affected by a number of factors, including organic carbon levels in sediment and water, pH, salinity, clay content, and the presence of inorganic constituents such as iron oxides (EPA, 1996). Due to its complex behavior in the aquatic environment, no sediment quality criteria have been adopted for TBT in marine sediments. In 1988, the Puget Sound Dredge Disposal Analysis (PSDDA) agencies developed an interim screening level (ISL) for use in the PSDDA program based on best available knowledge of the chemical and its properties (Michelsen et al., 1996). The ISL was set at 30 ug/kg (as Sn). This corresponds to a concentration of 73 ug/kg (reported as TBT-ion). Exceedance of the ISL requires biological testing to be performed. TBT levels in Shelton Harbor sediments are compared to the PSDDA ISL in Table 5.

Table 5. Comparison of Tributyltin Results in Inner Shelton Harbor Sediments to Applicable Screening Values.

Station	Shelton Harbor ugTBT(ion)/kg, dry	PSDDA ISL ugTBT(ion)kg, dry	Shelton Harbor ugTBT/kg, OC	Hylebos WW SSCL ugTBT/kg, OC
SCS-6	$\boxed{1300}$	73	$\boxed{70000}$	17500
SCS-7	23		1200	
SCS-8	23		1500	
SCS-9	$\boxed{98}$		3600	
REF	4.5u		900u	

u = Not detected at detection limit shown
PSDDA ISL = Puget Sound Dredge Disposal Analysis Interim Screening Level (Michelsen, 1996)
Hylebos WW SSCL = Hylebos Waterway Site-Specific Cleanup Level (EPA, 1996)
$\boxed{\text{Outline}}$ = Concentration exceeds screening value

The north shore of the harbor adjacent to the vessel haul-out railway (SCS-6 = 1,300 ugTBT/kg) and the Shelton Marina (SCS-9 = 98 ugTBT/Kg) both exceeded the PSDDA ISL. TBT was not detected at the reference site. The data collected indicate that sediments at SCS-6 and SCS-9 would be required to undergo biological toxicity testing under the PSDDA program.

For perspective, TBT concentrations in lower Budd Inlet at four locations (primarily marinas) sampled by Ecology in 1998 ranged from 250 to 1,300 ugTBT/kg with a mean of 880 ugTBT/kg (Norton, 1999a). In addition, the Thurston County Health Department sampled 13 locations in 1991 from Budd Inlet and found concentrations ranging from 6 to 170 ugTBT/kg with a mean of 44 ugTBT/kg (TCHD, 1991).

In 1996, an interagency work group was formed to review the available information on TBT, with the goal of developing a site-specific cleanup level for Hylebos Waterway in Tacoma and Harbor Island in Elliott Bay in support of sediment cleanup activities. The cleanup level determined for Hylebos Waterway was based on an interstitial water concentration of 0.7 ugTBT/L, which is believed to protect many organisms from most acute effects from TBT (EPA, 1996). Applying EPA's equilibrium partitioning approach to this interstitial water level yields a bulk sediment cleanup concentration of 17,500 ugTBT(ion)/kg, OC.

Converted to comparable units (ugTBT/kg, OC), TBT levels measured in inner Shelton Harbor sediments ranged from < 900 to 70,000 ugTBT/kg, OC. Sediment from the vessel haul-out railway (SCS-6) was the only location exceeding the Hylebos Waterway specific cleanup level (Table 5). Hylebos Waterway criteria are being provided here only for informational purposes. At the present time sediments outside Hylebos Waterway should be evaluated using the PSDDA/SMS interim screening level of 73 ugTBT/kg. The use of interstitial water concentrations for evaluating TBT contamination is under consideration for adoption in both the PSDDA and SMS programs. However, this change has not been implemented in either program.

Wood Waste Evaluation

Physical Measurements

Surface sediments were collected from 37 stations distributed among nine strata in inner Shelton Harbor to evaluate the distribution of wood waste. The results of physical analysis of these samples are summarized in Appendix B, Tables B1 and B2.

TOC levels in the wood waste strata were variable, ranging from 0.26 to 9.2%, with a mean of 3.7%. The mean TOC level of each stratum is shown in Figure 4.

On average the highest TOC levels were measured in stratum 8 (S8, located at the chip barge loading area) followed by S7, S3, and S6. All four of these strata are active log handling areas of the harbor.

The grain size distribution of sediments from each of the strata is displayed in Figure 5.

Sediments from S1, S2, and S4 were primarily coarse grain material (gravel + sand). S1 and S2 encompass the outer most portion of the north harbor. S4 included the mouth of Goldsbough Creek. The remaining strata are primarily composed of silt and clay size particles. Prior to performing grain size determinations, samples from the wood waste strata were pre-screened through a 1/4" sieve. This procedure reduces the amount of coarse material reported in the grain size analysis.

The distribution of wood in the >1/4" and <1/4" size fractions is shown in Table 6.

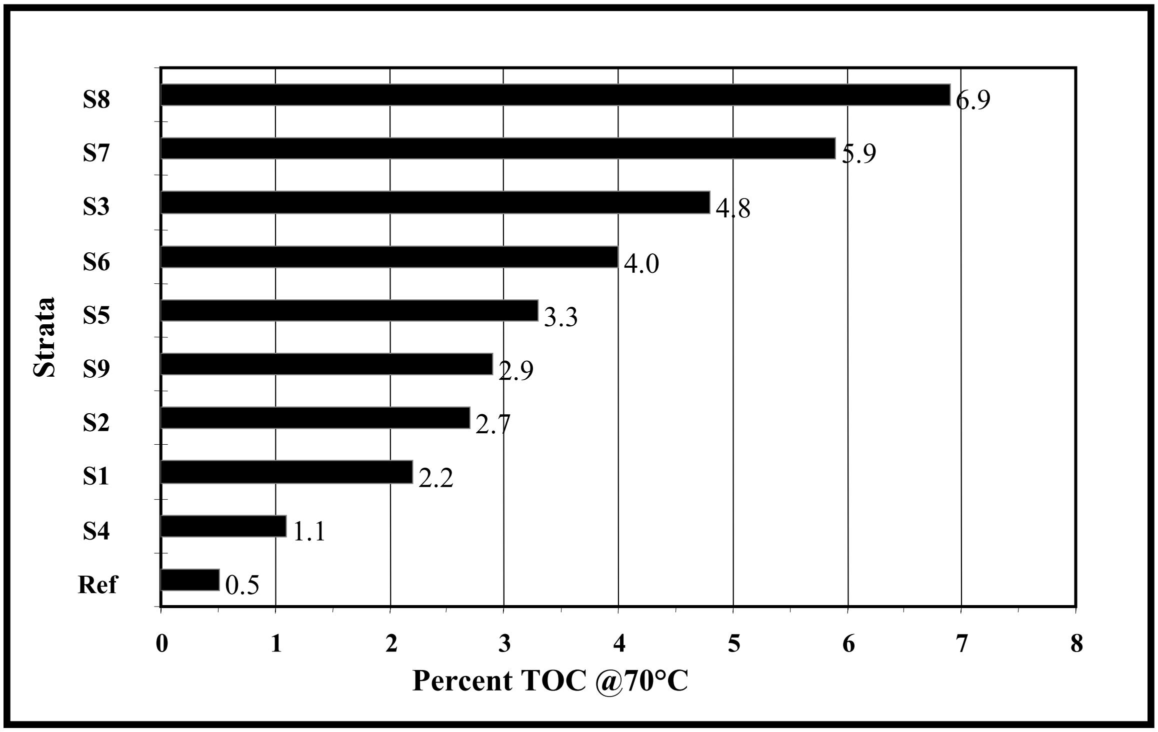

Figure 4. Average TOC Levels in Inner Shelton Harbor Wood Characterization Strata.

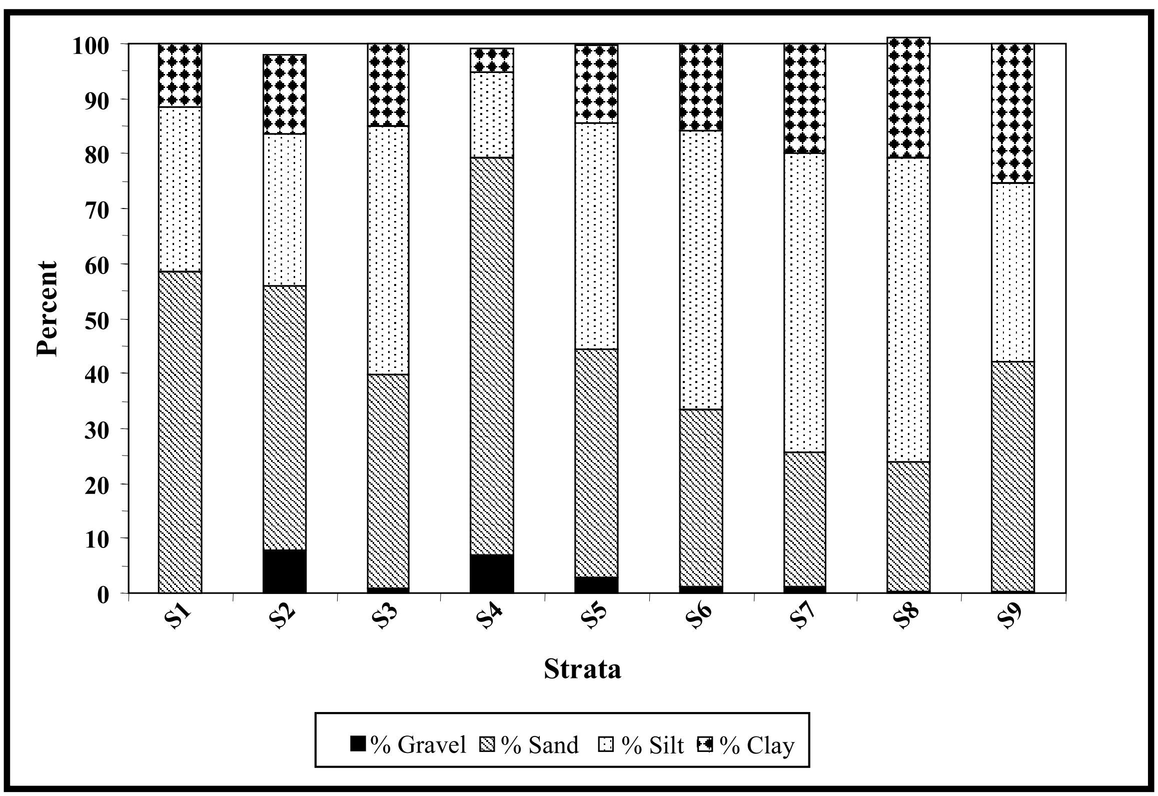

Figure 5. Grain Size Distribution of Sediments from the Wood Characterization Strata.

Table 6. Summary Statistics for Percent of Sample and Wood Content of the >1/4" and <1/4" Size Fractions.

Statistic	>1/4" Fraction % of Sample	>1/4" Fraction % Wood (by weight)	<1/4" Fraction % of Sample	<1/4" Fraction % Wood (by weight)
Minimum	0	0	50.1	1.3
Maximum	49.9	99.2	100	26.8
Mean	3.5	54.3	96.5	10.3
Standard Deviation	8.1	28.2	8.1	6.4

Number of samples = 37

On average the >1/4" size fraction comprised only about 3.5% of the total sample weight in individual grabs. However, slightly more than 50% of this fraction was typically wood as measured by TVS. The average wood content of the <1/4" size fraction was about 10%. These data suggest that most of the wood included in the grab samples was <1/4" in size.

The overall mean (>1/4" + <1/4") percent wood content (weight basis) for each of the strata samples are displayed in Figure 6.

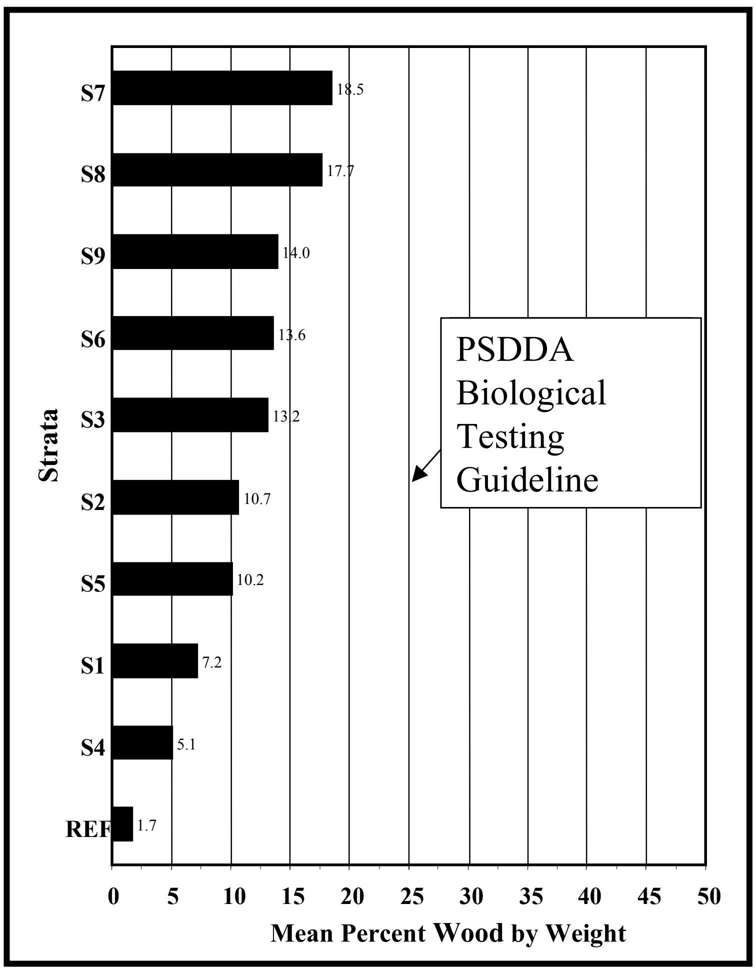

Figure 6. Mean Wood Content (Weight Basis) of Wood Characterization Strata.

