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ENVIRONMENTAL CONTAMINANTS INVESTIGATIONS AT THE PROPOSED GRAYS HARBOR NATIONAL WILDLIFE REFUGE, GRAYS HARBOR, WASHINGTON

U.S. Fish and Wildlife Service
Ecological Services
Olympia Field Office
Olympia, Washington

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INTRODUCTION

The U.S. Fish and Wildlife Service proposes to obtain approximately 1,812 acres of land in Grays Harbor, Washington, which will serve as the basis for establishing the Grays Harbor National Wildlife Refuge. The objectives of the Refuge will be to protect habitat for migratory and resident shorebirds and waterfowl, protect threatened and endangered wildlife, and provide wildlife recreation opportunities. A preacquisition environmental contaminant survey was conducted for the establishment of the Refuge as part of the land acquisition process.

The Superfund Amendment Reauthorization Act to the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act) requires that landowners, including the Federal government, may be responsible for the entire cost of cleaning up a hazardous waste site on their lands even if they were not responsible for or had prior knowledge of those wastes. In certain situations, the cost of remediating contaminated lands can far exceed the value of the land itself and become a liability to the Federal government.

Service policy is to 'avoid acquisition of lands that will require costly cleanup of contaminants unless the resource values of those lands clearly outweigh those costs...'. The Service policy requires that a contaminants survey be conducted to determine the possible presence of hazardous substances and the potential environmental impacts from those substances.

In adherence to the above policy, the Olympia Field Office was requested to conduct a preacquisition environmental contaminant survey for property to be acquired for the Grays Harbor National Wildlife Refuge. Specifically, a survey was requested for a 68 acre tract owned by the City of Hoquiam and the portion of land adjacent to the northern boundary of the Bowerman Airport which is owned by the Port of Grays Harbor.

A Level I preacquisition survey was conducted for all upland properties proposed for acquisition and adjacent properties. An initial site visit was conducted on March 21, 1989 by the Environmental Contaminant Specialist and project biologist from the Olympia Field Office. The objective of the site visit was to inspect properties to determine the potential presence of contaminant sources, contaminants, and associated liabilities to the Service. A determination also was to be made regarding the need to conduct additional studies at the site and estimated costs.

SITE DESCRIPTION

Grays Harbor is a 94-square mile estuary located along the Washington coast, approximately 45 miles north of the mouth of the Columbia River (Figure 1). Various habitat types that exist in and around Grays Harbor include upland and lowland forests, floodplains, coastal dunes, fresh and salt water wetlands, and intertidal and eelgrass flats.

The 68 acres of City of Hoquiam property consists two parcels of land. One parcel (5.8 acres) is located between Route 109 and the intertidal area and

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constitutes the northern boundary of the proposed Refuge. It was determined in the Level I preacquisition survey that there was no or little concern for contaminants on this parcel.

The remaining portion of the City of Hoquiam property makes up the eastern boundary of the Refuge. This area contains saltwater and freshwater marshes. Two small creeks flow through the freshwater and saltwater marshes. A dredged material disposal area which received sediments from Grays Harbor is also located on the City of Hoquiam property. Freshwater wetlands are located on the disposal area.

The Port of Grays Harbor parcel located adjacent to Bowerman Airport is a narrow strip of land that contains shrubs and salt marsh vegetation. The remaining portion of the property (approximately 1,700 acres) is subtidal and intertidal habitat which is also owned by the Port of Grays Harbor.

AREAS OF CONTAMINANT CONCERN

A log storage yard is located immediately to the east of the proposed Refuge boundary. The two small creeks drain surface water runoff from the log storage yard. The creeks also receive surface water runoff from Route 109 and Paulson Road which makes up the eastern boundary of the Refuge.

The dredge material disposal area is approximately 21 acres in size. The dredge material originated from Grays Harbor. Although this area contains freshwater wetlands, there is a portion (2 acres) that is devoid of vegetation. Although the reason for the lack of vegetation is unknown, it may be simply due to surface grading at the site and compaction of the substrate.

Sediments in Grays Harbor receive contaminants from pulp mills, industrial discharges, sewage treatment plants, shipping, nonpoint runoff from the cities of Hoquiam and Aberdeen, and intensely managed forest and agricultural lands within the watershed. Land use practices and urban related activities can contribute various contaminants to the sediments including polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls and metals.

Activities at Bowerman Airfield include a repair shop which is drained by a ditch that enters the narrow strip of property at the southern boundary of the Refuge. Five metal drums (55 gallon) were present outside of the repair shop and appear to be used at the repair shop. The contents of the drums could not be determined, but most likely contain either hydraulic fluids or solvents which are commonly used in cleaning aircraft parts. This piece of property also receives surface water runoff from the airport runway and other airport roadways. Potential contaminants from these activities include PAHs, aliphatic hydrocarbons and metals.

There was no evidence of industrial or municipal dumping on property proposed to be included in the Refuge or on adjacent properties. In addition, no storage tanks (above or below ground) or chemical storage buildings were observed on any of the properties.

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Due to land use activities in the Grays Harbor watershed and immediately adjacent to the proposed Refuge, the Olympia Field Office recommended that a Level II preacquisition contaminant survey be conducted for the proposed Refuge. As part of the Level II survey, the collection and analysis of sediment, soil and water samples was recommended for selected aquatic, wetland, and upland areas. Sediments, clams, amphipods and juvenile chinook salmon from intertidal and subtidal areas were investigated as part of a separate environmental contaminants special study of Grays Harbor. Analytical sample results from both the Level II preacquisition survey and the environmental contaminants special study are presented in this report. Further information on the Grays Harbors special study methods, data and results is provided in a separate report currently in preparation (Benkert 1992).

SAMPLE COLLECTION AND ANALYSIS

As part of the Level II preacquisition survey, sediment, soil and water samples for contaminant analysis were collected during the week of June 12, 1989. The samples for the Grays Harbor study were collected in July and August of 1990.

Sediment samples were collected to a depth of 10 centimeters using a garden spade. Only sediment not in direct contact with the spade was used for sample analysis. Three sediment subsamples were collected at each sampling site and were composited in an acid cleaned stainless steel mixing bowl. Samples were homogenized by mixing the sediment with an acid washed stainless steel spoon. Following homogenization, samples were placed in pre-cleaned amber glass jars and placed on ice. Samples were returned to the Olympia Field Office and frozen.

Soil core samples were collected with an acid cleaned stainless steel soil core sampler. All soil cores were taken to a depth of 40-50 centimeters except for the dredge disposal area. Soil samples from the dredge disposal area were taken to a depth between 8 and 10 centimeters. Samples were placed in an acid cleaned stainless steel mixing bowl. Five subsamples per sampling site were homogenized with a stainless steel spoon to make up composite soil samples. Samples were place in pre-cleaned amber glass jars and placed on ice until transferred for freezing.

Water samples were collected directly into sample containers by submerging the containers 4-10 centimeters under the water surface. Integrated samples were taken by collecting portions of the sample either across the stream channel or at points down the center of the channel. Samples for inorganic analyses were collected in 1,000 milliliter (ml) polyethylene bottles and acidified to pH 2 or less with nitric acid immediately following collection. Samples for organic analyses were collected in 500 ml amber glass jars. Water samples were not filtered. All samples were place on ice following collection.

Samples were analyzed for inorganic and organic contaminants (Table 1) by analytical laboratories under contract through the Service's Patuxent Analytical Control Facility (PACF). Samples were shipped on ice by

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overnight carrier to appropriate laboratories. Sample collection, shipment, and analyses were completed using the Service's rapid turnaround protocols.

Arsenic and selenium residues were determined by hydride generation on an atomic absorption spectrophotometer. Mercury was analyzed using the cold vapor analytical methodology. All other inorganic contaminant (metals) analyses were accomplished using Inductively Coupled Plasma (ICP). Analyses of organic contaminants were conducted using capillary, flame ionization gas chromatography and fluorescence high performance liquid chromatography.

Quality control and quality assurance of all sample analyses were completed by personnel at PACF. No quality control, quality assurance, or analytical problems were identified. **All metals data are presented in dry weights and organics data are presented in wet weights.**

SAMPLE SITES

Preacquisition Study. Sediment samples were collected from the two unnamed creeks (SD1, SD4) which receive surface water from area roads, a drainage ditch (SD2) which receives runoff from the log storage area and from the drainage ditch (SD3) near the airport maintenance shop (Figure 3). Soil samples were collected from the dredge disposal area (SL2, SL4), base of the dredge disposal area (SL3), and forested wetland (SL1) which is located on Port of Grays Harbor property. Water samples were collected on the City of Hoquiam property from the northern most creek (W3) and a drainage ditch (W2) that enters this creek. A water sample (W1) was collected from a small pond within the log storage area which is also the source of water for the southern most creek on the property.

Grays Harbor Special Study. Sediment, juvenile fall chinook salmon (Oncorhynchus tshawytscha), clam (Mya arenaria), amphipod (Corophium spp.) samples were collected from sites within Grays Harbor and from a reference site in Willapa Bay. The Grays Harbor sites include two sites in Bowerman Basin (Bowerman 1, Bowerman 2) and single sites located at Cow Point, the Weyerhaeuser discharge, North Bay, South Bay and South Channel (Figure 1). The Willapa Bay reference site (Figure 2) is approximately 4 kilometers north of Willapa National Wildlife Refuge headquarters on the east bank of Stanley Channel. Duplicate samples from the same site are indicated as Sample "A" and Sample "B". Fish were not collected in Bowerman Basin.

RESULTS

Polycyclic Aromatic Hydrocarbons (PAHs). The chemicals comprising PAHs are based upon a fused ring structure involving two or more benzene rings. The PAHs are naturally present in petroleum but are also associated with the by-products of incomplete combustion, such as particulates from engine exhaust, cigarette smoke and used oils. Anthropogenic sources of PAH contamination include spills of petroleum hydrocarbons, industrial and domestic effluents, wood treatment facilities, and surface water runoff in urban areas (Eisler, 1987). All of these sources are present in the Grays

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Harbor estuary and the immediate vicinity of the sampling sites of this study.

PAHs were found in all of the sediment samples. A total PAH residue value was calculated for each sample by summing the individual residue values for each of the 14 PAHs analyzed in the laboratory scan (Table 1).

Concentrations of total PAH in the preacquisition sediment samples from Bowerman Basin ranged from 0.11 ppm (parts per million) to 0.32 ppm wet weight (Table 2). The highest total PAH concentration was identified in sediment from site SD1 which was located in the northern most creek on the Hoquiam property (Figure 3). The highest concentrations of individual PAH compounds were also found at site SD1: pyrene (0.09 ppm), fluoranthrene (0.06 ppm) and phenanthrene (0.04 ppm).