Stratum 7 (S7) had the highest mean wood content by weight (18.5%) followed by S8 (17.7%). S7 is an active short-term raft storage area in the southwest portion of the harbor adjacent to the chip barge loading area. S8 includes the chip barge loading area. The lowest wood waste levels were measured in S4, which includes the intertidal area at the mouth of Goldsbough Creek.

Analysis of variance was performed (arcsine square root transformed wood content by weight) to determine if stratum had a significant effect on the level of wood in sediments. This analysis indicated that stratum did have a significant effect ($p = 0.003$) on the amount of wood. A posteriori comparison was used to compare different strata to each other and the reference site using Tukey's Test Statistic (Zar, 1996). The results of this analysis indicated that S6, S7, S8, and S9 had significantly higher levels of wood than the reference site. Within the inner harbor (excluding reference), only S4 and S7 had significantly different ($p = 0.044$) levels of wood. S7 samples had the highest overall wood content, while S4 had the lowest. All statistical analysis was performed using Systat software, version 7.01 (SPSS, 1996).

Ecology has regulated dredge material with wood debris volumes >50% by weight under Section 401 (water quality certification) as generally being unsuitable for unconfined open-water disposal. Dredge material that contains significant amounts of woody material/debris is generally required to have the organic fraction quantified. In the PSDDA program, dredge material containing an organic fraction (usually measured by TVS) >25% by weight is required to undergo biological testing to assess the suitability for unconfined open-water disposal (Kendall and Michelsen, 1997). Based on strata means, none of the strata in inner Shelton Harbor exceeded 25% by weight as measured by TVS. However, three individual stations (S3-4, S7-4, S9-3) exceeded 25% by weight.

Wood debris can be quantified in the laboratory on either a volume or weight-specific basis. While quantifying wood debris in sediments on a volumetric basis may be more ecologically meaningful, it is more difficult and less accurate than quantifying it on a weight-specific basis. For dredge material assessments of wood debris, the PSDDA program uses a conversion factor of 2 (e.g., 25% by weight = 50% by volume) to express results on a volumetric basis. Using this conversion factor, the wood content of each of the inner Shelton Harbor strata are displayed on a volumetric basis in Figure 7.

Three ranges of wood are displayed: 10-20%, 20-30%, and 30-40%. Two strata (S7, S8) near the chip barge loading area fall into the upper range (30-40%). The majority of strata (five) were between 20-30% wood by volume. Two strata (S1, S4) fell into the lower range.

Combining the information on average wood content (Figure 7) with the area that each stratum represents of the total area of the inner harbor, yields a distribution of wood by volume in the inner harbor shown in Table 7.

To put the amount of wood in inner Shelton Harbor into perspective, values from the present study are compared to wood levels from Hylebos Waterway (Tacoma) and selected areas of Grays Harbor in Table 8.

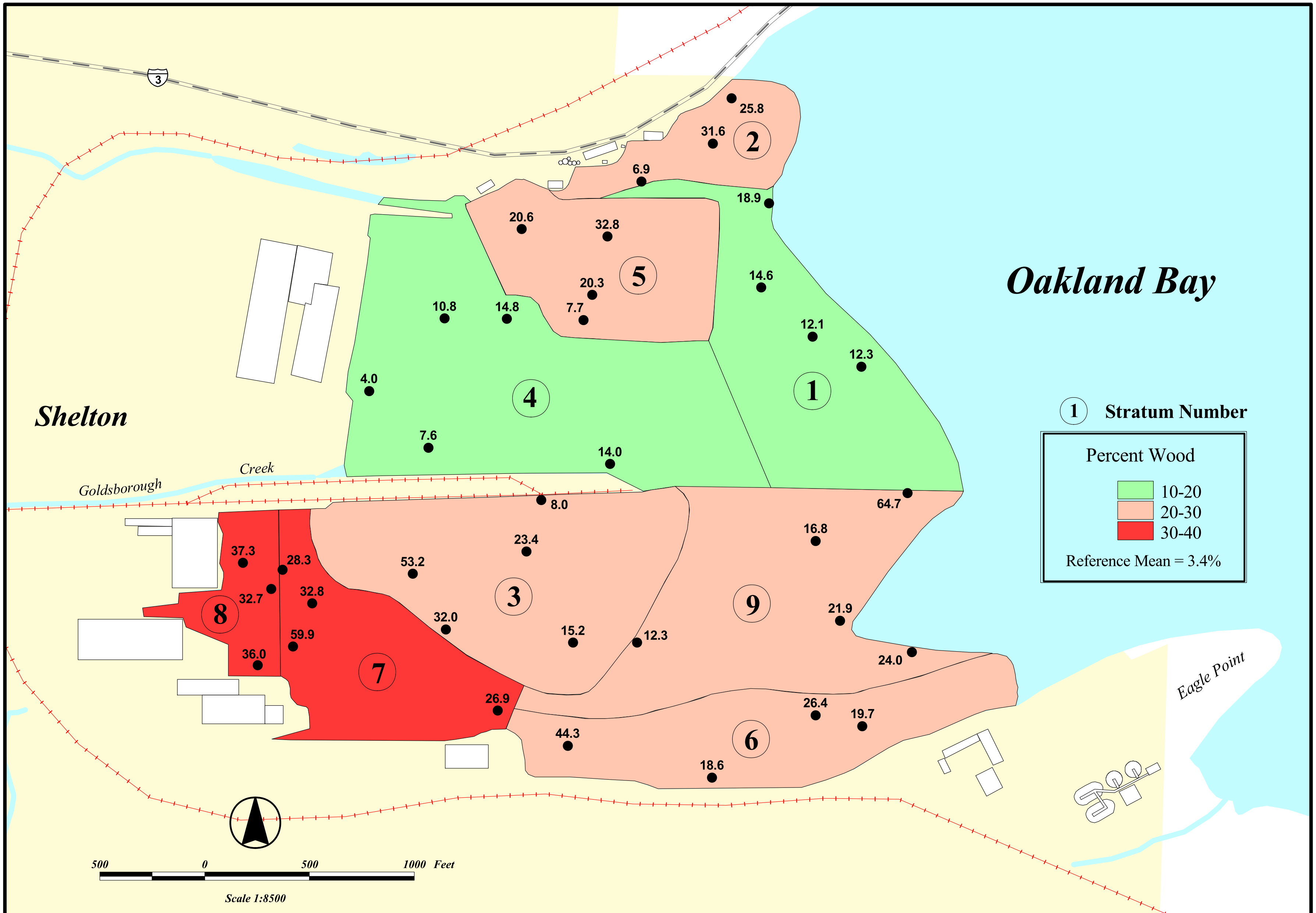

Figure 7. Mean Percent Wood by Volume in Inner Shelton Harbor Sediment Strata

Table 7. Percentage Distribution of Wood in Shelton Harbor.

Wood Content (by volume)	Inner Harbor Area
10 – 20%	34%
20 – 30%	54%
30 – 40%	12%

Table 8. Comparison of Percent Wood by Volume in Inner Shelton Harbor Sediments to Other Data from Washington State.

Range of Wood by Volume	Inner Shelton Harbor* (present study) (n = 37)	Hylebos Waterway (HDG, 1999) (n = 160)	Grays Harbor (Norton, 1999b) (n=14)
1 - 5%	3%	53%	14%
5 - 15%	30%	23%	36%
15 - 30%	41%	9%	29%
30 - 50%	22%	8%	21%
>50%	8%	7%	0%

*Reference area excluded from calculation
Values shown are percent of stations in range

The distribution of wood measured in inner Shelton Harbor most closely resembles the distribution observed in Grays Harbor. Compared to Hylebos Waterway, Shelton has a higher percentage of stations in the 15-30% range and a much lower percentage in the 1-5% range. The differences noted between Hylebos Waterway and Shelton are probably related to differences in the density of stations between the two studies. This Shelton study was designed to be a screening level evaluation of wood debris. Given the variability in the distribution of wood debris observed, a much higher density of stations would be required to accurately map and evaluate the range of wood content in inner Shelton Harbor sediments. Any further wood characterization work in the harbor should take this variability into consideration.

Vertical profiles of temperature, salinity and dissolved oxygen were collected at six locations in the inner harbor to assess water column conditions (see Appendix A for location descriptions). Individual profiles for each of the casts are displayed in Appendix E, Figures E1-E6. These data indicated that a highly oxygenated freshwater layer approximately one meter thick was present throughout the inner harbor. Dissolved oxygen levels in the surface layer ranged from 12.7 to 16.3 mg/l with a mean of 14.4 mg/l. Near-bottom waters contained dissolved oxygen levels ranging from 7.9 to 10.0 mg/l with a mean of 9.3 mg/l. The average salinity measured in near bottom waters was 25.5%. Inner Shelton Harbor is classified as Class B marine waters under the State of Washington Water Quality Standards (Ecology, 1998b). The dissolved oxygen standard for Class B waters is 5.0 mg/l. No violations of the dissolved oxygen standard were observed at the time of sampling.

Chemicals Associated with Wood

Potentially toxic compounds released from wood waste include phenols, methylated phenols, benzoic acid, benzyl alcohol, terpenes, and tropolones. The severity of wood waste effects in sediments depends directly on its physical form, the degree of flushing, habitat (freshwater or marine), and type of wood from which the waste is derived. Consequently, adverse impacts of wood waste are site-specific and can vary considerably even within a small area (Kendall and Michelsen, 1997).

A complete list of semivolatile organics detected in the wood waste strata composite samples are listed in Appendix B, Table B5. Detected compounds are compared to the SMS in Appendix C, Table C2. Compounds exceeding the SMS are summarized in Table 9.

Table 9. Summary of Chemicals Exceeding Ecology's Sediment Management Standards in Wood Waste Strata Composite Samples (Values shown are elevation factors; only strata with chemicals exceeding standards are shown).

Station		Elevation Factor Above		
ID	Chemical	SQS	CSL	Reference Area
S2	Benzoic Acid	1.1	1.1	1.6
S6	Phenol	7.1	2.5	ND
	Benzoic Acid	1.1	1.1	1.7
S7	4-Methylphenol	1.9	1.9	39
	Benzoic Acid	1.0	1.0	1.6
S8	4-Methylphenol	1.8	1.8	36

SQS = Sediment Quality Standard; Marine Criteria
CSL = Cleanup Screening Level
ND = Chemical was not detected at reference area- unable to calculate elevation factor

Three compounds (benzoic acid, phenol, 4-methylphenol) exceeded the CSL in four of the strata composites. All three of these compounds are known to be associated with wood waste.

Because of the potential of wood waste to cause adverse impacts to aquatic life, Ecology will require wood waste cleanup at sites when it is demonstrated to be harmful. Like other contaminants for which chemical criteria are not available, sediments contaminated with wood waste and chemical byproducts of the breakdown of wood waste will be assessed through biological testing procedures – bioassay and/or benthic studies (Kendall and Michelsen, 1997). These procedures are listed in the SMS and described in the PSEP protocols. Based on findings from the present study, some form of biological testing seems warranted for S6, S7, and S8 since each had more than one chemical measured above the CSL. In addition, S7 and S8 had some of the highest levels of wood measured in this study.

Pentachlorophenol was also detected in all of the wood waste strata composites. Concentrations ranged from 96 to 280 ug/kg, with a mean 200 ug/kg. Based on the chemical screening and wood waste composite samples, it appears that low-level pentachlorophenol contamination is present throughout inner Shelton Harbor.

As previously discussed, it is recommended that in areas with very low or high TOC values biological testing or the use of dry weight AETs should be considered along with the organic-carbon normalized criteria (Michelsen, 1992). Non-ionizable organics detected in the wood waste strata composite samples are compared to the dry weight AETs in Appendix C, Table C4. No chemicals were measured above the dry weight AET values in the wood waste strata composites.

Visual Observations

Field descriptions, digital photographs, and an underwater video were used to qualitatively evaluate wood accumulations in subtidal sediments. Wood debris observed in individual grabs ranged in size from small wood fibers and chips to larger material including sticks, bark, and pieces of logs. By far the most common wood debris observed was bark. Some form of wood debris was noted in all grabs collected except two (S1-4 and S2-3). In approximately 50% of the grabs, wood was not evident on the sediment surface but was present at depth (>5cm) in the sediments. Twenty percent of the samples had wood distributed throughout the sediment column. All three individual stations (S3-4, S7-4, and S9-3) that had TVS values in excess of 25% by weight fell into this category.

Examination of the towed underwater video indicated a patchy distribution of wood in all areas of the harbor. Conditions ranged from a clean bottom with no visible wood debris to bark accumulations approximately 15 cm thick. In areas with thick bark accumulations, the sediment surface was completely covered. Intact logs were present in some areas of the harbor but were scattered. Much of the inner harbor was covered with a mat of sulfur-reducing bacteria, which would indicate that anaerobic conditions exist in the sediments. Relatively few organisms were observed in the inner harbor. Organisms observed include crabs, starfish, attached anemones, and burrowing macroinvertebrates. Very little attached algae were noted.

In contrast to the inner harbor, a higher density of organisms was observed at the reference site. These included small fish, crabs, burrowing macroinvertebrates, and sea cucumbers. Attached algae were plentiful. There was no evidence of sulfur-reducing bacteria mats. Most of the wood debris observed at the reference site was tree branches.

On a larger scale, a significant accumulation of wood chips was observed on the north side of the chip barge loading area at low tide. This accumulation is shown below in Figure 8.

The accumulation of wood chips appears to be the result of wind drift during barge loading operations. Implementation of best management practices during loading operations would greatly reduce this loss of chips into the marine environment.

Figure 8. Chip Barge Loading Area at Simpson Mill, Shelton.

Current wood handling practices in inner Shelton Harbor are summarized in Figure 9. This summary was compiled from field observations and aerial photos. It is generalized representation of wood handling practices only, since a detailed survey was not performed.

Log transfer facilities in the inner harbor include the Simpson train dump located in the central portion of the harbor, a truck dump on the north side of the harbor, and the Manke truck dump along the south shore. The greatest volume of logs appears to be handled by the train dump. Logs are rafted immediately adjacent to these unloading areas. Raft storage usually occurs in the outer part of the harbor.

No clear correlation was observed between different log handling areas and the amount of wood debris observed on the sediment surface. All areas examined had a patchy distribution of wood with some areas of heavy accumulations. Other studies on the distribution of wood debris associated with log handling operations have indicated that the majority of wood debris lost to sediments is bark, which is dislodged during transfer operations (HDG, 1999). However, the accumulation rate of bark and wood debris is extremely variable, presumably due to the ability of currents (both tidal and vessel induced) and wave action to disperse the debris over a wide area (Pease, 1974; O'Clair and Freese, 1988). This theory might explain the distribution of wood observed in the inner harbor.

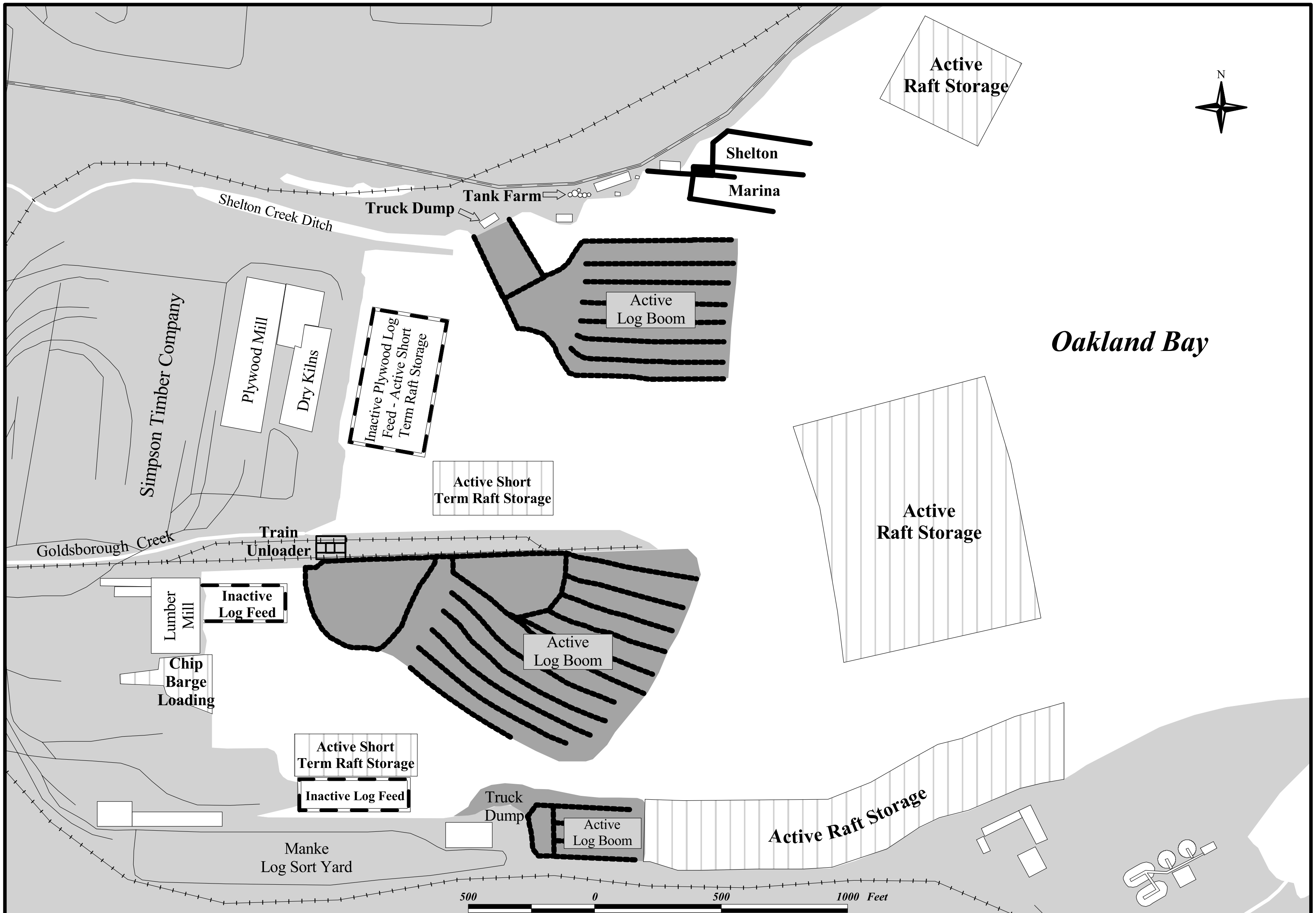

Figure 9. Summary of Wood Handling Activities in Inner Shelton Harbor

The most severe biological effects would be expected in those areas of the harbor where wood debris coverage of the bottom approached 100%, because infauna is cut off from the sediment-water interface. In one study from southeast Alaska, a decline in the survival of the littleneck clams (*Protothaca stamina*) and bay mussels (*Mytilus edulis*) was observed when bark reached a depth of 6 cm. Survival of these two species declined most rapidly between 10-15cm of bark accumulation (O'Clair and Freese, 1987).

Given the potential for impacts on benthic communities from bark accumulations and the apparent low numbers of organisms observed in the inner harbor, biological testing (benthic macroinvertebrates) is recommended for selected areas in the inner harbor. This sampling would most likely target areas of S6, S7, and S8. The purpose of the testing would be to determine if adverse effects to biological resources exceed the SMS criteria in areas with heavy accumulations of wood debris.

On a broader scale, using log handling practices that avoid in-water contact of logs (rafting and transport) are preferred. Implementation of this type of best management practice would be the most effective way to eliminate concerns about adverse impacts from ongoing loss of wood debris into the marine environment.

Conclusions

Concentrations of metals and organics were relatively low at the ten nearshore sites evaluated for chemical contamination in inner Shelton Harbor. Most of the contamination at these sites seemed to be associated with specific sources. Nineteen violations of the sediment quality standards were noted at the ten sites tested.

- Seven of these exceedances were also above cleanup screening levels. Chemicals exceeding the cleanup screening levels included benzoic acid (sites SCS-2, SCS-5, and SCS-8), 4-methylphenol and 2,4-dimethylphenol (SCS-4), and copper (SCS-6, SCS-7).
- Tributyltin concentrations adjacent to an old marine railway (SCS-6) and at the Shelton Marina (SCS-9) exceeded the PSDDA/SMS interim screening level of 73ugTBT/kg.
- PCBs were low at all sites tested.
- Low to moderate pentachlorophenol contamination was measured throughout inner Shelton Harbor.

A combination of physical measurements (total organic carbon, grain size, total volatile solids) and qualitative observations (field descriptions, digital photos, and towed underwater video) was used to estimate the distribution of wood debris in the inner harbor. In general, the highest wood levels were measured in the southwest portion of the harbor (strata S7, S8). Four strata (S6, S7, S8, S9) had significantly higher levels of wood than the reference site. Within the inner harbor, only strata S4 and S7 were statistically different. Based on means, none of the strata exceeded 25% wood by weight (as measured by total volatile solids); an exceedence would usually require biological testing to be performed under the PSDDA regulations. Three organic compounds (benzoic acid, phenol, 4-methylphenol) associated with wood debris were measured at concentrations above the SMS cleanup screening levels in composite samples from four of the strata.

Underwater video examination of the area indicated a patchy distribution of wood debris, ranging from a clean bottom to bark accumulations that completely covered the sediment surface. The predominant wood debris was bark. Sulfur-reducing bacteria mats also covered much of the sediment surface in the inner harbor, which would indicate anoxic conditions in the sediments. Implementation of best management practices at the chip barge loading area is recommended to control the loss of chips into the marine environment during barge loading operations.

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Recommendations

Based on the results of this study, the following recommendations are made:

Chemical Screening Sites

- The following chemical screening stations had violations of the Sediment Management Standards (SMS) cleanup screening levels. Given the lack of widespread contamination, no immediate remedial action is recommended. However, any activities with the potential to disturb sediments in these areas should include prior sediment monitoring for the chemicals listed. The purpose of this monitoring would be to evaluate the potential for (1) transporting contaminated sediments to adjacent areas and (2) determining appropriate disposal options for the material if dredging is being considered.

Table 10. Summary of Chemical Screening Station Violations of the Sediment Management Standards.

Station ID	Chemical	Elevation Factor Above CSL
SCS-2	Benzoic Acid	1.2
SCS-4	4-Methylphenol	3.9
	2,4-Dimethylphenol	1.3
SCS-5	Benzoic Acid	1.5
SCS-6	Copper	1.3
SCS-7	Copper	1.2
SCS-8	Benzoic Acid	1.1

- Tributyltin concentrations in bulk sediment from station SCS-6 (old marine railway) and at SCS-9 (Shelton Marina) exceeded the PSDDA/SMS interim screening level of 73 ugTBT/kg. In addition, SCS-6 exceeded the Cleanup Screening Levels (CSL) for copper. Biological testing of sediments should be considered for both locations to determine the potential for adverse biological effects.

Wood Waste Strata

- Immediately develop and implement best management practices to control the release of wood chips into the marine environmental during barge loading operations at the Simpson Mill.

- Biological testing should be considered for areas with heavy surface accumulations of bark and chemicals exceeding the CSL, to determine if a healthy benthic community is present. Potential areas to target include strata S6, S7, and S8. If dredging activities are planned for these areas, it would be appropriate to include biological testing as part of the dredging requirements.

- If adverse effects are indicated in the biological testing program, more accurate mapping of wood debris should be considered. This effort should include a much higher density of stations than was used in the present study, in order to accurately map the distribution of wood debris in inner Shelton Harbor. If this work is undertaken, a combination of Sediment Vertical Profile Imaging, Plan View Photos, and towed underwater video is recommended.

- Where possible, consider implementation of log handling practices that avoid in-water contact. This would be the best way to eliminate concerns associated with the loss of wood debris into the marine environment.

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Appendices

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Appendix A

Station Descriptions and Positions
and
Sediment Sample Descriptions

Chemical Screening Sites
CTD Profiles
Wood Waste Strata

Table A1: Station Descriptions for Shelton Harbor Sediment Investigation

I. Chemical Screening Stations

Station ID	Description	Average Depth @MLLW (ft)
SCS-1	Below South Shore Sort Yard	Intertidal
SCS-2	Below Manke Machine Shed	Intertidal
SCS-3	South Shore Marine Lab Drainage	Intertidal
SCS-4	Below Outfall Center of Chip Barge Dock	11
SCS-5	Sawmill Log Feed	10
SCS-6	North Shore Base of Vessel Haul-Out Railway	Intertidal
SCS-7	Adjacent to Boat Crib at Marina	Intertidal
SCS-8	North Shore Below Tank Farm	Intertidal
SCS-9	Shelton Marina	14
SCS-10	North Shore Near Shellfish Operation	39
REF	Reference Area	16

II. CTD Profiles

Station ID	Description	Depth @ Sampling MLLW (ft)
CTD-1	Inner Harbor near Chip Barge Loading Area	16
CTD-2	Near Manke Log Loading Dock	12
CTD-3	South Shore middle of Manke Log Boom	9
CTD-4	East End of Manke Boom Grounds	14
CTD-5	Shelton Marina	17
CTD-6	North of Goldsborough Cr. Boom Grounds	7

III. Wood Waste Strata

Strata	Description	No. Stations	% of Total Area	Average Depth @MLLW (ft)
S1	Outer Harbor North Central Portion	4	12.7	16
S2	Shelton Marina	3	4.4	8
S3	Inner Harbor South of Goldsbourgh Cr.	5	14.9	0
S4	Inner Harbor North of Goldsbourgh Cr.	5	20.9	0
S5	North Shore Inner Harbor	4	8.7	0.6
S6	Outer Harbor South Shore	4	10.2	1
S7	Inner Harbor South Shore	4	8.9	7
S8	Inner Harbor Chip Barge Dock	3	3.4	5
S9	Outer Harbor South Central Portion	5	15.9	9
REF	Reference Area	3	-	16
	Total	40	100	

Table A2: Station Positions for Inner Shelton Harbor Sediment Investigation.