A likely source of PAH contamination at sites SD1 and SD3 is surface water runoff from nearby road surfaces. Studies have shown that urban runoff from stormwater and highways can account for as much as 71% of the total input of high molecular weight PAH (HPAH) contamination (Hoffman et al. 1984). The HPAHs made up the greatest percentage of PAH compounds present in the sediment samples from this study. The HPAH compounds of fluoranthrene and pyrene accounted for 47% of the total PAH at SD1 and SD3 and 40% at site SD4.

Total PAHs in sediments from throughout Grays Harbor (Table 3) ranged from 0.04 ppm in South Bay to 0.47 in North Bay. The Willapa Bay reference site had a total PAH concentration of 0.22 ppm. Total PAHs measured in Bowerman Basin sediments do not indicate contamination at levels above what was found throughout the Grays Harbor system. Total PAH concentrations in sediments from both the Grays Harbor study and the preacquisition study were an order of magnitude less than concentrations known to cause biological effects (Long and Morgan 1990).

Soil concentrations of total PAH were lower than those found in the sediments and ranged from 0.01 ppm to 0.15 ppm (Table 2). The highest total PAH concentration in soil (0.15 ppm) was located at site SL1, a freshwater wetland located on the dredge disposal area. As was found in the sediment samples, the HPAHs predominated in the soil samples.

Marine bivalve mollusks, such as oysters and mussels, accumulate PAHs (Eisler 1987b; Moore and Ramamoorthy 1984a). The accumulation of PAHs fluctuates seasonally, with higher residue levels present in spring and summer when lipid stores are maximal for reproduction. The total PAHs measured in clams (Table 3) from the Grays Harbor study were low and do not indicate pollution.

The amphipod sample from the Bowerman 1 site had a relatively high concentration of total PAHs (1.03 ppm). The remaining amphipod samples were lower, ranging from 0.06 ppm at South Bay to 0.14 ppm total PAHs (Table 3) at the Willapa Bay reference site. The lack of amphipod residue data from other estuarine systems for purposes of comparison, limits conclusions on the level or degree of contamination at the Bowerman 1 site.

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Aliphatic Hydrocarbons (Alkanes). The aliphatic hydrocarbons are a class of chemicals found naturally in petroleum and gas deposits. They include both straight and branched alkanes (paraffins) and cyclohexanes. Aliphatic hydrocarbons can enter aquatic systems from a variety of sources through point and non-point source discharges. Point sources can include wastewater treatment plants, industrial effluents, spills and exhaust from gasoline powered engines. Non-point discharges can occur from highway and urban stormwater runoff. Five of the thirteen aliphatic hydrocarbons detected in the analytical scan are known to be used in the paper processing industry: n-dodecane, n-hexadecane, n-octadecane, phytane and n-eicosane (Verschueren 1983).

A total aliphatic residue value was calculated by summing all of the individual aliphatic hydrocarbon residues. Aliphatics were detected in all of the preacquisition study sediment samples. Total aliphatic concentrations ranged from a low of 0.16 ppm at site SD3 to a high of 1.76 ppm at site SD2. Sampling sites SD2 and SD1 (0.94 ppm) receive surface runoff from nearby roads. Petroleum products from the road surfaces are the likely source of aliphatics to these two streams.

Total aliphatics in sediments from the Grays Harbor special study ranged from a low of 0.24 ppm in South Bay to a high of 3.40 ppm at the Bowerman 1 site (Table 4). Those sites located the furthest from both roads and the Weyerhaeuser discharge had the lowest values. The reference site in Willapa Bay, which located in relatively close proximity to the highway, had a value of 1.92 ppm.

Total concentrations of aliphatics in soil samples ranged from 0.01 ppm at site SL2 to 0.80 ppm at site SL3. Aliphatics were not detected in any of the water samples.

Total aliphatics in clams from the Grays Harbor study ranged from 0.10 ppm to 0.53 ppm (Table 4). Total aliphatics in amphipods ranged from 0.07 ppm at South Bay to 27.56 ppm at the Weyerhaeuser site. Marine invertebrates in an environment of chronic aliphatic hydrocarbon exposure have residues ranging from 1 to 150 ppm wet weight (Moore and Ramamoorthy 1984a). Although the residues in amphipods are indicative of chronic low level aliphatic hydrocarbon exposure at the Bowerman Basin, Weyerhaeuser and the Willapa Bay sites, the high variability in duplicate samples from Weyerhaeuser (Table 4), requires additional data to support that conclusion.

Total aliphatics in juvenile chinook (Table 4) ranged from a low of 3.10 ppm in Willapa Bay to 8.26 ppm in North Bay. Aliphatic hydrocarbon residues in oceanic fish range from <0.5 to 5 ppm, while inshore fish generally have higher levels (Moore and Ramamoorthy 1984a). Although, the levels measured in the juvenile chinook may indicate chronic exposure to aliphatic hydrocarbons, the lack of chinook data from other estuarine systems, limits further conclusions on the level or degree of contamination.

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Organochlorines. Organochlorines pesticides and polychlorinated biphenyl (PCB) compounds, were analyzed in the sediment and soil samples from the preacquisition study. None were detected (detection limit = 0.01 ppm) in any of the samples.

Dioxins/Furans. Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), by-products of the chlorine bleaching process of wood pulp for paper production, are released in paper mill effluents. As PCDDs and PCDFs are not highly soluble in water and preferably bind with organic particles, they are commonly detected in downstream sediments from paper mills (Schweer et al. 1990; BCI and Shapiro & Associates 1991).

PCDDs and PCDFs, like other organochlorine compounds, generally are environmentally stable and highly lipophilic, tending to accumulate in the fat of organisms. Documented effects of exposure to PCDDs and PCDFs on fish and birds include death, immune system failure, reproductive failure, internal organ lesion development, reduced feeding, erratic swimming and fin necrosis (Eisler 1986; Schweer et al. 1990). The most toxic PCDD isomer is 2,3,7,8-tetrachlorodibenzo-p-dioxin.

Analyses of total and isomer specific dioxin and furan compounds were conducted on selected sediment (Table 5) and biological samples (Table 6) from the Grays Harbor study. The reported dioxins and furans in sediments have been normalized for total organic carbon content (TOC). The biological samples were not normalized for lipid content as the amphipod sample was of insufficient size for lipid analysis.

Sediments from the Bowerman 2 site had the highest level of 2,3,7,8-tetrachlorodibenzo-p-dioxin, followed by sediments from the Weyerhaeuser discharge site (Table 5). The highest dioxin levels generally were found at the Bowerman 2 site. The maximal furan levels were distributed among the sites, without any discernable pattern. [Background???]

Dioxins and furans concentrations (Table 6) measured in juvenile salmon were low (<10 parts per trillion wet weight 2,3,7,8-tetrachlorodibenzo-p-dioxin) in comparison to levels measured in fish from contaminated aquatic systems (Baumann and Whittle 1988; Johnson, Serdar and Magoon 1991). It should be noted though, that juvenile salmon are migratory through the Grays Harbor system and thus, dioxin and furan levels in resident species are likely to be greater.

Dioxin and furan concentrations in the Weyerhaeuser site clams were similar to levels measured in the juvenile salmon (Table 6). Although, the clams are resident species in close contact with sediments and proximally located to the effluent discharge, the concentrations present are low.

Relatively high levels of dioxins, particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin, were measured in the amphipod sample (Table 6). Although the lack of lipid content data for the amphipod sample prevents normalization of the data for comparison purposes, it does not eliminate the question of exposure to those organisms feeding on these amphipods. Corophium amphipods are important prey items for both juvenile salmon and shorebirds.

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The dioxin levels measured in this single amphipod sample introduces serious questions regarding food chain effects.

Metals: sediments. The biogeochemistry of metal cycles in aquatic systems is complex. Metals exist in flux among dissolved, adsorbed bottom particulates and suspended particulate states. Ambient environmental conditions of pH and reduction-oxidation potential (Eh) are major factors in controlling the flux of metals from one state to another. Biotic contact and interactions with metals occur in all states of the cycle, although metals in a dissolved state are more biologically available (Elder 1988).

Sediments are generally considered as sinks for metals in the aquatic environment. Metals are strongly adsorbed to various types of particulates and settle out in low flow conditions. Clay-mineral particulates are one type of substrate which strongly binds metals. Organic particles and iron (Fe) and manganese (Mn) hydroxides also tightly bind metals (Elder 1988). Silt and clay sized sediment particles physico-chemically provide more binding sites for the attachment of organic and metal contaminants than other sediment size fractions.

Grain size analysis of the sediment samples from the Grays Harbor special study indicated that Bowerman Basin is a depositional environment with sediments comprised of over 84 percent silt and clay (Table 7). The Willapa Bay sediment sample was 77 percent silt and clay. All other samples were less than 36 percent silt and clay. Bowerman Basin also had the highest levels of total organic carbon (TOC) measured in the Grays Harbor study sediments (Table 7). The TOC correlates with the percent silt in the grain size analysis of the sediments.

Sediment criteria and guidelines have been established by various State and Federal agencies and countries. Sediment criteria and guidelines provided for comparison purposes in this report (Table 8) include the apparent effects thresholds for both amphipod toxicity and benthic effects and the State of Washington proposed chemical criteria for marine sediments (Environmental Protection Agency 1991). The apparent effects threshold is the concentration, of a specific chemical, present in the sediment at which statistically significant ($p \leq 0.05$) reductions in benthic infauna or elevated mortalities from toxicity occur. The sediment standards and apparent effects threshold criteria do not adjust or standardize the residue levels for differences in sediment grain size or organic content. Thus, exceedance of a guideline or criteria should be viewed conservatively.

Priority pollutant metals were analyzed in all sediment, soil, and water samples from the preacquisition study. These metals include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn). Priority pollutant metals were not measured above the detection level in any of the water samples.

Soils collected from site SL2, located at the dredged material disposal site, had the highest concentrations of several of the metals: cadmium

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(0.70 ppm), chromium (178 ppm), copper (181 ppm), nickel (88.6 ppm), and zinc (111 ppm) (Table 9). None of these metal concentrations exceeded the Dutch soil clean-up criteria, although the criteria recommend that copper concentrations exceeding 100 ppm should be evaluated further (Beyer 1990). The State of New Jersey soil clean-up guidelines identify chromium levels of 170 ppm or less as protective of ground water resources (Beyer 1990).

Metal concentrations in the preacquisition (Table 9) and the Grays Harbor (Table 10) study sediments did not exceed the apparent effects thresholds or the proposed marine sediment standards (Table 8). When compared to the Puget Sound Dredged Disposal Analysis sediment screening levels, which are normalized for organic carbon content, none of the Grays Harbor study sediments were in exceedance (Table 11). Organic carbon was not analyzed in the preacquisition study samples.