I. Chemical Screening Stations

	Latitude		Longitude	
No.	Deg	Min	Deg	Min
SCS-1	47	12.368	123	5.313
SCS-2	47	12.389	123	5.380
SCS-3	47	12.386	123	5.571
SCS-4	47	12.477	123	5.689
SCS-5	47	12.528	123	5.669
SCS-6	47	12.823	123	5.259
SCS-7	47	12.865	123	5.173
SCS-8	47	12.837	123	5.238
SCS-9	47	12.840	123	5.070
SCS-10	47	13.110	123	4.728
REF	47	12.443	123	3.883

Datum= WGS84

II. CTD Profiles

	Latitude		Longitude	
No.	Deg	Min	Deg	Min
CTD-1	47	12.476	123	5.677
CTD-2	47	12.424	123	5.443
CTD-3	47	12.428	123	5.059
CTD-4	47	12.444	123	5.824
CTD-5	47	12.837	123	5.108
CTD-6	47	12.735	123	5.073

Datum= WGS84

Table A2 (cont): Station Postions for Inner Shelton Harbor Sediment Investigation.

III. Wood Waste Strata

Strata 1- Outer Harbor North Central Portion

Station	Site 1		Site 2		Site 3		Site 4	
Latitude	47	12.695	47	12.755	47	12.716	47	12.819
Longitude	123	4.878	123	4.995	123	4.937	123	4.990

Strata 2- Shelton Marina

Station	Site 1		Site 2		Site 3	
Latitude	47	12.901	47	12.866	47	12.819
Longitude	123	5.038	123	5.056	123	5.217

Strata 3- Inner Harbor South of Goldsbourgh Creek

Station	Site 1		Site 2		Site 3		Site 4		Site 5	
Latitude	47	12.471	47	12.539	47	12.478	47	12.520	47	12.582
Longitude	123	5.200	123	5.257	123	5.346	123	5.386	123	5.242

Strata 4- Inner Harbor North of Goldsbourgh Creek

Station	Site 1		Site 2		Site 3		Site 4		Site 5	
Latitude	47	12.620	47	12.722	47	12.664	47	12.724	47	12.613
Longitude	123	5.373	123	5.358	123	5.440	123	5.286	123	5.164

Strata 5- North Shore Inner Harbor

Station	Site 1		Site 2		Site 3		Site 4	
Latitude	47	12.746	47	12.794	47	12.726	47	12.789
Longitude	123	5.190	123	5.274	123	5.199	123	5.173

Strata 6- Outer Harbor South Shore

Station	Site 1		Site 2		Site 3		Site 4	
Latitude	47	12.414	47	12.370	47	12.413	47	12.383
Longitude	123	4.907	123	5.035	123	4.867	123	5.248

Strata 7- Inner Harbor South Shore

Station	Site 1		Site 2		Site 3		Site 4	
Latitude	47	12.521	47	12.416	47	12.494	47	12.462
Longitude	123	5.535	123	5.284	123	5.500	123	5.520

Strata 8- Inner Harbor Chip Barge Loading Dock

Station	Site 1		Site 2		Site 3	
Latitude	47	12.524	47	12.444	47	12.504
Longitude	123	5.584	123	5.561	123	5.547

Strata 9- Outer Harbor South Central Portion

Station	Site 1		Site 2		Site 3		Site 4		Site 5	
Latitude	47	12.499	47	12.557	47	12.597	47	12.469	47	12.474
Longitude	123	4.891	123	4.912	123	4.820	123	4.811	123	5.127

Strata REF- Reference Area

Station	Site 1		Site 2		Site 3	
Latitude	47	12.433	47	12.448	47	12.445
Longitude	123	3.833	123	3.884	123	3.893

Positions listed in Deg/min
Datum= WGS84

Table A3: Sample Descriptions for Inner Shelton Harbor Sediment Samples

Site: Chemical Screening Stations

Station No	Grab No.	Depth (ft)	Date	Time	Penetration (cm)	Sample Description
1	1	0	05/17/99	1415	10	Black mud w/H2S odor and Wood chips
2	1	0	05/17/99	1436	10	Black Sandy Silt w/ wood fibers H2S odor, some shell
3	1	0	05/18/99	1250	10	Brown to black silt scattered gravel, cobble, no wood
4	1	19	05/18/99	1030	12	Gravel w/some sand wood fibers, oil droplets
-	2	22	05/18/99	1035	12	Range of wood fibers: chips, bark in sand and silt (brown)
-	3	18	05/18/99	1042	12	Sandy with some gravel, shell debris, wood chips, oil present
5	1	21	05/18/99	1000	17	Gray to black silty sand and Oil Droplets
-	2	25	05/18/99	1007	17	Black to gray silt w/ black layer underneath, wood fibers, oil drops
-	3	19	05/18/99	1013	17	Black to gray silt w/ black layer underneath, wood fibers, oil drops
6	1	0	05/17/99	1330	10	Black to gray silt w/gravel and shell, H2S odor
7	1	0	05/17/99	1318	10	Gray to black mud with rock and shell
8	1	0	05/17/99	1330	10	Black to gray silt/sand w/ H2S odor, rock and shell, oil droplets
9	1	24	05/17/99	1010	17	Gray silty clay uniform
-	2	24	05/17/99	1020	17	Gray silty clay uniform
-	3	23	05/17/99	1030	17	Gray silty clay uniform
10	1	51	05/17/99	1045	10	Gray to brown sandy silt with shell fragments and sticks, rocks
-	2	37	05/17/99	1100	10	Shell debris covering gray sandy silt
-	3	52	05/17/99	1110	9	Brown gray silt covered with small bark debris
Ref-1	1	20	05/17/99	1140	11	Gray sandy silt, no debris
Ref-2	1	20	05/17/99	1155	9.5	Gray sandy silt, no debris
Ref-3	1	19	05/17/99	1210	15	Gray sandy silt, uniform

Site: Wood Waste Strata

Station No	Grab No.	Depth (ft)	Date	Time	Penetration (cm)	Sample Description
S1-1	1	15	05/18/99	1400	15	Gray to brown silt w/ black underneath. Wood at depth
S1-2	1	16	05/18/99	1420	16	Gray to brown sandy silt w/ black material at depth, very little wood
S1-3	1	14	05/18/99	1435	17	Gray to brown sandy silt w/ black at depth, little wood
S1-4	1	17	05/18/99	1445	17	Gray sandy silt deep oxygenated layer, no wood
S2-1	1	25	05/19/99	1015	17	Brown to grat silt w/ wood chunks @ depth >10cm. No odor
S2-2	1	26	05/19/99	1000	14	Gray to brown silt and clay shells, wood chunks, and red algae no odor
S2-3	1	10	05/19/99	0945	9	Gray to brown silt w/ gravel underneath some shell, no wood
S3-1	1	9	05/20/99	1120	14	Gray to black some with silt shells and smaller wood fragments
S3-2	1	8	05/20/99	1155	14	Brown to black silt w/ small wood at depth H2S
S3-3	1	17	05/20/99	1145	17	Brown to gray silt w/ wood at depth, black material H2S
S3-4	1	12	05/20/99	1140	14	Gray to black silty sand a lot of wood debris H2S smell
S3-5	1	2	05/20/99	1205	9	Hard clayey sand, brown some small bark, black @ depth
S4-1	1	13	05/19/99	1045	14	Brown to gray silty sand very little wood debris, oil droplets, no odor
S4-2	1	9	05/19/99	1100	14	Brown to gray sand silt, some shell, wood debris at depth, slight odor and sheen
S4-3	1	9	05/19/99	1115	14	Brown sand w/ sticks, took 3 grabs to get sample, some oil sheen
S4-4	1	13	05/19/99	1130	9	Main shell debris w/ some sand
S4-5	1	6	05/19/99	1145	10	Brown silty sand some shell, little wood
S5-1	1	8	05/19/99	1215	11	Brown silty mud, wood debris @ depth
S5-2	1	4	05/19/99	1245	17	Brown silty mud, wood debris @ depth
S5-3	1	7	05/19/99	1310	9	Gray sand w/ shell debris, wood debris @ depth
S5-4	1	7	05/19/99	1250	14	Brown silty mud, wood debris throughout
S6-1	1	12	05/20/99	1220	16	Brown to black silty wood plentiful @ depth, H2S odor
S6-2	1	5	05/20/99	1240	14	Brown to gray sandy silt, some wood and gravel at depth
S6-3	1	8	05/20/99	1230	16	Brown sandy silt wood @ depth, deep aerobic layer (5cm)
S6-4	1	12	05/20/99	1300	12	Brown to black silt w/ abundant wood H2S thin aerobic layer
S7-1A	1	14	05/18/99	1135	17	Gray to black silt w/ black underneath, some wood at depth, H2S smell
S7-2	1	9	05/18/99	1200	16	Brown organic sediment w/ some wood chunks at depth
S7-3	1	12	05/18/99	1220	17	Brown to black silt w/ H2S odor, some wood chips at depth
S7-4	1	12	05/18/99	1230	17	Variety of wood debris throughout. Bark, chips, black material
S8-1	1	15	05/18/99	1100	17	Silts, Gray with Black underneath
S8-2	1	13	05/18/99	1109	17	Gray to brown silt some wood at depth
S8-3	1	15	05/18/99	1115	17	Gray to black silt, some H2S. Some wood debris at depth
S9-1	1	23	05/20/99	0945	14	Gray to black silt H2S odor. Some shell, little wood debris
S9-2	1	21	05/20/99	1100	17	Gray to brown silty wood @ depth
S9-3	1	23	05/20/99	0945	12	Gray to black silt w/ lots of bark chips, H2S odor, oil droplets
S9-4	1	24	05/20/99	1015	14	Gray to black silt some wood. H2S odor
S9-5	1	13	05/20/99	1035	12	Gray sandy silt some shell and wood debris

Recorder: Dale Norton

Table A4: CTD Profile Descriptions for Inner Shelton Harbor Study.

Site: CTD Casts

Station	Depth (ft)	Date	Time	Bottle No.	Description
CTD-1	16	05/20/99	1350	2	Near Chip Barge Dock
CTD-2	11.5	05/20/99	1401	3	Off Manke Loading Dock
CTD-3	9	05/20/99	1411	4	Middle of Manke Storage Boom
CTD-4	13.5	05/20/99	1421	5	East End of Boom Grounds
CTD-5	17	05/20/99	1431	6	Shelton Marina
CTD-6	6.5	05/20/99	1438	7	North of Goldsborough Boom Grounds

Recorder: Dale Norton

Appendix B

Summary of Analytical Results

Conventionals
Metals
Organics

Table B1: Results of Total Organic Carbon and Grain Size Analysis of Inner Shelton Harbor Sediments.

Station ID	Sample No.	%TOC @70°C	%TOC @104°C	% Gravel (>2mm)	% Sand (2mm-62um)	% Silt (62-4um)	% Clay (<4um)
Chemical Screening Stations							
SCS-1	99208500	9.2	9.2	1.6	58.5	29.9	9.5
SCS-2	99208501	10.6	12.0	1.3	20.4	56.9	21.1
SCS-3	99208502	2.4	2.6	40.8	36.6	17.1	5.5
SCS-4	99208503	8.4	8.2	44.7	25.5	24	5.8
SCS-5	99208504	6.0	6.3	0.6	11.5	60.8	27.1
SCS-6	99208505	1.9	2.0	20.2	40.0	31.5	8.3
SCS-7	99208506	2.0	2.1	0	38.2	43.9	17.9
SCS-8	99208507	1.6	1.6	5.2	46.2	39.8	8.5
SCS-9	99208508	2.7	2.8	0	38.2	43.9	17.9
SCS-10	99208509	1.1	1.0	17.9	66.4	9.6	6.1
REF-1	99208548	0.4	0.4	0.1	86.6	9	4.3
REF-2	99208549	0.4	0.4	0	89.4	7	3.6
REF-3	99208550	0.7	0.9	0	91.6	5.2	3.2
Wood Waste Stations							
S1-1	99208511	1.9	1.9	0.1	67.5	22.4	10
S1-2	99208512	2.2	2.2	0.1	55.8	32.4	11.7
S1-3	99208513	2.1	2.2	0.1	59.3	30.3	10.3
S1-3(dup)	99208552	2.4	2.5	0.1	59.1	28.9	11.9
S1-4	99208514	2.2	2.2	0	50.6	35.4	14
S2-1	99208515	3.3	3.4	0.5	56.8	25.7	16.9
S2-2	99208516	3.0	3.1	0.9	48.7	35.4	15
S2-3	99208517	1.7	1.7	21.7	39.3	21.9	11.3
S3-1	99208518	2.4	2.5	1.2	58.1	29.7	11
S3-2	99208519	4.5	4.7	0.6	21.6	58	19.8
S3-3	99208520	6.7	7.2	1.5	21.6	54.9	22
S3-4	99208521	9.2	9.0	1.1	30.2	51.1	17.6
S3-5	99208522	1.1	1.1	0	62.5	32.8	4.7
S4-1	99208523	1.0	1.0	0.8	93.7	4.1	1.4
S4-2	99208524	1.1	1.1	0.6	72.5	21.4	5.2
S4-3	99208525	0.3	0.3	0.8	93.7	4.1	1.4
S4-4	99208526	0.6	0.7	31.1	59.3	4.8	1.8
S4-5	99208527	2.4	2.5	1.2	42	43.5	12.4
S5-1	99208528	3.0	3.1	1.5	46.2	40.6	11.7
S5-2	99208529	5.2	5.4	0.3	22	58.6	19.1
S5-3	99208530	1.2	1.2	7.9	74.9	12.2	4.2
S5-4	99208531	3.8	3.7	1.8	23	53	22
S6-1	99208532	4.1	4.1	1.1	24.1	56.7	18.1
S6-2	99208533	3.1	3.2	0.2	35.6	43.5	20.7
S6-3	99208534	3.1	3.3	1.5	44.5	41.1	12.9
S6-4	99208535	5.7	5.7	1.3	25.1	61.4	12.2

Table B1 (cont): Results of Total Organic Carbon and Grain Size Analysis of Inner Shelton Harbor Sediments.

Station ID	Sample No.	%TOC @70°C	%TOC @104°C	% Gravel (>2mm)	% Sand (2mm-62um)	% Silt (62-4um)	% Clay (<4um)
Wood Waste Stations							
S7-1	99208536	5.7	5.9	0.5	16	59.7	23.8
S7-2	99208537	4.6	4.9	0.6	30.2	51	18.2
S7-3	99208538	5.7	6.0	0	21.9	57	21.1
S7-4	99208539	7.5	7.9	3.4	30	50.6	16
S8-1	99208540	6.5	6.6	0.1	20.7	58.3	25.4
S8-2	99208541	6.9	7.3	0.4	26.9	55.6	17.1
S8-2(dup)	99208553	8.1	8.5	0.4	24.8	52.2	22.6
S8-3	99208542	5.9	6.2	0.1	22.7	54.4	22.8
S9-1	99208543	3.3	3.5	0.1	31.9	48.3	19.7
S9-2	99208544	2.7	2.8	0	36.9	7.1	56
S9-3	99208545	3.0	3.1	0.7	36.6	42.2	20.5
S9-4	99208546	3.9	4.2	0.4	31.6	46.6	21.4
S9-5	99208547	1.5	1.5	0.5	71.1	19.6	8.8

Table B2: Total Volatile Solids, Total Solids, and Wood Content of Inner Shelton Harbor Sediments.

		>1/4" Fraction			<1/4" Fraction			Total Wood by	Total Wood by
Station ID	Sample No.	% Retained	Tot. Sol (%)	TVS (%)	% Retained	Tot. Solids (%)	TVS (%)	Weight (%)	Volume (%)
S1-1	99208511	0.5	32.3	53.6	99.5	53.3	5.9	6.1	12.3
S1-2	99208512	0.0	-	-	100.0	50.3	7.3	7.3	14.6
S1-3	99208513	0.3	42.8	64.4	99.7	51.4	6.1	6.3	12.5
S1-3(dup)	99208552	0.1	57.6	7.6	99.9	50.9	5.8	5.8	11.6
S1-4	99208514	0.2	58.3	94.9	99.8	49.2	9.3	9.5	18.9
S2-1	99208515	0.6	41.8	79.5	99.4	44.7	12.5	12.9	25.8
S2-2	99208516	1.5	47.4	75.8	98.5	45.5	14.9	15.8	31.6
S2-3	99208517	49.9	95.4	0.8	50.1	59.3	6.1	3.5	7.0
S3-1	99208518	1.3	51.3	59.5	98.7	48.1	6.9	7.6	15.2
S3-2	99208519	0.3	28.2	36.6	99.7	35.3	11.6	11.7	23.4
S3-3	99208520	4.7	31.7	10.4	95.3	30.6	16.3	16.0	32.0
S3-4	99208521	6.6	31.1	24.0	93.4	29.6	26.8	26.6	53.2
S3-5	99208522	0.1	12.1	20.1	99.9	61.2	4.0	4.0	8.0
S4-1	99208523	0.2	15.2	55.6	99.8	63.2	3.7	3.8	7.6
S4-2	99208524	0.5	41.5	67.7	99.5	61.7	5.1	5.4	10.8
S4-3	99208525	0.0	19.0	43.5	100.0	77.1	2.0	2.0	4.0
S4-4	99208526	6.2	74.5	89.3	93.8	76.1	2.0	7.4	14.8
S4-5	99208527	0.0	26.5	7.4	100.0	53.1	7.0	7.0	14.0
S5-1	99208528	4.2	33.1	22.7	95.8	46.4	9.6	10.2	20.3
S5-2	99208529	1.7	59.3	22.4	98.3	36.1	10.1	10.3	20.6
S5-3	99208530	4.2	76.8	6.8	95.8	67.8	3.7	3.8	7.7
S5-4	99208531	5.8	30.8	76.4	94.2	37.4	12.7	16.4	32.8
S6-1	99208532	2.7	32.7	53.7	97.3	33.5	12.1	13.2	26.4
S6-2	99208533	5.0	55.2	31.9	95.0	44.8	8.1	9.3	18.6
S6-3	99208534	3.2	62.5	18.0	96.8	43.8	9.6	9.9	19.7
S6-4	99208535	9.4	27.4	75.6	90.6	32.1	16.6	22.1	44.3
S7-1	99208536	0.5	46.9	27.9	99.5	30.8	14.1	14.2	28.3
S7-2	99208537	0.9	24.7	73.1	99.1	33.2	12.9	13.4	26.9
S7-3	99208538	0.9	26.5	81.1	99.1	30.9	15.8	16.4	32.8
S7-4	99208539	11.3	30.4	84.3	88.7	28.2	23.0	29.9	59.9
S8-1	99208540	2.5	15.5	89.5	97.5	28.3	16.8	18.6	37.3
S8-2	99208541	2.1	44.5	34.2	97.9	29.1	17.2	17.6	35.1
S8-2(dup)	99208553	2.0	26.6	74.8	98.0	29.1	17.2	18.4	36.7
S8-3	99208542	0.6	23.0	71.8	99.4	30.7	16.0	16.3	32.7
S9-1	99208543	1.4	30.1	69.5	98.6	39.4	10.1	10.9	21.9
S9-2	99208544	0.2	24.7	58.7	99.8	40.8	8.3	8.4	16.8
S9-3	99208545	9.0	23.0	90.4	91.0	41.8	26.6	32.3	64.7
S9-4	99208546	1.6	40.1	49.3	98.4	37.1	11.4	12.0	24.0
S9-5	99208547	0.4	29.6	70.5	99.6	57.0	5.9	6.2	12.3
REF-1	99208548	0.0	-	-	100.0	66.6	2.0	2.0	4.0
REF-2	99208549	0.1	83.3	3.3	99.9	69.4	1.3	1.3	2.6
REF-3	99208550	0.0	8.0	77.4	100.0	68.0	1.8	1.8	3.6

Table B3: Summary of Metals Analysis of Inner Shelton Harbor Sediment Samples from Chemical Screening Sites.

Station	SCS-1		SCS-2		SCS-3		SCS-4		SCS-5		SCS-6		SCS-7	
Sample No. 20-	8500		8501		8502		8503		8504		8505		8506	
Metals (mg/kg,dry)														
Arsenic	2.97		4.97		3.94		3.84		5.69		4.82		4.54	
Cadium	0.5	u	0.76		0.5	u	0.78		1.1		0.5	u	0.76	
Chromium	31.5		41.1		44.9		43		47.4		37		39	
Copper	42.4		56.7		51.6		149		71.5		493		447	
Lead	11		21.6		18		56.2		20		39.4		13	
Mercury	0.07		0.15		0.18		0.45		0.50		0.16		0.31	
Silver	0.4	u	0.4	u	0.4	u	0.4	u	0.4	u	0.4	u	0.4	u
Zinc	89.3		110		78.6		106		106		179		175	

Station	SCS-8		SCS-9		SCS-9 (Dup)		SCS-10		SCS-REF	
Sample No. 20-	8507		8508		8551		8509		8510	
Metals (mg/kg,dry)										
Arsenic	3.18		5.35		5.24		3.31		3	
Cadium	0.5	u	0.73		0.80		0.5	u	0.5	u
Chromium	37.1		39.8		41.9		30		24.7	
Copper	115		42.1		41.1		18.2		12	
Lead	20		12		13		3.6		2.5	
Mercury	0.06		0.10		0.13		0.03		0.02	
Silver	0.4	u	0.4	u	0.4	u	0.4	u	0.4	u
Zinc	103		88		92.8		51		36.9	

u= Not detected at detection limit shown

Table B4: Summary of Organics Detected in Inner Shelton Harbor Sediment Samples- Chemical Screening Sites.

Station	SCS-1		SCS-2		SCS-3		SCS-4		SCS-5		SCS-6		SCS-7		SCS-8		SCS-9		SCS-9 (Dup)		SCS-10		SCS-REF	
Sample No. 20-	8500		8501		8502		8503		8504		8505		8506		8507		8508		8551		8509		8510	
Semivolatiles (ug/kg, dry)																								
Acenaphthene	18		81		9		656		313		33		129		113		26		37		1.7	j	1.3	j
Acenaphthylene	7.9	u	45		13		305		180		32		257		103		38		48		3.4	j	7.2	
Naphthalene	19		257		104		3970		1170		70		453		243		203		262		39		53	
Fluorene	25		88		15		516		330		43		159		139		37		45		6.4	u	3.6	j
Anthracene	25		156		26		396		569		103		566		296		80		93		6.7		7	
Phenanthrene	133		474		109		2940		1520		366		865		2210		248		289		33		45	
Sum LPAH	220		1100		280		8800		4100		650		2400		3100		630		770		84	j	120	j
Fluoranthene	297		1120		162		2840		3270		892		4060		6190		456		653		68		50	
Benzo(a)anthracene	59		368		44		264		1010		360		1680		1190		131		209		15		14	
Chrysene	111		417		57		364		1000		432		2760		2040		195		351		22		15	
Pyrene	227		728		128		3840		2990		846		5290		5780		524		881		43		53	
Benzo fluoranthenes	108	j	376	j	103	j	473		1611	j	708		2344		2052		225		369		37.5		23	
Benzo(a)pyrene	48	j	235	j	38	j	212		571	j	259		1140		647		104		139		14		11	
Dibenzo(a,h)anthracene	7.9	uj	12	uj	5	uj	15		75	j	45		182		87		27		32		6.4	u	5.3	u
Indeno(1,2,3-cd)pyrene	7.9	uj	40	j	27	j	34		347	j	192		147		77		73		96		6.4	u	9.3	
Benzo(g,h,i)perylene	7.9	uj	229	j	34	j	247		467	j	176		602		269		109		120		21		9.7	
Sum HPAH	830	j	3500	j	590	j	5300		11000	j	3900		18000		18000		1800		2900		220		190	
1-Methylnaphthalene	5.7	j	35		6.9		311		124		17		47		215		16		16		1.7	j	0.11	j
2-Methylnaphthalene	8.4		50		13		406		198		25		73		380		28		33		3.5	j	2	j
Dibenzofuran	21		90		19		470		342		35		116		112		45		58		9.1		6.5	
Carbazole	26	u	12	u	21	u	94		200		51		126		250		100		36	u	23	u	5.3	u
Retene	1290		746		153		11000		3450		110		158		92		170		223		325		25	
Phenol	515		263	u	343		475		396	u	77	u	109	u	120	u	8.7	u	75	u	64	u	64	u
2-Methylphenol	20		12	u	5.2	u	5.6	u	19	u	6.1	u	6.2	j	6.1	j	8.7	u	8.6	u	6.4	u	5.3	u
4-Methylphenol	160		223		113		2610		562		66		111		59		65		130		41		33	
2,4-Dichlorophenol	16	u	24	u	11	u	9.5	j	39	u	12	u	15	u	14	u	18	u	17	u	13	u	11	u
2,4-Dimethylphenol	7.9	u	12	u	5.2	u	37		19	u	6.1	u	7.4	u	6.8	u	8.7	u	8.6	u	6.4	u	5.3	u
Pentachlorophenol	130	u	241	nj	104	j	313		401	j	159		376		142		170		181		125		87	
2,4-Dimethylphenol	7.9	u	12	u	5.2	u	37		19	u	6.1	u	7.4	u	6.8	u	8.7	u	8.6	u	6.4	u	5.3	u
2,4,6-Trichlorophenol	16	u	24	u	11	u	14	n	39	u	12	u	15	u	14	u	18	u	17	u	13	u	11	u
2,4,5-Trichlorophenol	16	u	24	u	11	u	28		39	u	12	u	13	j	14	u	18	u	17	u	13	u	11	u

-= Not analyzed
u=Not detected at detection limit shown
j=Estimated concentration
uj=Estimated detection limit
nj= Presumptive evidence of material

Table B4 (cont.): Summary of Organics Detected in Inner Shelton Harbor Sediment Samples- Chemical Screening Sites.