Metals: Clams. Uptake of metals by clams occurs primarily through ingestion and water filtration. As metals are most bioavailable in the dissolved state (Elder 1988), the metal residues accumulated by clams primarily should reflect the availability of metals from the water column. Limited metal uptake from dermal contact with the sediments also is possible.

Mollusks, in general, are poor regulators of metals, especially non-essential trace elements (Rand and Petrocelli 1985). Consequently, some metals will accumulate to relatively high levels, particularly in comparison to metal residues typically found in fish.

The National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends (NST) Program measures organics and metals in marine bivalves (NOAA 1987) from 145 sites nationwide. The NST values were measured in both oysters (Crassostrea virginica) and mussels (Mytilus spp.). Although, bioaccumulation of metals in mollusks will vary by species, general comparisons can be made. Metals in softshell clams from the Grays Harbor study are compared to the NST results in Table 10. Results from the NST site located at the Grays Harbor Westport jetty (GHWJ), are also included.

Bioaccumulation of both copper and zinc is strongly species dependent (NOAA 1987) and limit comparison of concentrations measured in different species. Thus, the NST results are presented by species for these metals. In addition, the NST results suggest, although do not confirm, that chromium and lead may have species specific bioaccumulation rates.

In general, the metal concentrations measured in clams in the Grays Harbor study are within the 12.5 to 87.5 percentile distribution of the NST values (Table 12). Sites with relatively elevated concentrations in clams include Bowerman 1 (64.4 ppm Cu), Bowerman 2 (28.8 ppm As) and Willapa Bay (31.0 ppm As). Zinc concentrations were relatively low in clams from Bowerman 2 (100 ppm Zn), Weyerhaeuser (105 ppm Zn) and Willapa Bay (108 ppm Zn).

Metals: Amphipods. Limited amphipod data were collected during the Grays Harbor study (Table 13). Copper and lead concentrations in amphipods were

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found to be highly variable between sites. This variability did not appear to be linked to copper and lead levels in the sediments. The levels of arsenic, cadmium, chromium, mercury, nickel, selenium and zinc among sites were not elevated relative to each other. The lack of duplicate samples and comparative marine amphipod data limits further conclusions.

SUMMARY DISCUSSION

The contaminant levels measured in sediments, soils, water and biota from Bowerman Basin were generally low, with the notable exception of 2,3,7,8-tetrachlorodibenzo-p-dioxin in the amphipod sample. Samples from Bowerman Basin, a sediment depositional zone in the Grays Harbor system, commonly were found to have higher aliphatic hydrocarbon, PAH and metal concentrations relative to other sites sampled in Grays Harbor. As expected, soils from the dredged disposal site in Bowerman Basin also had relatively higher levels of contaminants.

With the exception of the dioxin contaminated amphipods, the existing levels of other contaminant residues in Bowerman Basin do not present an acute threat to the health of fish and wildlife resources. As Bowerman Basin is a depositional environment in an industrialized estuary, the continued accumulation of contaminants in sediments is likely. Low-level chronic effects may occur in trust resources from present and/or increasing levels of contaminants in sediments, water and prey items. Future implementation of adequate and additional source controls on the industries located in the watershed should reduce future inputs of metals, dioxins, furans, aliphatic hydrocarbons and PAHs into the estuary.

The single amphipod sample analyzed for dioxins and furans raises many questions and answers none. The bioavailability of dioxin and furans on the proposed Grays Harbor National Wildlife Refuge may introduce resource management concerns relative to food chain effects in migratory birds and other fish and wildlife. To address these concerns, the Washington Department of Fisheries (Schroeder and Fresh 1992) has recommended that the Service conduct extensive sampling of amphipods in Grays Harbor to assess the extent and degree of dioxin and furan contamination. The Olympia Fish and Wildlife Enhancement Field Office and the Service's Western Washington Fisheries Resource Office presently are exploring funding options to undertake this survey.

Service acquisition of lands for the Grays Harbor National Wildlife Refuge should avoid the assumption of any costs or liability associated with the possible future removal and/or containment of contaminated sediments in Bowerman Basin. Although, sediment contaminant levels in Bowerman Basin are currently are below the PSDDA screening level and proposed State of Washington sediment standards, the Service should not assume liability for future accumulation of contaminants in Bowerman Basin sediments.

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LITERATURE CITED

Baumann, P. C. and D. M. White. 1988. The status of selected organics in the Laurentian Great Lakes: an overview of DDt, PCBs, dioxins, furans, and aromatic hydrocarbons. Aq. Tox. 11: 241-257.

BCI and Shapiro & Associates, Inc. 1991. Chemical and Biological Literature Inventory: Grays Harbor and Willapa Bay. 104+ pp.

Benkert, K. 1992. Grays Harbor contaminants study. In preparation. U.S. Fish and Wildlife Service, Olympia Field Office Contaminants Report.

Beyer, N. W. 1990. Evaluating soil contamination. U.S. Fish and Wildlife Service Biological Report 90(2). 25 pp.

Eisler, R. 1986. Dioxin hazards to fish, wildlife, and invertbrates: a synoptic review. U.S. Fish Wildlf. Serv. Biol. Rep. 85 (1.8). 37 pp.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildfl. Serv. Biol. Rep. 85 (1.11). 81 pp.

Elder, J. F. 1988. Metal biogeochemistry in surface-water systems: a review of principles and concepts. U.S. Geological Survey Circular 1013. 43 pp.

Environmental Protection Agency. 1991. Pollutants of concern in Puget Sound. EPA 910/9-91-003. EPA Region 10, Seattle, Washington. 105 pp + appendix.

Hoffman, E. J., G. L. Mills, J. S. Latimer and J. G. Quinn. 1984. Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. Environ. Sci. Technol. 18: 580-587.

Johnson, A., D. Serdar, and S. Magoon. 1991. Polychlorinated dioxins and -furans in Lake Roosevelt (Columbia River) sportfish, 1990. Washington Department of Ecology, Olympia, Washington; Publication #91-4. 47 pp. + appendix

Long, E. R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Technical Memorandum NOS OMA 52. Seattle, WA. 175 pp. + appendices.

Moore, J. W. 1990. Inorganic Contaminants of Surface Water. Springer -Verlag. New York. 334 pp.

Moore, J. W. and S. Ramamoorthy. 1984a. Organic Chemicals in Natural Waters. Springer-Verlag. New York. 289 pp.

Moore, J. W. and S. Ramamoorthy. 1984b. Heavy Metals in Natural Waters.

<00006013.tif>

Springer-Verlag. New York. 268 pp.

National Oceanic and Atmospheric Administration (NOAA). 1987. National Status and Trends Program for marine environmental quality. Progress Report; NOAA Tech. Memo. NOS OMA 38. Rockville, MD. 23 pp + appendices.

Rand, G. M. and S. R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology: Methods and Applications. Hemisphere Publishing Corp. Washington, DC. 666 pp.

Schroeder, S. and K. Fresh (Eds.). 1992. Results of the Grays Harbor coho survival investigations, 1987-1990. Washington Department of Fisheries; Technical Report #118.

Schweer, G., B. Gregg, L. Schultz, P. Wood, T. Leighton, C. D'Ruiz, R. Fares, G. Huse, C. Carpenter, J. Konz, and D. Arrenholz. 1990. Background document to the integrated risk assessment for dioxins and furans from chlorine bleaching in pulp and paper mills. EPA 560/5-90-014. Environmental Protection Agency, Washington, DC. 98 pp.

Verschueren, K. 1983. Handbook of Environmental Data on Organic Chemicals. 2nd Edition. Van Nostrand Reinhold Company. New York. 1,310 pp.

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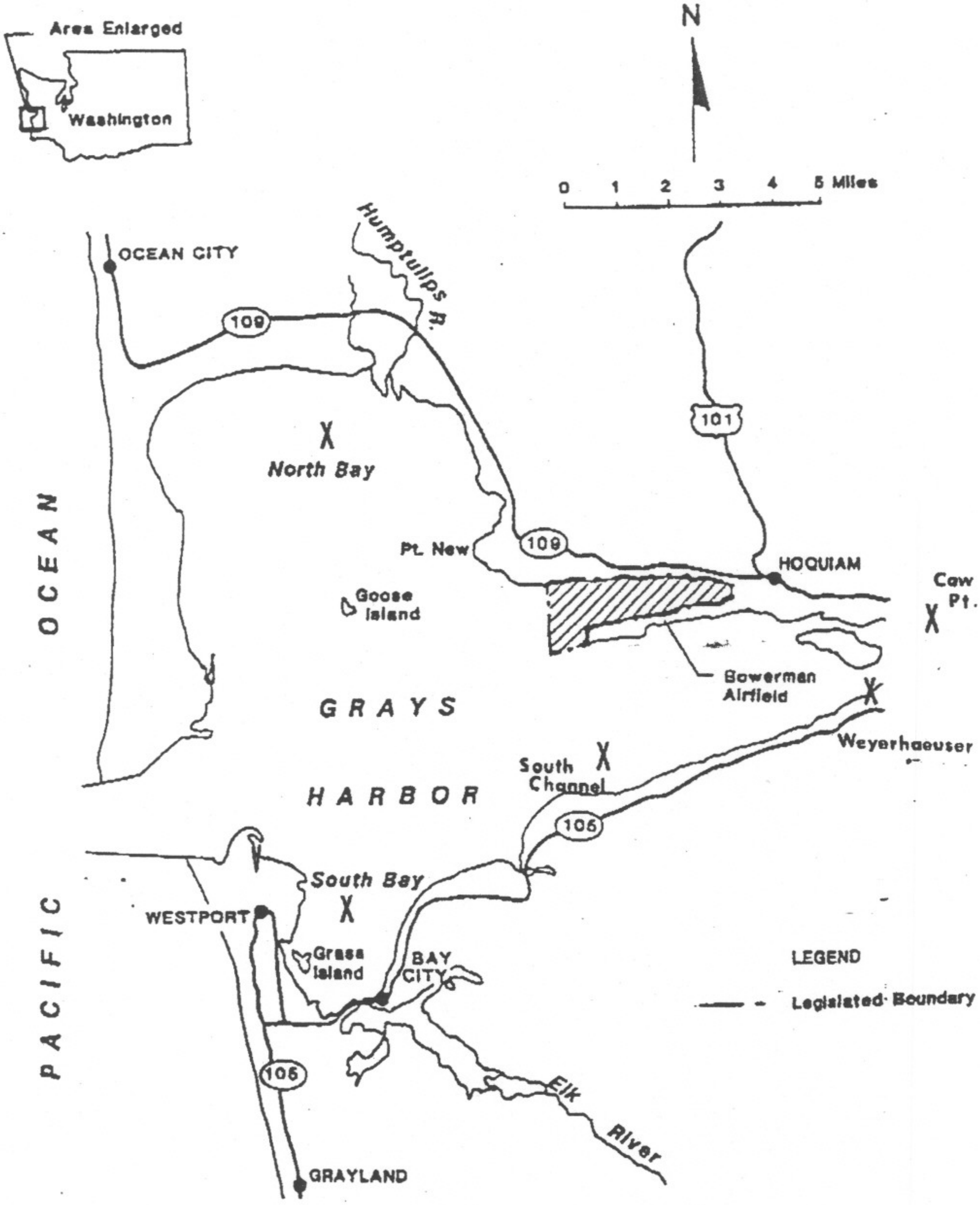

Figure 1. Grays Harbor Study Sites.

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Figure 2. Willapa Bay Reference Site.

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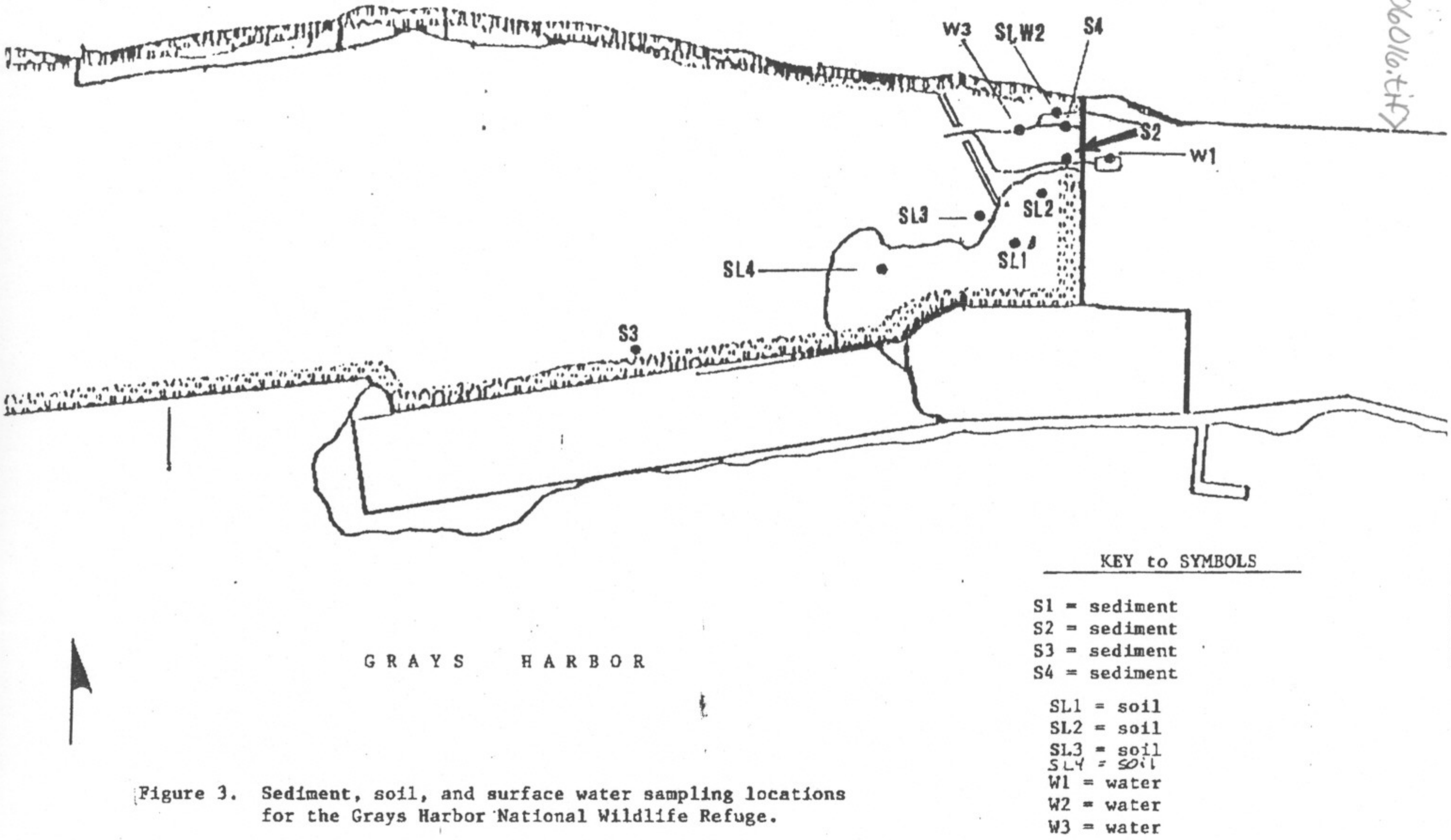

Figure 3. Sediment, soil, and surface water sampling locations for the Grays Harbor National Wildlife Refuge.

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Table 1. Organic chemicals and metals measured in study samples.

Aliphatic Hydrocarbons

n-Dodecane
n-Tridecane
n-Tetradecane
Octylcyclohexane
n-Pentadecane
Nonylcyclohexane
n-Hexadecane
n-Heptadecane
Pristane
n-Octadecane
Phytane
n-Nonadecane
n-Eicosane

Metals

Mercury (Hg)
Lead (Pb)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Nickel (Ni)
Zinc (Zn)
Arsenic (As)
Selenium (Se)

Dioxins/Furans

See Table 5

Polycyclic Aromatic Hydrocarbons

Naphthalene
Fluorene
Phenanthrene
Anthracene
Fluoranthrene
Pyrene
1,2-Benzanthracene
Chrysene
Benzo(b)fluoranthrene
Benzo(k)fluoranthrene
Benzo(e)pyrene
Benzo(a)pyrene
1,2,5,6-Dibenzanthracene
Benzo(g,h,i)perylene

Organochlorines

HCB (hexachlorobenzene)
α-BHC
β-BHC
γ-BHC (lindane)
δ-BHC
Heptachlor epoxide
Toxaphene
PCB's (total)
Mirex
Endrin
Dieldrin
o,p'-DDT
p,p'-DDT
o,p'-DDE
p,p'-DDE
o,p'-DDD
p,p'-DDD
Oxychlordane
α-Chlordane
γ-Chlordane
cis-Nonachlor
trans-Nonachlor

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Table 2. Organic chemical levels (ppm wet weight) measured in sediments and soils collected from Bowerman Basin for the preacquisition study. ND = not detected.

SITE	Total Aliphatic Hydrocarbons	Total Polycyclic Aromatic Hydrocarbons	Organochlorines
SD1	0.94	0.32	ND
SD2	1.76	0.11	ND
SD3	0.16	0.17	ND
SD4	0.61	0.18	ND
SL1	0.65	0.15	ND
SL2	0.01	0.01	ND
SL3	0.80	0.11	ND
SL4	0.07	0.08	ND

Table 3. Total polycyclic aromatic hydrocarbons (ppm wet weight) measured in sediments and biota from the Grays Harbor special study. N/A indicates a sample was not collected for analysis.

SITE	SEDIMENTS	CLAMS	AMPHIPODS
Bowerman 1	0.35	0.06	1.03
Bowerman 2	0.29	0.07	0.10
Weyerhaeuser A	0.16	0.06	N/A
Weyerhaeuser B	N/A	N/A	0.08
Cow Point A	0.26	0.07	N/A
Cow Point B	0.24	N/A	N/A
North Bay	0.47	N/A	0.11
South Bay	0.04	0.04	0.06
South Channel A	0.15	0.04	0.10
South Channel B	N/A	0.04	N/A
Willapa Bay	0.22	0.02	0.14

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Table 4. Total aliphatic hydrocarbons (ppm wet weight) measured in sediments and biota from the Grays Harbor special study. N/A indicates a sample was not collected for analysis.

SITE	SEDIMENTS	CLAMS	FISH (Whole Body)	AMPHIPODS
Bowerman 1	3.40	0.53	N/A	3.38
Bowerman 2	0.77	0.10	N/A	1.28
Weyerhaeuser A	1.30	0.19	5.05	27.56
Weyerhaeuser B	N/A	N/A	3.69	0.27
Cow Point A	0.54	0.19	4.71	N/A
Cow Point B	0.88	N/A	N/A	N/A
North Bay	0.39	N/A	8.26	0.08
South Bay	0.24	0.14	4.77	0.07
South Channel A	0.69	0.11	7.82	0.08
South Channel B	N/A	0.13	N/A	N/A
Willapa Bay	1.92	0.15	3.10	2.85

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Table 5. Dioxin and furan concentrations (parts per trillion wet weight) in sediments normalized for total organic carbon content. ND = not detected; E = chemical detected but with analytical interference.

ISOMER	SITE							
	Willapa	South Channel	South Bay	North Bay	Bowerman 1	Bowerman 2 (N=2)	Weyer-haeuser	Cow Point (N=2)
2378-TCDD	ND	0.79	ND	ND	0.31	0.87	0.83	0.78
12378-PeCDD	ND	0.83	ND	ND	0.5	1.1	0.86	0.82
123478-HxCDD	ND	ND	ND	ND	ND	0.71	ND	0.29
123678-HxCDD	0.52	1.4	1.6	ND	1.2	1.8	1.9	1.5
123789-HxCDD	0.21	3.1	2.6	ND	1.2	3.5	2.0	3.0
1234678-HpCDD	5.0	16.7	14.0	13.0	13.0	25.2	19.0	23.4
OCDD	34.1	89.4	47.6	ND	96.5	137.6	150.0	157.6
2378-TCDF	ND	3.3	2.3	ND	0.81	2.6	2.1	1.6
12378-PeCDF	0.12	0.23	ND	ND	0.14	0.12	ND	ND
23478-PeCDF	ND	0.26	0.40	ND	ND	0.16	ND	0.11
123478-HxCDF	ND	0.44	1.32	ND	0.23	0.65	ND	ND
123678-HxCDF	0.14	0.23	ND	ND	0.29	0.39	ND	ND
234678-HxCDF	ND	0.30	1.0	1.2	ND	0.53	ND	0.48
123789-HxCDF	ND	ND	ND	ND	ND	ND	ND	ND
1234678-HpCDF	1.3	5.3	6.0	4.3	4.7	7.6	16.4	5.3
1234789-HpCDF	ND	ND	1.12	ND	ND	ND	ND	ND
OCDF	2.0	7.1	12.4	8.0	7.1	12.4	15.0	13.2
TOTAL TCDD	0.25	3.0	1.8	ND	1.7	3.7	2.0	4.1
TOTAL PeCDD	0.74	5.1	ND	ND	2.4	7.3	2.7	3.1
TOTAL HxCDD	3.4	20.7	16.0	13.7	12.5	29.3	30.0	24.0
TOTAL HpCDD	11.6	35.6	28.0	31.7	28.5	58.2	41.0	55.7
TOTAL TCDF	1.0	9.7	6.4	ND	2.6	9.6E	6.7	6.2E
TOTAL PeCDF	1.2	3.1	4.8	3.3	3.9	6.2	5.0	3.4
TOTAL HxCDF	0.76	7.9	ND	4.0	5.3	12.0	18.7	6.9
TOTAL HpCDF	1.5	13.7	14.4	5.7	10.6	19.5	39.6	11.9
% MOISTURE	51.3	20.5	20.3	38.9	63.3	31.6	30.3	20.5

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Table 6. Dioxin and furans (parts per trillion wet weight) in biota from the Grays Harbor study. ND = not detected; N/A = not applicable.