Station	SCS-1		SCS-2		SCS-3		SCS-4		SCS-5		SCS-6		SCS-7		SCS-8		SCS-9		SCS-9 (Dup)		SCS-10		SCS-REF	
Sample No. 20-	8500		8501		8502		8503		8504		8505		8506		8507		8508		8551		8509		8510	
Semivolatiles (ug/kg, dry)																								
Diethylphthalate	76		42	u	9.3	u	12		49	u	9	u	13	u	25	u	82		14	u	46	u	67	u
Dimethyl phthalate	7.9	u	12	u	5.2	u	5.6	u	19	u	29		7.4	u	290		6.2	j	8.6	u	6.4	u	2.5	j
Di-n-butyl phthalate	978		584	u	218	u	98	u	1590		2510	j	346	u	300	u	2020		222	u	435	u	647	
Bis(2EH)phthalate	204		516		183		77	u	659		935		112	u	190		318		184	u	48	u	74	u
1,4-Dichlorobenzene	7.9	u	12	u	5.2	u	9.7		19	u	6.1	u	3	j	6.8	u	8.7	u	6.6	j	6.4	u	5.3	u
Benzoic Acid	554	j	774	j	338	j	343	j	1040	j	468	j	507	j	702		464	j	450	j	583		420	j
3B-Coprostanol	158	uj	240	uj	105	uj	112	u	388	uj	98	j	256		137	u	768		140	j	170		55	j
1,2-Diphenylhydrazine	16	u	24	u	11	u	11		39	u	12	u	15	u	44	j	18	u	40		13	u	11	u
1,4-Dichlorobenzene	7.9	u	12	u	5.2	u	9.7		19	u	6.1	u	3	j	6.8	u	8.7	u	6.6	j	6.4	u	5.3	u
Butyltins (ug/kg, dry)																								
Monobutyltin Trichloride	-	-	-	-	-	-	-	-	-	-	1300		39		39		19	j	8.7	u	-	-	5.1	u
Dibutyltin Dichloride	-	-	-	-	-	-	-	-	-	-	4100		56		56		21		7.6	j	-	-	5.1	u
Tributyltin Chloride	-	-	-	-	-	-	-	-	-	-	1500		26		26		160		54		-	-	5.1	u
Tetrabutyltin	-	-	-	-	-	-	-	-	-	-	210	u	5.1	u	5.1	u	5.3	u	5.1	u	-	-	5.1	u
PCB'S (ug/kg, dry)																								
PCB - 1016	10	u	16	u	7.0	u	7.3	u	16	u	8.1	u	9.4	u	8.8	u	12	u	11	u	8.3	u	7.2	u
PCB - 1221	10	u	16	u	7.0	u	7.3	u	16	u	8.1	u	9.4	u	8.8	u	12	u	11	u	8.3	u	7.2	u
PCB - 1232	10	u	16	u	7.0	u	7.3	u	16	u	8.1	u	9.4	u	8.8	u	12	u	11	u	8.3	u	7.2	u
PCB - 1242	10	u	16	u	7.0	u	7.3	u	16	u	5.2	j	9.4	u	8.8	u	5.5	j	6.1	j	8.3	u	7.2	u
PCB - 1248	10	u	16	u	7.0	u	7.3	u	16	u	8.1	u	9.4	u	8.8	u	12	u	11	u	8.3	u	7.2	u
PCB - 1254	54		33		15		11		16	u	35		40		12	u	20		23		8.3	u	7.2	u
PCB - 1260	9.9		15		8.9		10		12	j	8.3		11		6.8	j	7.4	j	7.7	j	4.2	j	7.2	u
Total PCBs	64		48		24		21		12	j	43	j	51		6.8	j	33	j	37	j	4.2	j	-	

-= Not analyzed
u=Not detected at detection limit shown
j=Estimated concentration
uj=Estimated detection limit
nj= Presumptive evidence of material

Table B1 (cont): Results of Total Organic Carbon and Grain Size Analysis of Inner Shelton Harbor Sediments.

Station ID	Sample No.	%TOC @70°C	%TOC @104°C	% Gravel (>2mm)	% Sand (2mm-62um)	% Silt (62-4um)	% Clay (<4um)
Wood Waste Stations							
S7-1	99208536	5.7	5.9	0.5	16	59.7	23.8
S7-2	99208537	4.6	4.9	0.6	30.2	51	18.2
S7-3	99208538	5.7	6.0	0	21.9	57	21.1
S7-4	99208539	7.5	7.9	3.4	30	50.6	16
S8-1	99208540	6.5	6.6	0.1	20.7	58.3	25.4
S8-2	99208541	6.9	7.3	0.4	26.9	55.6	17.1
S8-2(dup)	99208553	8.1	8.5	0.4	24.8	52.2	22.6
S8-3	99208542	5.9	6.2	0.1	22.7	54.4	22.8
S9-1	99208543	3.3	3.5	0.1	31.9	48.3	19.7
S9-2	99208544	2.7	2.8	0	36.9	7.1	56
S9-3	99208545	3.0	3.1	0.7	36.6	42.2	20.5
S9-4	99208546	3.9	4.2	0.4	31.6	46.6	21.4
S9-5	99208547	1.5	1.5	0.5	71.1	19.6	8.8

Appendix C

Comparison to Sediment Management Standards (WAC 173-204)

Metals
Organics

Table C1: Comparison of Metals and Organics Concentrations in Inner Shelton Harbor Sediments- Chemical Screening Sites- to Ecology's Sediment Management Standards.

Station	SCS-1	SCS-2	SCS-3	SCS-4	SCS-5	SCS-6	SCS-7	SCS-8	SCS-9	SCS-10	SCS-REF	SMS	
Sample No. 20-	8500	8501	8502	8503	8504	8505	8506	8507	8508	8509	8510	SQS	CSL
Total Organic Carbon (%)	9.2	10.6	2.4	8.4	6.0	1.9	2.0	1.6	2.7	1.1	0.51		
Metals (mg/kg,dry)													
Arsenic	3	5	4	3.9	5.7	4.82	4.5	3.2	5.3	3.3	3	57	93
Cadium	0.5 u	0.76	0.5 u	0.78	1.1	0.5 u	0.76	0.5 u	0.8	0.5 u	0.5 u	5.1	6.7
Chromium	31.5	41.1	44.9	43	47	37	39	37.1	40.9	30	24.7	260	270
Copper	42	56.7	51.6	150	72	**490**	**450**	120	41.6	18.2	12	390	390
Lead	11	21.6	18	56.2	20	39.4	13	20	12.5	3.6	2.5	450	530
Mercury	0.07	0.15	0.18	**0.45**	**0.50**	0.16	0.31	0.06	0.1	0.03	0.02	0.41	0.59
Silver	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	0.4 u	6.1	6.1
Zinc	89	110	78.6	110	110	180	180	100	90.4	51	36.9	410	960
Organics (mg/kg, OC)													
Acenaphthene	0.2	0.76	9	7.8	5.2	1.7	6.5	7.1	1.2	0.2 j	0.3 j	16	57
Acenaphthylene	0.1 u	0.4	0.5	3.6	3.0	1.7	13	6.4	1.6	0.3 j	1.4	66	66
Naphthalene	0.2	2.4	4.3	47	20	3.7	23	15	8.6	3.5	10	99	170
Fluorene	0.3	0.8	0.6	6.1	5.5	2.3	8.0	8.7	1.5	0.6 u	0.7 j	23	79
Anthracene	0.3	1.5	1.1	4.7	9.5	5.4	28	19	3.2	0.6	1.4	220	1200
Phenanthrene	1.4	4.5	4.5	35	25	19	43	140	9.9	3.0	8.8	100	480
Sum LPAH	2.4	10	12	100	68	34	120	200	26	7.6 j	24 j	370	780
Fluoranthene	3.2	11	6.8	34	55	47	**200**	**390**	21	6.2	9.8	160	1200
Benzo(a)anthracene	0.6	3.5	1.8	3.1	17	19	84	74	6.3	1.4	2.7	110	270
Chrysene	1.2	3.9	2.4	4.3	17	23	**140**	**130**	10	2.0	2.9	110	460
Pyrene	2.5	6.9	5.3	46	50	45	260	360	26	3.9	10	1000	1400
Benzo fluoranthenes	1.2 j	3.5 j	4.3 j	5.6	27 j	37	120	130	11	3.4	4.5	230	450
Benzo(a)pyrene	0.5 j	2.2 j	1.6 j	2.5	9.5 j	14	57	40	4.5	1.3	2.2	99	210
Dibenzo(a,h)anthracene	0.1 uj	0.1 uj	1.8	0.2	1.3 j	2.4	9.1	5.4	1.1	0.6 u	1.0 u	12	33
Indeno(1,2,3-cd)pyrene	0.1 uj	0.4 j	1.1 j	0.4	5.8 j	10	7.4	4.8	3.1	0.6 u	1.8	34	88
Benzo(g,h,i)perylene	0.1 uj	2.2 j	1.4 j	2.9	7.8 j	9.3	30.1	17	4.2	1.9	1.9	31	78
Sum HPAH	9.0 j	33 j	27 j	63	190 j	210	900	**1100**	87	20	37	960	5300
2-Methylnaphthalene	0.1	0.5	0.5	4.8	3.3	1.3	3.7	24	3.0	0.3 j	0.4 j	38	64
Dibenzofuran	0.2	0.8	0.8	5.6	5.7	1.8	5.8	7.0	1.9	0.8	1.3	15	58
Dimethyl phthalate	0.1 u	0.1 u	0.2 u	0.1 u	0.3 u	1.5	0.4 u	18.0	0.2 j	0.6 u	0.5 j	53	53
Diethylphthalate	0.8	0.4 u	0.4 u	0.1	0.8 u	0.5 u	0.7 u	1.6 u	1.8	4.2 u	13 u	61	110
Di-n-butyl phthalate	11	5.5 u	9.1 u	1.2 u	27	130 j	17.0 u	19 u	42	40 u	130	220	1700
Bis(2EH)phthalate	2.2	4.9	7.6	0.9 u	11	**49**	5.6 u	12	9.3	4.4 u	14 u	47	78
1,4-Dichlorobenzene	0.1 u	0.1 u	0.2 u	0.1	0.3 u	0.3 u	0.2 j	0.4 u	0.2 j	0.6 u	1.0 u	3.1	9
Total PCBs	0.7	0.5	1.0	0.3	0.2 j	2.3 j	2.6	0.4 j	1.3 j	0.4 j	1.4 u	12	65
Organics (ug/kg, dry)													
Phenol	**520**	260 u	340	**480**	400 u	77 u	110 u	120 u	42 u	64 u	64 u	420	1200
2-Methylphenol	20	12 u	5.2 u	5.6 u	19 u	6.1 u	6.2 j	6.1 j	8.7 u	6.4 u	5.3 u	63	63
4-Methylphenol	160	220	110	**2600**	560	66	110	59	98	41	33	670	670
2,4-Dimethylphenol	7.9 u	12 u	5.2 u	**37**	19 u	6.1 u	7.4 u	6.8 u	8.7 u	6.4 u	5.3 u	29	29
Pentachlorophenol	240 nj	240 nj	100 j	310	**400 j**	160	**380**	140	180	130	87	360	690
Benzoic Acid	560 j	**770 j**	340 j	350 j	**1000 j**	470 j	510 j	**700**	460 j	580	420 j	650	650

u= Not detected at detection limit shown
SMS= Ecology Sediment Management Standards (WAC-173-204)
Bold= Value exceeds Sediment Quality Standard

j=Estimated concentration
uj=Estimated detection limit
n= Presumptive evidence of material

Table C2: Comparison of Organics Detected in Inner Shelton Harbor Sediments-Wood Waste Strata Composites- to Sediment Management Standards.