ISOMER	Weyerhaeuser	Weyerhaeuser	Bowerman 1
	Juvenile Chinook Salmon	Clams	Amphipods
2378-TCDD	1.32	ND	23.4
12378-PeCDD	ND	ND	ND
123478-HxCDD	ND	ND	14.9
123678-HxCDD	ND	ND	ND
123789-HxCDD	ND	ND	ND
1234678-HpCDD	1.81	2.03	114
OCDD	9.86	12.2	2268
2378-TCDF	1.55	1.10	27.5
12378-PeCDF	ND	ND	ND
23478-PeCDF	ND	ND	ND
123478-HxCDF	ND	ND	41.1
123678-HxCDF	ND	ND	34.8
234678-HxCDF	ND	ND	ND
123789-HxCDF	ND	ND	ND
1234678-HpCDF	ND	ND	85.1
1234789-HpCDF	ND	ND	ND
OCDF	ND	ND	97.1
TOTAL TCDD	1.23	ND	97.0
TOTAL PeCDD	ND	ND	ND
TOTAL HxCDD	ND	1.72	37.1
TOTAL HpCDD	1.81	4.86	223
TOTAL TCDF	2.99	1.75	575
TOTAL PeCDF	ND	0.787	314
TOTAL HxCDF	ND	ND	162
TOTAL HpCDF	ND	ND	85.1
% LIPIDS	4.77	0.95	N/A

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Table 7 . Total organic carbon (ppm dry weight) and percent grain size fractions in sediments from the Grays Harbor study.

SITE	Total Organic Carbon (TOC)	% Clay	% Silt	% Sand
Bowerman 1	2.6	17.8	74.7	7.6
Bowerman 2	2.0	20.5	64.0	15.6
Weyerhaeuser	0.7	6.4	16.4	77.2
Cow Point A	0.8	6.4	29.2	64.4
Cow Point B	0.7	3.4	14.4	82.2
North Bay	0.3	4.1	7.0	88.9
South Bay1	0.3	2.6	3.8	93.6
South Channel	1.0	8.2	23.7	68.1
Willapa Bay	2.0	20.9	55.7	23.4

Table 8. Metal threshold criteria for biological effects and proposed marine sediments standards.

Sediment Standards or Criteria	METAL (ppm dry weight)							
	Hg	Pb	As	Cd	Cr	Cu	Ni	Zn
Apparent Effects Threshold for Marine Benthic Effects	-	450	57	5.1	260	530	>140	410
Apparent Effects Threshold for Marine Amphipod Toxicity	2.1	660	93	6.7	270	1,300	>140	960
Proposed Marine Sediment Standards (State of Washington)	.41	450	57	5.1	260	390	140	410

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Table 9. Metal concentrations (ppm dry weight) measured in soils and sediments collected from Bowerman Basin for the preacquisition study. A "< value" indicates sample was less than the detection limit.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SD1	10.7	0.80	89.4	75.0	<0.02	41.6	28.0	<.30	119
SD2	1.73	0.75	31.9	27.8	<0.02	16.7	<15	<.30	111
SD3	3.51	0.91	57.5	51.2	<0.02	34.1	40.9	<.30	337
SD4	9.68	0.92	75.3	63.4	<0.02	35.3	24.0	0.39	116
SL1	5.97	<0.5	77.3	55.3	<0.02	38.7	34.3	0.40	94.1
SL2	0.38	0.70	178	181	<0.02	88.6	15.9	<.30	111
SL3	5.90	0.65	76.1	52.9	<0.02	36.8	15.3	0.32	99.4
SL4	4.04	<0.5	65.5	30.8	<0.02	31.9	<15	<.30	80.1

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

Table 10. Metal concentrations (ppm dry weight) measured in sediments collected for the Grays Harbor special study. A "< value" indicates sample was less than the detection limit.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	6.5	<0.3	43	47.8	0.10	25	20	0.3	76.1
Bowerman 2	8.7	<0.3	46	46.3	0.07	25	23	0.3	79.5
Weyerhaeuser	5.3	<0.3	34	43.2	0.03	29	17	0.2	74.5
Cow Point A	4.9	<0.3	18	44.6	0.04	27	19	<0.1	76.4
Cow Point B	5.0	<0.3	22	44.6	0.03	30	19	0.2	81.9
North Bay	5.2	<0.2	20	11	0.02	14	10	<0.1	46.2
South Bay	5.5	<0.2	22	7.4	0.03	11	9	<0.1	32.6
South Channel	5.8	<0.2	27	21	0.03	18	10	0.2	52.3
Willapa Bay	9.2	<0.3	32	26.9	0.07	20	20	0.2	76.4

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

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Table 11. Organic carbon normalized metal concentrations (ppm dry weight) in sediments from the Grays Harbor study. Puget Sound Dredged Disposal Analysis (PSSDA) sediment screening level provided for comparison. ND = not detected.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	2.5	ND	16	18.4	0.04	10	8	0.1	29.3
Bowerman 2	4.3	ND	23	23.2	0.04	12	12	0.1	39.8
Weyerhaeuser	7.6	ND	49	61.7	0.04	41	24	0.3	106.4
Cow Point A	6.1	ND	22	55.8	0.05	34	24	ND	95.5
Cow Point B	7.1	ND	31	63.7	0.04	43	27	0.3	117.0
North Bay	17.3	ND	67	36.7	0.07	47	33	ND	154.0
South Bay	18.3	ND	73	24.7	0.10	37	30	ND	108.7
South Channel	5.8	ND	27	21.0	0.03	18	10	0.2	52.3
Willapa	4.6	ND	16	13.5	0.04	10	10	0.1	38.2
PSSDA Screening Level	57	-	-	81	0.21	140	66	-	160

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

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Table 12. Metal concentrations (ppm dry weight) in softshell clams from the Grays Harbor special study. NOAA Status and Trends (NST) metal concentrations (ppm dry weight) in mussels and oysters presented for comparison. NST values are for both mussels and oysters unless otherwise noted.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	5.5	<0.2	2.0	64.4	0.22	2.0	<4	1.3	196
Bowerman 2	28.8	0.3	3.7	16.0	0.12	2.0	7.0	1.5	100
Weyerhaeuser	7.8	<0.2	4.2	23	0.09	2.0	<4	1.8	105
Cow Point	12.0	0.3	6.0	22.0	0.09	1.0	<4	1.8	174
North Bay	17.0	<0.2	3.0	16.0	0.15	3.8	<4	1.9	204
South Channel A	12.0	0.2	6.8	17.0	0.09	4.6	<4	2.0	222
South Channel B	10.0	<0.2	5.9	17.0	0.09	4.7	<4	1.6	230
Willapa Bay	31.0	0.3	3.0	18.0	0.15	3.0	6.0	2.6	108
NOAA NST Grays Harbor Westport Jetty Site (mussels only)	8.83	2.63	1.73	10.33	0.05	2.33	0.44	2.13	150
NOAA NST Range: 12.5- 87.5 Percentile	5.4-110	1.0-5.1	0.25-2.2	62-143 oyster	0.04-0.21	0.97-3.4	0.19-3.13	1.53-3.27	883-2,600 oyster
				7.6-11 mussel					93-310 oyster
NOAA NST Maximum	42.7	13	10.9	1603 oyster	0.48	12.6	23.3	8.17	13,000 oyster
				20.3 mussel					310 mussel

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

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Table 13. Metal concentrations (ppm dry weight) measured in amphipods from Grays Harbor and Willapa Bay.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	2.2	<0.2	2.0	81.6	0.09	<1.0	10	0.91	65.9
Bowerman 2	2.5	0.6	3.5	124	0.05	2.0	140	0.86	60.6
North Bay	2.2	0.4	<1.0	280	0.05	1.0	72	0.69	82.5
South Bay	2.8	<0.2	<1.0	108	0.09	<1.0	120	0.93	69.4
South Channel	1.8	<0.2	2.0	86.9	0.04	2.0	8.0	0.56	61.1
Willapa Bay	3.4	0.76	2.0	123	0.06	2.0	150	0.98	62.5

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

ENVIRONMENTAL CONTAMINANTS INVESTIGATIONS AT THE PROPOSED GRAYS HARBOR NATIONAL WILDLIFE REFUGE, GRAYS HARBOR, WASHINGTON

U.S. Fish and Wildlife Service
Ecological Services
Olympia Field Office
Olympia, Washington

August 1992

INTRODUCTION

The U.S. Fish and Wildlife Service proposes to obtain approximately 1,812 acres of land in Grays Harbor, Washington, which will serve as the basis for establishing the Grays Harbor National wildlife Refuge. The objectives of the Refuge will be to protect habitat for migratory and resident shorebirds and waterfowl, protect threatened and endangered wildlife, and provide wildlife recreation opportunities. A preacquisition environmental contaminant survey was conducted for the establishment of the Refuge as part of the land acquisition process.

The superfund Amendment Reauthorization Act to the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund Act) requires that landowners, including the Federal government, may be responsible for the entire cost of cleaning up a hazardous waste site on their lands even if they were not responsible for or had prior knowledge of those wastes. In certain situations, the cost of remediating contaminated lands can far exceed the value of the land itself and become a liability to the Federal government.

Service policy is to `avoid acquisition of lands that will require costly cleanup of contaminants unless the resource values of those lands clearly outweigh those costs...'. The Service policy requires that a contaminants survey be conducted to determine the possible presence of hazardous substances and the potential environmental impacts from those substances.

In adherence to the above policy. the Olympia Field Office was requested to conduct a preacquisition environmental contaminant survey for property to be acquired for the Grays Harbor National Wildlife Refuge. Specifically, a survey was requested for a 68 acre tract owned by the city of Hoquiam and the portion of land adjacent to the northern boundary of the Bowerman Airport which is owned by the Port of Grays Harbor.