Station	S1-C	S2-C	S3-C	S4-C	S5-C	S6-C	S7-C	S8-C	S9-C	SMS	
Sample No. 20-	8554	8555	8556	8557	8558	8559	8560	8561	8562	SQS	CSL
Total Organic Carbon (%)	2.2	2.7	4.8	1.1	3.3	4.0	5.9	9.1	2.9		
Organics (mg/kg, OC)											
Acenaphthene	1.7 j	2.3	0.4	0.9	1.1	1.0	1.6	2.8	0.8	16	57
Acenaphthylene	2.1	2.3	0.5	0.4 j	0.5	0.9	1.2	1.2	1.2	66	66
Naphthalene	18	17	2.3	3.1	2.7	8.7	12	13	12	99	170
Fluorene	1.4 j	2.8	0.6	1.3	1.1	1.2	1.6	2.2	0.8	23	79
Anthracene	2.0	4.8	1.5	1.5	1.8	2.3	3.2	3.0 j	1.9 j	220	1200
Phenanthrene	8.5	14	4.8	7.5	5.5	6.9	8.1	11 j	6.7 j	100	480
Sum LPAH	34 j	44	10	15	13	21	27	33 j	24 j	370	780
Fluoranthene	12	25	11	12	12	13	14	16 j	11 j	160	1200
Benzo(a)anthracene	2.0	5.4	3.1	3.2	3.2	3.1	4.2	3.3 j	2.3 j	110	270
Chrysene	3.5	9.9	6.3	5.7	5.5	5.4	5.8	3.4 j	4.0 j	110	460
Pyrene	16 j	31	12	12	13	14	18	19 j	14 j	1000	1400
Benzo fluoranthenes	4.5 j	11	6.7	6.8	6.8	6.0	7.4 j	5.9 j	5.8 j	230	450
Benzo(a)pyrene	2.1 j	4.6	2.1	3.1	2.8	2.5	2.6	2.5 j	2.2 j	99	210
Dibenzo(a,h)anthracene	0.6 j	0.9	0.3	2.2	0.6	0.2 u	0.5	0.1 uj	0.3 uj	12	33
Indeno(1,2,3-cd)pyrene	1.3 j	2.9	1.3	2.7	1.8	0.4	0.4	0.3 j	0.2 j	34	88
Benzo(g,h,i)perylene	2.3 j	3.3	1.4	2.7	2.2	2.1	2.6	1.9 j	2.1 j	31	78
Sum HPAH	45 j	93	44	50	48	45	56 j	53 j	41 j	960	5300
2-Methylnaphthalene	1.1	1.9	0.3	0.6	0.4	0.8	1.4	1.7	0.9	38	64
Dibenzofuran	2.0 j	3.1	0.5	1.2	1.1	1.4	1.7	2.5	1.4	15	58
Diethylphthalate	0.4 u	1.6	0.2 u	5.5	0.2 u	0.2 u	1.5 u	0.4	0.6 u	61	110
Butylbenzylphthalate	1.7	1.8	0.3	1.5	0.2 u	0.2 u	0.2 u	0.1 uj	0.3 uj	4.9	64
Organics (ug/kg, dry)											
Phenol	60 u	8.9 u	51 u	5.6 u	44 u	**3000**	120 u	120 u	110 u	420	1200
4-Methylphenol	110	210	77	19 u	43 u	430	**1300**	**1200**	260	670	670
Pentachlorophenol	210	270	110	96	150	210	260	280 j	180 j	360	690
Benzoic Acid	350 j	**700** j	330 j	310 j	510 j	**710** j	**670** j	560 u	510 j	650	650
Benzyl alcohol	7 u	8.9 u	21 u	16 u	21 u	9.2 u	12	38 u	9.1 u	57	73

SMS= Ecology Sediment Management Standards (WAC 173-204)

u= Not detected at detection limit shown

j= Estimated concentration

Bold= Value exceeds Sediment Quality Standard

Table C3: Comparison of Nonionizable Organics in Inner Shelton Harbor Sediment Samples- Chemical Screening Sites- to the Dry Weight Apparent Effect Threshold Values.

Station	SCS-1	SCS-2	SCS-3	SCS-4	SCS-5	SCS-6	SCS-7	SCS-8	SCS-9	SCS-9 (Dup)	SCS-10	Dry Wt AET	
Sample No. 20-	8500	8501	8502	8503	8504	8505	8506	8507	8508	8551	8509	SQS	CSL
Organics (ug/kg, dry)													
Acenaphthene	18	81	9	**656**	313	33	129	113	26	37	1.7 j	500	500
Acenaphthylene	7.9 u	45	13	305	180	32	257	103	38	48	3.4 j	1300	1300
Naphthalene	19	257	104	**3970**	1170	70	453	243	203	262	39	2100	2100
Fluorene	25	88	15	516	330	43	159	139	37	45	6.4 u	540	540
Anthracene	25	156	26	396	569	103	566	296	80	93	6.7	960	960
Phenanthrene	133	474	109	**2940**	**1520**	366	865	**2210**	248	289	33	1500	1500
Sum LPAH	220	1100	280	**8800**	4100	650	2400	3100	630	770	84 j	5200	5200
Fluoranthene	297	1120	162	**2840**	**3270**	892	**4060**	**6190**	456	653	68	1700	2500
Benzo(a)anthracene	59	368	44	264	1010	360	**1680**	1190	131	209	15	1300	1600
Chrysene	111	417	57	364	1000	432	**2760**	**2040**	195	351	22	1400	2800
Pyrene	227	728	128	**3840**	**2990**	846	**5290**	**5780**	524	881	43	2600	3300
Benzo fluoranthenes	108 j	376 j	103 j	473	1611 j	708	2344	2052	225	369	37.5	3200	3600
Benzo(a)pyrene	48 j	235 j	38 j	212	571 j	259	1140	647	104	139	14	1600	1600
Dibenzo(a,h)anthracene	7.9 uj	12 uj	5 uj	15	75 j	45	182	87	27	32	6.4 u	230	230
Indeno(1,2,3-cd)pyrene	7.9 uj	40 j	27 j	34	347 j	192	147	77	73	96	6.4 u	600	690
Benzo(g,h,i)perylene	7.9 uj	229 j	34 j	247	467 j	176	602	269	109	120	21	670	720
Sum HPAH	830 j	3500 j	590 j	5300	11000 j	3900	**18000**	**18000**	1800	2900	220	12000	17000
2-Methylnaphthalene	8.4	50	13	406	198	25	73	380	28	33	3.5 j	670	670
Dibenzofuran	21	90	19	470	342	35	116	112	45	58	9.1	540	540
Diethylphthalate	76	42 u	9.3 u	12	49 u	9 u	13 u	25 u	82	14 u	46 u	200	1200
Dimethyl phthalate	7.9 u	12 u	5.2 u	5.6 u	19 u	29	7.4 u	**290**	6.2 j	8.6 u	6.4 u	71	160
Di-n-butyl phthalate	978	584 u	218 u	98 u	**1590**	**2510 j**	346 u	300 u	**2020**	222 u	435 u	1400	5100
Bis(2EH)phthalate	204	516	183	77 u	659	935	112 u	190	318	184 u	48 u	1300	3100
1,4-Dichlorobenzene	7.9 u	12 u	5.2 u	9.7	19 u	6.1 u	3 j	6.8 u	8.7 u	6.6 j	6.4 u	110	110
Total PCBs	64	48	24	21	12 j	43 j	51	6.8 j	33 j	37 j	4.2 j	130	1000

u=Not detected at detection limit shown
j=Estimated concentration
uj=Estimated detection limit
AET= Apparent Effects Threshold (dry weight basis)
Bold= Value exceeds AET

Table C4: Comparison of Nonionizable Organics Detected in Inner Shelton Harbor Composite Sediment Samples-
Wood Waste Strata- with Apparent Effects Threshold Values.

Station	S1-C		S2-C		S3-C		S4-C		S5-C		S6-C		S7-C		S8-C		S9-C		Dry Wt AET	
Sample No. 20-	8554		8555		8556		8557		8558		8559		8560		8561		8562		SQS	CSL
Organics (ug/kg, dry)																				
Acenaphthene	38	j	63		21		10		35		39		93		257		24		500	500
Acenaphthylene	46		62		24		4.8	j	17		34		70		110		35		1300	1300
Naphthalene	400		465		108		34		89		348		721		1160		360		2100	2100
Fluorene	31	j	76		27		14		37		48		96		198		24		540	540
Anthracene	44		129		70		17		60		92		186		271	j	54	j	960	960
Phenanthrene	188		371		231		82		182		276		480		1030	j	195	j	1500	1500
Sum LPAH	750	j	1200		480		160		420		840		1600		3000	j	690	j	5200	5200
Fluoranthene	269		666		525		133		405		505		836		1490	j	310	j	1700	2500
Benzo(a)anthracene	43		147		150		35		107		125		245		300	j	67	j	1300	1600
Chrysene	78		267		300		63		182		215		342		313	j	116	j	1400	2800
Pyrene	344	j	829		579		130		419		542		1090		1760	j	394	j	2600	3300
Benzo fluoranthenes	100	j	298		320		75		225		238		439	j	540	j	168	j	3200	3600
Benzo(a)pyrene	47	j	124		102		34		92		101		155	j	231	j	63	j	1600	1600
Dibenzo(a,h)anthracene	14	j	25		16		11		20		9.2	u	31	j	13	uj	9.1	uj	230	230
Indeno(1,2,3-cd)pyrene	29	j	78		62		24		60		16		24	j	28	j	50	j	600	690
Benzo(g,h,i)perylene	51	j	89		69		30		74		85		152	j	172	j	61	j	670	720
Sum HPAH	980	j	2500		2100		550		1600		1800		3300	j	4800	j	1200	j	12000	17000
2-Methylnaphthalene	25		50		13		6.3		14		33		83		151		26		670	670
Dibenzofuran	44	j	85		24		13		36		57		103		226		41		540	540
Butylbenzylphthalate	37		48		12		16		8	u	9.2	u	12	u	13	uj	9.1	uj	63	900
Diethylphthalate	9.4	u	43	u	8.8	u	61		8	u	9.2	u	88	u	37		18	u	200	1200

u= Not detected at detection limit shown

j= Estimated concentration

uj= Estimated detection limit

AET= Apparent Effects Threshold

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Appendix D

Water Column Profile Plots

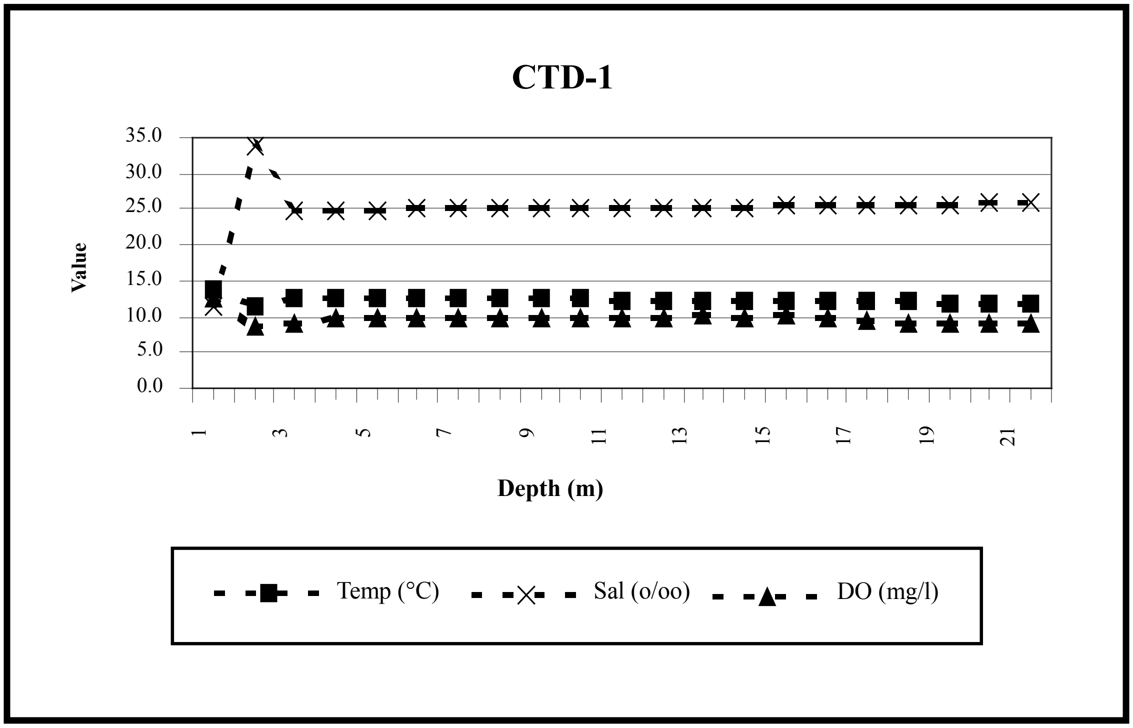

Figure D1: Temperature, Salinity, and Dissolved Oyxgen Profile for CTD-1.

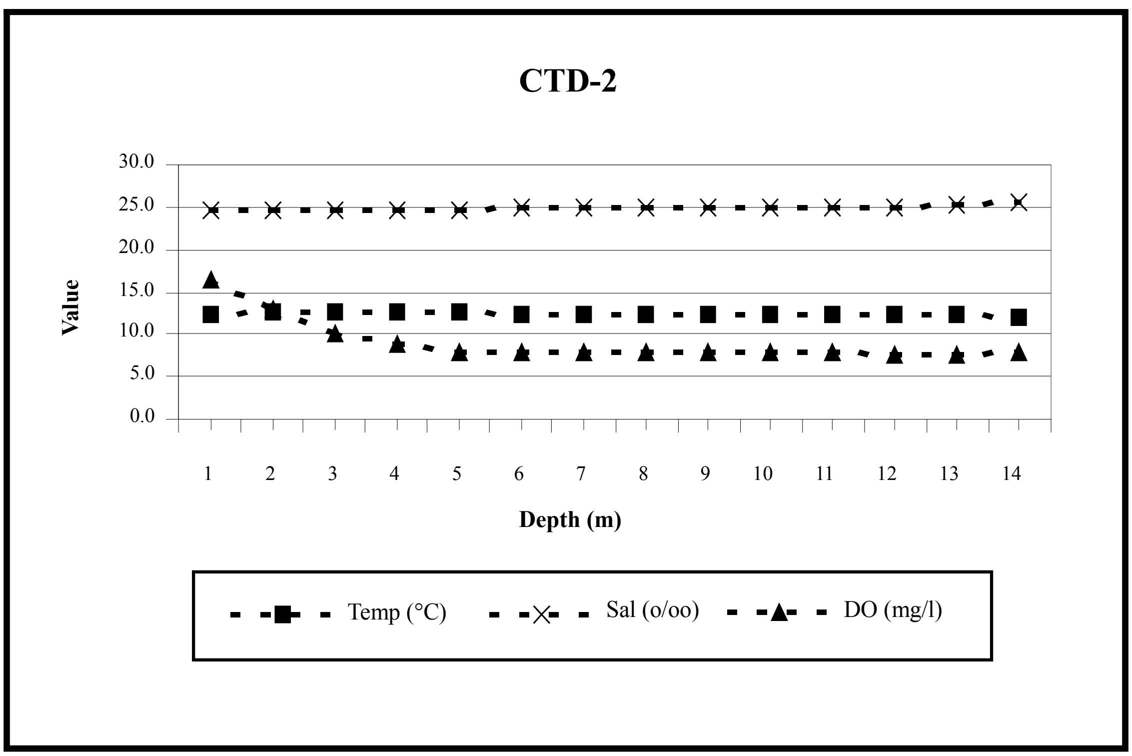

Figure D2: Temperature, Salinity, and Dissolved Oyxgen Profile for CTD-2.

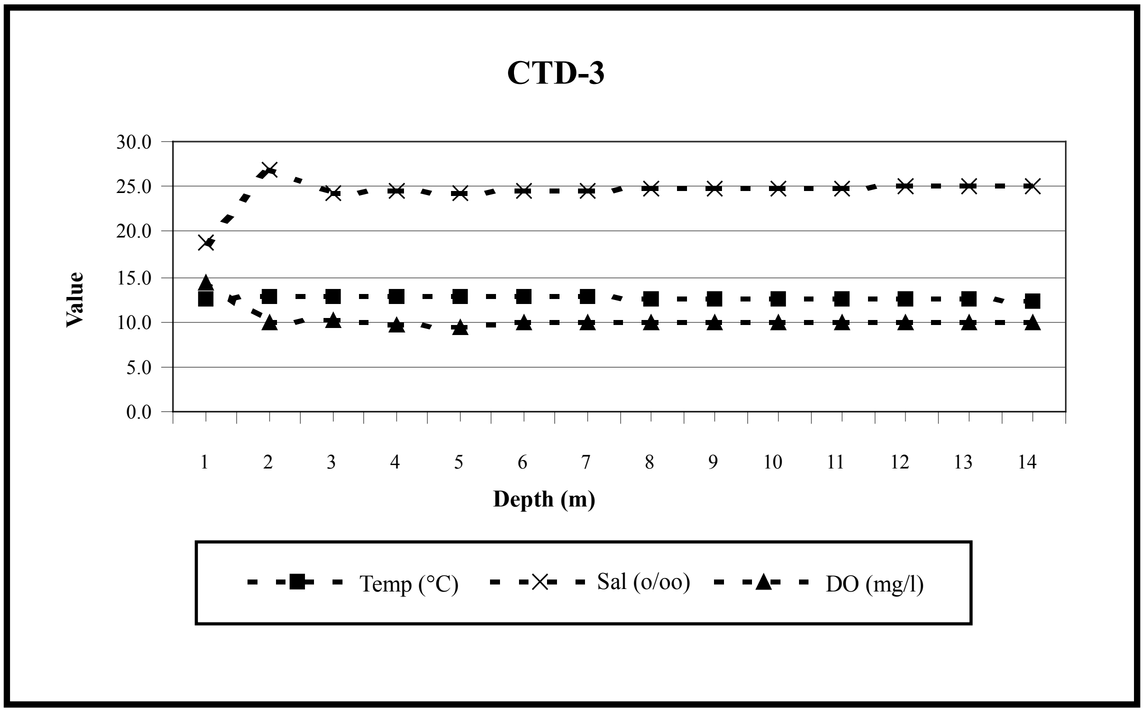

Figure D3: Temperature, Salinity, and Dissolved Oyxgen Profile for CTD-3.

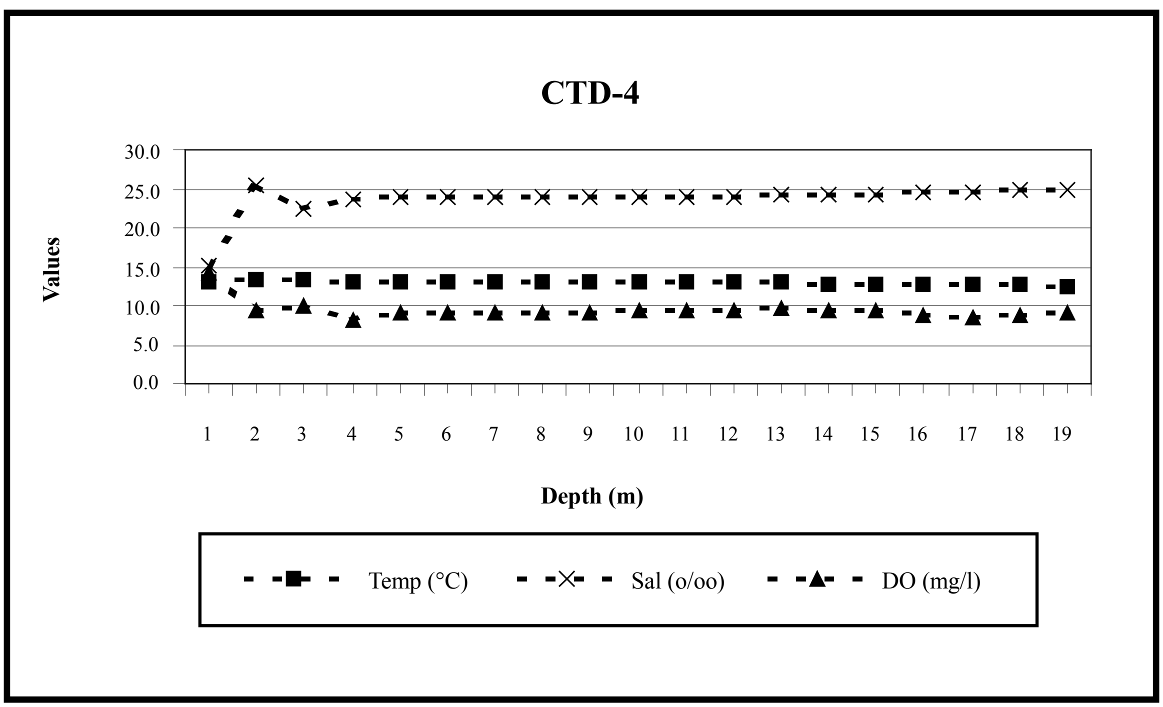

Figure D4: Temperature, Salinity, Dissolved Oyxgen Profile for CTD-4.

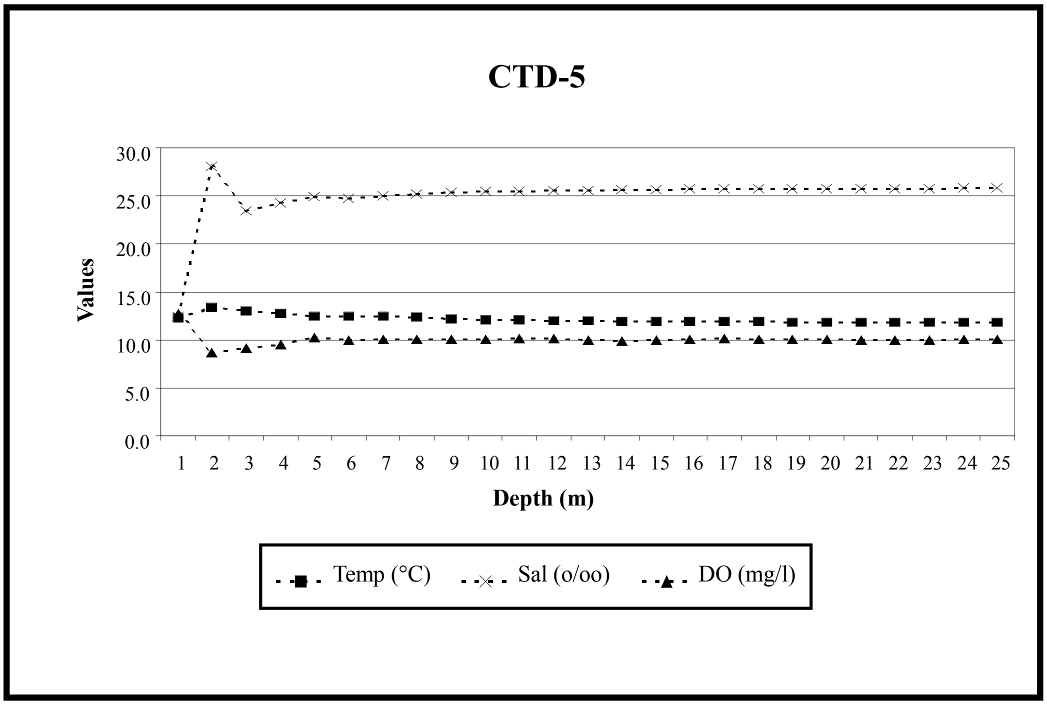

Figure D5: Temperature, Salinity, and Dissolved Oyxgen Profile for CTD-5.

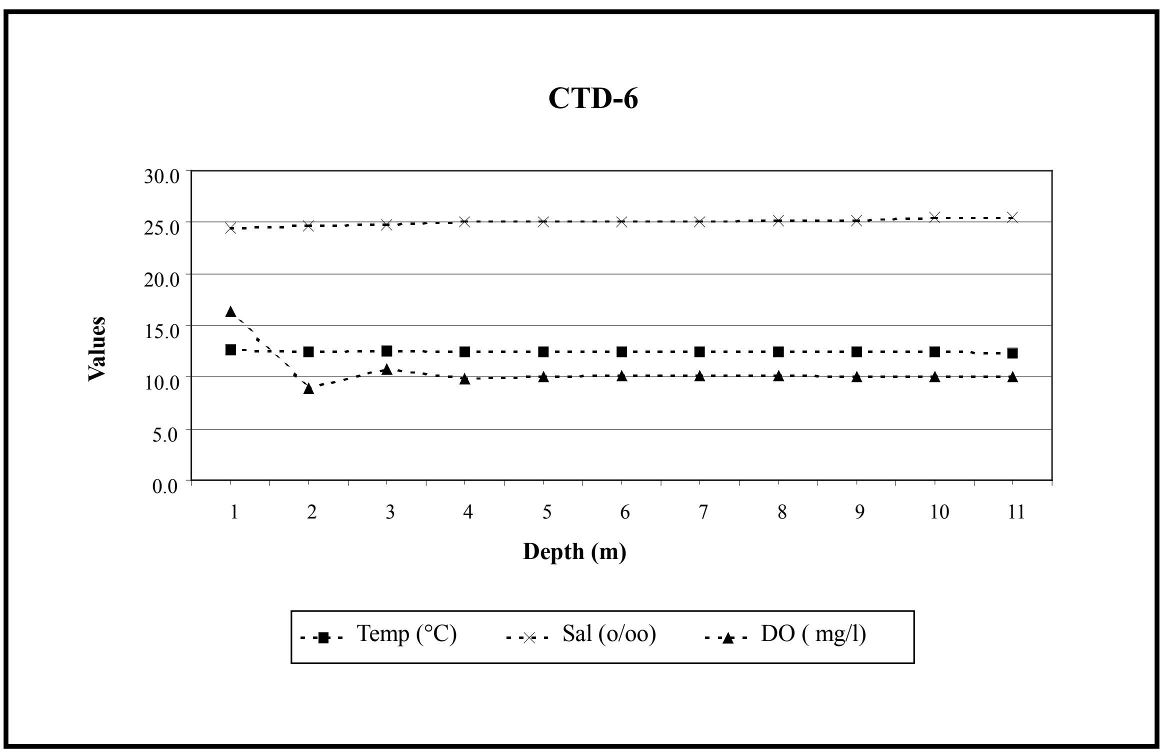

Figure D6: Temperature, Salinity, and Dissolved Oyxgen Profile for CTD-6.