A Level I preacquisition survey was conducted for all upland properties proposed for acquisition and adjacent properties. An initial site visit was conducted on March 21, 1989 by the Environmental Contaminant Specialist and project biologist from the Olympia Field Office. The objective of the site visit was to inspect properties to determine the potential presence of contaminant sources, contaminants, and associated liabilities to the Service. A determination also was to be made regarding the need to conduct additional studies at the site and estimated costs.

SITE DESCRIPTION

Grays Harbor is a 94-square mile estuary located along the Washington coast, approximately 45 miles north of the mouth of the Columbia River (Figure 1). Various habitat types that exist in and around Grays Harbor include upland and lowland forests, floodplains, coastal dunes, fresh and salt water wetlands, and intertidal and eelgrass flats.

The 68 acres of City of Hoquiam property consists two parcels of land. One parcel (5.8 acres) is located between Route 109 and the intertidal area and

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constitutes the northern boundary of the proposed Refuge. It was determined in the Level I preacquisition survey that there was no or little concern for contaminants on this parcel.

The remaining portion of the city of Hoquiam property makes up the eastern boundary of the Refuge. This area contains saltwater and freshwater marshes. Two small creeks flow through the freshwater and saltwater marshes. A dredged material disposal area which received sediments from Grays Harbor is also located on the City of Hoquiam property. Freshwater wetlands are Located on the disposal area.

The Port of Grays Harbor parcel located adjacent to Bowerman Airport is a narrow strip of land that contains shrubs and salt marsh vegetation. The remaining portion of the property (approximately 1,700 acres) is subtidal and intertidal habitat which is also owned by the Port of Grays Harbor.

AREAS OF CONTAMINANT CONCERN

A log storage yard is located immediately to the east of the proposed Refuge boundary. The two small creeks drain surface water runoff from the log storage yard. The creeks also receive surface water runoff from Route 109 and Paulson Road which makes up the eastern boundary of the Refuge.

The dredge material disposal area is approximately 21 acres in size. The dredge material originated from Grays Harbor. Although this area contains freshwater wetlands, there is a portion (2 acres) that is devoid of vegetation. Although the reason for the lack of vegetation is unknown, it may be simply due to surface grading at the site and compaction of the substrate.

Sediment in Grays Harbor receive contaminants from pulp mills, industrial discharges, sewage treatment plants, shipping, nonpoint runoff from the cities of Hoquiam and Aberdeen, and intensely managed forest and agricultural land within the watershed. Land use practices and urban related activities can contribute various contaminants to the sediments including polynuclear aromatic hydrocarbons (PANs), polychlorinated biphenyls and metals.

Activities at Bowerman Airfield include a repair shop which is drained by a ditch that enters the narrow strip of property at the southern boundary of the Refuge. Five metal drums (55 gallon) were present outside of the repair shop and appear to be used at the repair shop. The contents of the drums could not be determined, but most likely contain either hydraulic fluids or solvents which are commonly used in cleaning aircraft parts. This piece of property also receives surface water runoff from the airport runway and other airport roadways. Potential contaminants from these activities include PANs, aliphatic hydrocarbons and metals.

There was no evidence of industrial or municipal dumping an property proposed to be included in the Refuge or on adjacent properties. In addition, no storage tanks (above or below ground) or chemical storage buildings were observed on any of the properties.

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Due to land use activities in the Grays Harbor watershed and immediately adjacent to the proposed Refuge, the Olympia Field Office recommended that a Level II preacquisition contaminant survey be conducted for the proposed Refuge. As part of the Level II survey, the collection and analysis of sediment, soil and water samples was recommended far selected aquatic, wetlands and upland area.. Sediments, clams, amphipods and juvenile chinook salmon from intertidal and subtidal areas were investigated as part of a separate environmental contaminants special study of Grays Harbor. Analytical sample results from both the Level II preacquisition survey and the environmental contaminants special study are presented in this report. Further information on the Grays Harbors special study methods, data and results is provided in a separate report currently in preparation (Benkert 1992).

SAMPLE COLLECTION AND ANALYSIS

As part of the Level II preacquisition survey, sediment, soil and water samples for contaminant analysis were collected during the week of June 12, 1989. The samples for the Gray Harbor study were collected in July and August of 1990.

Sediment samples were collected to a depth of 10 centimeters using a garden spade. Only sediment not in direct contact with the spade was used for sample analysis. Three sediment subsamples were collected at each sampling site and were composited in an acid cleaned stainless steel mixing bowl. Samples were homogenized by mixing the sediment with an acid washed stainless steel spoon. Following homogenization, samples were placed in pre-cleaned amber glass jars and placed on ice. Samples were returned to the Olympia Field Office and frozen.

Soil core samples were collected with an acid cleaned stainless steel soil core sampler. All soil core. were taken to a depth of 40-50 centimeters except for the dredge disposal area. Soil samples from the dredge disposal area were taken to a depth between 8 and 10 centimeters. Samples were placed in an acid cleaned stainless steel mixing bowl. Five subsamples per sampling site were homogenized with a stainless steel spoon to make up composite sail samples. Samples were place in pre-cleaned amber glue jars and placed on ice until transferred for freezing.

Water samples were collected directly into sample containers by submerging the containers 4-10 centimeters under the water surface. Integrated samples were taken by collecting portions of the sample either across the stream channel or at points down the center of the channel. Samples for inorganic analyses were collected in 1,000 milliliter (ml) polyethylene bottles and acidified to pH 2 or less with nitric acid immediately following collection. Samples for organic analyses were collected in 500 ml amber glass jars. Water samples were not filtered. All samples were place on ice following collection.

Samples were analyzed for inorganic and organic contaminants (Table 1) by analytical laboratories under contract through the Service's Patuxent Analytical control Facility (PACF). Samples were shipped on ice by

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overnight carrier to appropriate laboratories. Sample collection, shipment, and analyses were completed using the service's rapid turnaround protocols.

Arsenic and selenium residues were determined by hydride generation on an atomic absorption spectrophotometer. Mercury was analyzed using the cold vapor analytical methodology. All ether inorganic contaminant (metals) analyses were accomplished using Inductively Coupled Plasma (ICP). Analyses of organic contaminants were conducted using capillary, flame ionization gas chromatography and fluorescence high performance liquid chromatography.

Quality control and quality assurance of all sample analyses were completed by personnel at PACF. No quality control, quality assurance, or analytical problems were identified. All metals data are presented in dry weights and organics data are presented wet weights.

SAMPLE SITES

Preacquisition Study. Sediment sample were collected from the two unnamed creeks (SD1, SD4) which receive surface water from area roads, a drainage ditch (SD2) which receives runoff from the log storage area and from the drainage ditch (SD3) near the airport maintenance shop (Figure 3). Soil samples were collected from the dredge disposal area (SL2, SL4), base of the dredge disposaL area (SL3), and forested wetland (SL1) which is located on Port of Grays Harbor property. Water samples were collected on the city of Hoquiam property from the northern most creek (W3) and drainage ditch (W2) that enters this creek. A water sample (W1) was collected from a small pond within the log storage area which is also the source of water for the southern most creek on the property.

Grave Harbor Special Study. Sediment, juvenile fall chinook salmon (Oncorhynchus tshawystcha), clam (Mya arenaria), amphipod (Corophium spp.) samples were collected from sites within Grays Harbor and from a reference site in Willapa Bay. The Grays Harbor sites include two sites in Bowerman Basin. (Bowerman 1, Bowerman 2) and single sites located at Cow Point, the Weyerhaeuser discharge, North Bay, South Bay and South channel (Figure 1). The Willapa Bay reference site (Figure 2) is approximately 4 kilometers north of Willapa National Wildlife Refuge headquarters on the east bank of Stanley channel. Duplicate samples from the same site are indicated as Sample "A" and Sample "B". Fish were not collected in Bowerman Basin.

RESULTS

Polycyclic Aromatic Hydrocarbons (PAHs). The chemicals comprising PAHs are based upon a fused ring structure involving two or more benzene rings. The PAHs are naturally present in petroleum but are also associated with the by-products of incomplete combustion, such as particulates from engine exhaust, cigarette smoke and used oils. Athropogenic sources of PAH contamination include spills of petroleum hydrocarbons, industrial and domestic effluents, wood treatment facilities, and surface water runoff in urban areas (Eisler, 1987). All of these sources are present in the Grays

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Harbor estuary and the immediate vicinity of the sampling sites of this study.

PAHs were found in all of the sediment samples. A total PAH residue value was calculated for each sample by summing the individual residue values for each of the 14 PAHs analyzed in the laboratory scan (Table 1).

Concentrations of total PAH in the preacquisition sediment samples from Bowerman Basin ranged from 0.11 ppm (parts per million) to 0.32 ppm wet weight (Table 2). The highest total PAH concentration was identified in sediment from site SD1 which wae located in the northern most creek on the Hoquiam property (Figure 3). The highest concentrations of individuaL PAH compounds were also found at site SD1: pyrene (0.09 ppm), fluoranthrene (0.06 ppm) and phenanthrene (0.04 ppm).

A likely source of PAH contamination at sites SD1 and SD3 is surface water runoff from nearby road surfaces. Studies have shown that urban runoff from stormwater and highways can account for as much as 71% of the total input of high molecular weight PAH (WPAH) contamination (Hoffman et al. 1984). The HPAHs made up the greatest percentage of PAH compounds present in the sediment samples from this study. The HPAH compounds of fluoranthrene and pyrene accounted for 47% of the total PAH at SD1 and SD3 and 40% at site SD4.

Total PAHS in sediments from throughout Grays Harbor (Table 3) ranged from 0.04 ppm in South Bay to 0.47 in North Bay. The Willapa Bay reference site had a total PAH concentration of 0.22 ppm. Total PAHs measured in Bowerman Basin sediments do not indicate contamination at levels above what was found throughout the Grays Harbor system. Total PAH concentrations in sediments from both the Grays Harbor study and the preacquisition study were an order of magnitude less than concentrations known to cause biological effects (Long and Morgan 1990).

Soil concentrations of total PAH were lower than those found in the sediments and ranged from 0.01 ppm to 0.15 ppm (Table 2). The highest total.PAH concentration in soil (0.15 ppm) was located at site SL1, a freshwater wetland located on the dredge disposal area. As was found in the sediment samples. the HPAHs predominated in the soil samples.

Marine bivalve mollusks, such as oysters and mussels, accumulate PAHs (Eisler 1987b, Moore and Ramamoorthy 1984a). The accumulation of PAHs fluctuates seasonally, with higher residue levels present in spring and summer when lipid stores are maximal for reproduction. The total PAHs measured in clams (Table 3) from the Grays Harbor study were low and do not indicate pollution.

The amphipod sample from the Bowerman 1 site had a relatively high concentration of total PAHs (1.03 ppm). The remaining amphipod samples were lower, ranging from 0.06 ppm at South Bay to 0.14 ppm total PAHs (Table 3) at the Willapa Bay reference site. The lack of amphipod residue data from other estuarine systems for purposes of comparison, limits conclusions on the level or degree of contamination at the Bowerman 1 site.

5

Aliphatic Hydrcarbons (Alkanes). The aliphatic hydrocarbons are a class of chemicals found naturally in petroleum and gas deposit.. They include both straight and branched alkanes (paraffins) and cyclohexanes. Aliphatic hydrocarbons can enter aquatic systems from a variety of sources through point and non-point source discharges. Point sources can include wastewater treatment plants, industrial effluents, spills and exhaust from gasoline powered engine. Non-point discharges can occur from highway and urban stormwater runoff. Five of the thirteen aliphatic hydrocarbons detected in the analytical scan are known to be used in the paper processing industry: n-dodecane, n-hexadecane, n-octadecane, phytane and n-eicoeane (Verschueren 1983).

A total aliphatic residue value was calculated by summing all of the individual aliphatic hydrocarbon residues. Aliphatics were detected in all of the preacquisition study sediment samples. Total aliphatic concentrations ranged from a low of 0.16 ppm at site SD3 to a high of 1.76 ppm at site SD2. Sampling sites SD2 and SD1 (0.94 ppm) receive surface runoff from nearby roads. Petroleum products from the road surfaces are the likely source of aliphatics to these two streams.

Total aliphatic. in sediments from the Grays Harbor special study ranged from a low of 0.24 ppm in South Bay to a high of 3.40 ppm at the Bowerman 1 site (Table 4). Those sites located the furthest from both roads and the Weyerhaeuser discharge had the lowest values. The reference site in Willapa Bay, which located in relatively close proximity to the highway, had a value of 1.92 ppm.

Total concentrations of aliphatics in soil samples ranged from 0.01 ppm at site SL2 to 0.80 ppm at site SL3. Aliphatics were not detected in any of the water samples.

Total aliphatics in clams from the Grays Harbor study ranged from 0.10 ppm to 0.53 ppm (Table 4). Total aliphatics in amphipods ranged from 0.07 ppm at South Bay to 27.56 ppm at the Weyerhaeuser site. Marine invertebrates in an environment of chronic aliphatic hydrocarbon exposure have residues ranging from 1 to 150 ppm wet weight (Moore and Ramamoorthy 1964a). Although the residues in amphipods are indicative of chronic low level aliphatic hydrocarbon exposure at the Bowerman Basin, Weyerhaeuser and the Willapa Bay sites, the high variability in duplicate samples from

Weyerhaeuser (Table 4), requires additional data to support that conclusion.

Total aliphatics in juvenile chinook (Table 4) ranged from a low of 3.10 ppm in Willapa Bay to 8.26 ppm in North Bay. Aliphatic hydrocarbon residues in oceanic fish range from <0.5 to 5 ppm, while inshore fish generally have higher levels (Moore and Ramamoorthy 1984a). Although, the levels measured in the juvenile chinook may indicate chronic exposure to aliphatic hydrocarbons, the lack of chinook data from other estuarine systems, limits further conclusions on the level or degree of contamination.

6

Organochlorines. Organochlorines pesticides and polychlorinated biphenyl (PCB) compounds, were analyzed in the sediment and soil samples from the preacquisition study. None were detected (detection limit = 0.01 ppm) in any of the samples.

Dioxins/Furans. Polychlorinated dibenzodioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), by-products of the chlorine bleaching process of wood pulp for paper production, are released in paper mill effluents. As PCDDs and PCDFs are not highly soluble in water and preferably bind with organic particles, they are commonly detected in downstream sediments from paper mills (Schweer et al. 1990; BCI and Shapiro & Associates 1991).

PCDDs and PCDFs, like other organochlorine compounds, generally are environmentally stable and highly lipophilic, tending to accumulate in the fat of organisms. Documented effects of exposure to PCDDs and PCDFs on fish and birds include death, immune system failure, reproductive failure, internal organ lesion development, reduced feeding, erratic swimming and fin necrosis (Eisler 1986; Schweer et al. 1990). The most toxic PCDD isomer is 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin.

Analyses of total and isomer specific dioxin and furan compounds were conducted on selected sediment (Table 5) and biological samples (Table 6) from the Grays Harbor study. The reported dioxins and furans in sediments have been normalized for total organic carbon content (TOC). The biological samples were not normalized for lipid content as the amphipod sample was of insufficient size for lipid analysis.

Sediments from the Bowerman 2 site had the highest level of 2,3,7,8-tetrachlorodibenzo-p-dioxin, followed by sediments from the Weyerhaeuser discharge site (Table 5). The highest dioxin levels generally were found at the Bowerman 2 site. The maximal furan levels were distributed among the sites, without any discernable pattern. [Background???]

Dioxins and furans concentrations (Table 6) measured in juvenile salmon were low (<10 parts per trillion wet weight 2,3,7,8-tetrachlorodibenzo-p-dioxin) in comparison to levels measured in fish from contaminated aquatic systems (Baumann and Whittle 1988; Johnson, Serdar and Magoon 1991). It should be noted though, that juvenile salmon are migratory through the Grays Harbor system and thus, dioxin and furan levels in resident species are likely to be greater.

Dioxin and furan concentrations in the Weyerhaeuser site clams were similar to levels measured in the juvenile salmon (Table 6). Although, the clams are resident species in close contact with sediments and proximally located to the effluent discharge, the concentrations present are low.

Relatively high levels of dioxins, particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin, were measured in the amphipod sample (Table 6). Although the lack of lipid content data for the amphipod sample prevents normalization of the data for comparison purposes, it does not eliminate the question of exposure to those organisms feeding on these amphipods. Corophium amphipods are important prey items for both juvenile salmon and shorebirds.

The dioxin levels measured in this single amphipod sample introduces serious questions regarding food chain effects.

Metals sediments. The biogeochemistry of metal cycles in aquatic systems is complex. Metals exist in flux among dissolved, adsorbed bottom particulates and suspended particulate states. Ambient environmental conditions of pH and reduction-oxidation potential (Eh) are major factors in controlling the flux of metals from one state to another. Biotic contact and interactions with metals occur in all states of the cycle, although metals in a dissolved state are more biologically available (Elder 1988).

Sediments are generally considered as sinks for metals in the aquatic environment. Metals are strongly adsorbed to various types of particulates and settle out in Low flow conditions. Clay-mineral particulates are one type of substrate which strongly binds metals. Organic particles and iron (Fe) and manganese (Mn) hydroxides also tightly bind metals (Elder 1986). Silt and clay sized sediment particles physico-chemically provide more binding sites for the attachment of organic and metal contaminants than other sediment size fractions.

Grain size analysis of the sediment samples from the Grays Harbor special study indicated that Bowerman Basin is a depositional environment with sediments comprised of over 84 percent silt and clay (Table 7). The Willapa Bay sediment sample was 77 percent silt and clay. All other samples were less than 36 percent silt and clay. Bowerman Basin also had the highest levels of total organic carbon (TOC) measured in the Grays Harbor study sediments (Table 7). The TOC correlates with the percent silt in the grain size analysis of the sediments.

Sediment criteria and guidelines have been established by various State and Federal agencies and countries. Sediment criteria and guidelines provided for comparison purposes in this report (Table 6) include the apparent effects thresholds for both amphipod toxicity and benthic effects and the State of Washington proposed chemical criteria for marine sediments (Environmental Protection Agency 1991). The apparent effects threshold is the concentration, of a specific chemical, present in the sediment at which statistically significant (p ó 0.05) reductions in benthic infauna or elevated mortalities from toxicity occur. The sediment standards and apparent effects threshold criteria do not adjust or standardize the residue levels for differences in sediment grain size or organic content. Thus, exceedance of a guideline or criteria should be viewed conservatively.

Priority pollutant metals were analyzed in all sediment, soil, and water samples from the preacquisition study. These metals include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), selenium (Se) and zinc (Zn). Priority pollutant metals were not measured above the detection level in any of the water samples.

Soils collected from site SL2, located at the dredged material disposal site, had the highest concentrations of several of the metals: cadmium

(0.70 ppm), chromium (178 ppm), copper (181 ppm), nickel (88.6 ppm), and zinc (111 ppm) (Table 9). None of these metal concentrations exceeded the Dutch soil clean-up criteria, although the criteria recommend that copper concentrations exceeding 100 ppm should be evaluated further (Beyer 1990). The State of New Jersey soil clean-up guidelines identify chromium levels of 170 ppm or less as protective of ground water resources (Beyer 1990).

Metal concentrations in the preacquisition (Table 9) and the Grays Harbor (Table 10) study sediments did not exceed the apparent effects thresholds or the proposed marine sediment standards (Table 8). When compared to the Puget Sound Dredged Disposal Analysis sediment screening levels, which are normalized for organic carbon content, none of the Grays Harbor study sediments were in exceedance (Table 11). Organic carbon was not analyzed in the preacquisition study samples.

Metals: Clams. Uptake of metals by clams occurs primarily through ingestion and water filtration. As metals are most bioavailable in the dissolved state (Elder 1988), the metal residues accumulated by clams primarily should reflect the availability of metals from the water column. Limited metal uptake from dermal contact with the sediments also is possible.

Mollusks, in general, are poor regulators of metals, especially non-essential trace elements (Rand and Petrocelli 1985). Consequently, some metals will accumulate to relatively high levels, particularly in comparison to metal residues typically found in fish.

The National oceanic and Atmospheric Administration's (NOAA) National Status and Trends (NST) Program measures organics and metals in marine bivalves (NOAA 1987) from 145 site. nationwide. The NST values were measured in both oysters. (Crassostrea virginica) and mussels (Mytilus spp.). Although, bioaccumulation of metals in mollusks will vary by species, general comparisons can be made. Metals in softshell clams from the Grays Harbor study are compared to the NST results in Table 10. Results from the NST site located at the Grays Harbor Westport jetty (GHWJ), are also included.

Bioaccumulation of both copper and zinc is strongly species dependent (NOAA 1987) and limit comparison of concentrations measured in different species. Thus, the NST results are presented by species for these metals. In addition, the NST results suggest, although do not confirm, that chromium and lead may have species specific bioaccumulation rates.

In general, the metal concentrations measured in clams in the Grays Harbor study are within the 12.5 to 87.5 percentile distribution of the NST values (Table 12). Sites with relatively elevated concentrations in clams include Bowerman 1 (64.4 ppm Cu), Bowerman 2 (28.8 ppm As) and Willapa Bay (31.0 ppm As). Zinc concentrations were relatively low in clams from Bowerman 2 (100 ppm Zn), Weyerhaeuser (105 ppm Zn) and Willapa Bay (108 ppm Zn).

Metals: Amphipods. Limited amphipod data were collected during the Grays Harbor study (Table 13). copper and lead concentrations in amphipods were

found to be highly variable between sites. This variability did not appear to be linked to copper and lead levels in the sediments. The level of arsenic, cadmium, chromium, mercury, nickel, selenium and zinc among sites were not elevated relative to each other. The lack of duplicate samples and comparative marine amphipod data limit further conclusions.

SUMMARY DISCUSSION

The contaminant levels measured in sediments, soils, water and biota from Bowerman Basin were generally low, with the notable exception of 2,3,7,8-tetrachlorodibenzo-p-dioxin in the amphipod sample. Samples from Bowerman Basin, a sediment depositional zone in the Grays Harbor system, commonly were found to have higher aliphatic hydrocarbon. PAH and metal concentrations relative to other sites sampled in Grays Harbor. As expected, soils from the dredged disposal site in Bowerman Basin also had relatively higher levels of contaminants.

With the exception of the dioxin contaminated amphipods, the existing levels of other contaminant residues in Bowerman Basin do not present an acute threat to the health of fish and wildlife resources. As Bowerman

Basin is a depositional environment in an industrialized estuary, the continued accumulation of contaminants in sediments is likely. Low-level chronic effects may occur in trust resources from present and/or increasing levels of contaminants in sediments, water and prey items. Future implementation of adequate and additional source controls on the industries located in the watershed should reduce future inputs of metals, dioxins, furans, aliphatic hydrocarbons and PAHs into the estuary.

The single amphipod sample analyzed for dioxins and furans raises many questions and answers none. The bioavailability of dioxin and furans on the proposed Grays Harbor National Wildlife Refuge may introduce resource management concerns relative to food chain effects in migratory birds and other fish and wildlife. To address these concerns, the Washington Department of Fisheries (Schroeder and Fresh 1992) has recommended that the Service conduct extensive sampling of amphipods in Grays Harbor to assess the extent and degree of dioxin and furan contamination. The Olympia Fish and Wildlife Enhancement Field Office and the Service's Western Washington Fisheries Resource Office presently are exploring funding options to undertake this survey.

Service acquisition of lands for the Grays Harbor National Wildlife Refuge should avoid the assumption of any costs or liability associated with the possible future removal and/or containment of contaminated sediments in Bowerman Basin. Although, sediment contaminant levels in Bowerman Basin are currently are below the PGDDA screening level and proposed State of Washington sediment standards, the Service should not assume liability for future accumulation of contaminants in Bowerman Basin sediments.

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LITERATURE CITED

Baumann, P. C. and D. M. White. 1988. The status of selected organics in the Laurentian Great Lakes: an overview of DDt, PCBS, dioxins, furans. and aromatic hydrocarbons. Aq. Tox. 11: 241-257.

BCI and Shapiro & Associates, Inc. 1991. Chemical and Biological Literature Inventory: Grays Harbor and Willapa Bay. 104+ pp.

Benkert, K. 1992. Grays Harbor contaminants study. In preparation. U.S. Fish and Wildlife service, Olympia Field Office Contaminants Report.

Beyer, N. W. 1990. Evaluating soil contamination. U.S. Fish and Wildlife Service Biological Report 90(2). 25 pp.

Eisler, R. 1986. Dioxin hazards to fish, wildlife, and invertbrates: a synoptic review. U.S. Fish Wildlf. Serv. Biol. Pep. 85 (1.8). 37 pp.

Eisler, R. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildfl. Serv. Biol. Rep. 85 (1.11). 81 pp.

Elder, J. F. 1988. Metal biogeochimstry in surface-water systems: a review of principles and concepts. U.S. Geological Survey Circular 1013. 43 pp.

Environmental Protection Agency.- 1991. Pollutants of concern in Puget Sound. EPA 910/9-91-003. EPA Region 10, Seattle, Washington. 105 pp + appendix.

Hoffman, E. J., G. L. Mills, J. S. Latimer and J. G. Quinn. 1984. Urban runoff as a source of polycyclic aromatic hydrocarbons to coastal waters. Environ. Sci. Technol. 18: 580-587.

Johnson, A., D. Serdar, and S. Magoon. 1991. polychlorinated dioxins and

-furans in Lake Roosevelt (Columbia River) sportfish, 1990. Washington Department of Ecology, Olympia, Washington; Publication #91-4. 47 pp. + appendix

Long, E. R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Technical Memorandum NOS OMA 52. Seattle, WA. 175 pp. + appendices.

Moore, J. W. 1990. Inorganic Contaminants of Surface Water. Springer -Verlag. New York. 334 pp.

Moore, J. W. and S. Ramamoorthy. 1984a. Organic Chemicals in Natural Waters. Springer-Verlag. New York. 289 pp.

Moore, J. W. and S. Ramamoorthy. 1984b. Heavy Metals in Natural Waters.

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Springer-Verlag. New York. 268 pp.

National Oceanic and Atmospheric Administration (NOAA). 1987. National Status and Trends Program for marine environmental quality. Progress Report; NOAA Tech. Memo. NOS OMA 38. Rockville, MD. 23 pp + appendices.

Rand, G. M. and S. R. Petrocelli. 1985. Fundamentals of Aquatic Toxicology: - Methods and Applications. Hemisphere Publishing Corp. Washington, DC. 666 pp.

Schroeder, S. and X. Fresh (Eds.). 1992. Results of the Grays Harbor coho survival investigations, 1987-1990. Washington Department of Fisheries; Technical Report #118.

Schweer, G., B. Gregg, L. Schultz, P. Wood, T. Leighton, C. D'Ruiz, R. Fares, G. Huse, C. Carpenter, J. Konz, and D. Arrenholz. 1990. Background document to the integrated risk assessment for dioxins and furans from chlorine bleaching in pulp and paper mills. EPA 560/5-90-014. Environmental Protection Agency, Washington. DC. 98 pp.

Verschueren, K. 1983. Handbook of Environmental Data on Organic Chemicals. 2nd Edition. Van Nostrand Reinhold Company. New York. 1,310 pp.

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See Table/Figure

Figure 1. Grays Harbor Study Sites.

(SEE ORIGINAL)

See Table/Figure

Figure 2. Willapa Bay Reference Site.

(SEE ORIGINAL)

See Table/Figure

Figure 3. Sediment, soil, and surface water sampling locations for the Gray Harbor National Wildlife Refuge.

(SEE ORIGINAL)

Table 1. organic chemicals and metals measured-in study sample.

Aliphatic Hydrocarbons	Polycyclic Aromatic Hydrocarbons	Organochlorines
n-Dodecane	Naphthalene	HCB (hexachlorobenzene)
n-Tridecane	Fluorene	à-BHC
n-Tetradecane	Phenanthrene	á-BHC

Octylcyclohexane
n-Pentadecane
Nonylcyclohexane
n-Hexadecane
n-Heptadecane
Pristane
n-Octadecane
Phytane
n-Nonadecane
n-Eicosane
Benzo(g,h,i)perylene
p,p'-DDE
Mentals
Mercury (Hg)
Lead (Pb)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Nickel (Ni)
Zinc (Zn)
Arsenic (As)
Selenium (Se)

Anthracene
Fluoranthrene
Pyrene
1, 2-Benzanthracene
Chrysene
Benzo(b)fluoranthrene
Benzo(k)fluoranthrene
Benzo(e)pyrene
Benzo(a)pyrene
1,2,5, 6-Dibenzanthracene
o,p'-DDE

Y-BHC (lindane)
ë-BHC
Heptachlor epoxide
Toxaphene
PCB's (total)
Mirex
Endrin
Dieldrin
o,p'-DDT
p,p'-DDT

o,p'-DDD
p,p'-DDD
Oxychlordan
à-Chlordane
Y-Chlordane
cis-Nonachlor
trans-Nonachlor

Dioxins /Furans
see Table 5

Table 2. Organic chemical levels (ppm wet weight) measured in sediments and soils collected from Bowerman Basin for the preacquisition study. ND = not detected.

SITE -	Total Aliphatic Hydrocarbons	Total Polycyclic Aromatic Hydrocarbons	organochlorines
SD1	0.94	0.32	ND
SD2	1.76	0.11	ND
SD3	0.16	0.17	ND
6D4	0.61	0.18	ND
SL1	0.65	0.15	ND
SL2	0.01	0.01	ND
SL3	0.08	0.11	ND
SL4	0.07	0.08	ND

Table 3. Total polycyclic aromatic hydrocarbons (ppm wet weight) measured in sediments and biota from the Grays Harbor special study. N/A indicates a sample was not collected for analysis.

SITE	SEDIMENTS	CLAMS	AMPHIPODS
Bowerman 1	0.35	0.06	1.03
Bowerman 2	0.29	0.07	0.10
Weyerhaeuser A	0.16	0.06	N/A
Weyerhaeuser B	N/A	N/A	0.08
Cow Point A	0.26	0.07	N/A
Cow Point B	0.24	N/A	N/A
North Bay	0.47	N/A	0.11
South Bay	0.04	0.04	0.06
South Channel A	0.15	0.04	0.10
South Channel B	N/A	0.04	N/A
Willapa Bay	0.22	0.02	0.14

Table 4. Total aliphatic hydrocarbons (ppm wet weight) measured in sediments and biota from the Grays Harbor special study. N/A indicates a sample was not collected for analysis.

SITE (Whole Body)	SEDIMENTS	CLAMS	FISH	AMPHIPODS
Bowerman 1	3.40	0.53	N/A	3.38
Bowerman 2	0.77	0.10	N/A	1.28
Weyerhaeuser A	1.30	0.19	5.05	27.56
Weyerhaeuser B	N/A	N/A	3.69	0.27
Cow Point A	0.54	0.19	4.71	N/A
Cow Point B	0.88	N/A	N/A	N/A
North Bay	0.39	N/A	8.26	0.08
South Bay	0.24	0.14	4.77	0.07
South Channel A	0.69	0.11	7.82	0.08
South Channel B	N/A	0.13	N/A	N/A
Willapa Bay	1.92	0.15	3.10	2.85

Table 5. Dioxin and furan concentrations (parts per trillion wet weight) in sediments normalized for total organic carbon content. ND = not detected; E = chemical detected but with analytical interference.

ISOMER SITE

Willapa	South channel	South Bay	North Bay	Bowerman 1 (N=2)	Bowerman 2 ·	Weyer-heauser (N=2)	Cow Point
2378-TCDO	ND	0.79	ND	ND	0.31	0.87	0.83
12378-PeCDD	ND	0.53	ND	ND	0.5	1.1	0.86
123478-HxCDD	ND	ND	ND	ND	ND	0.71	ND
123678-HxCDD	0.52	1.4	1.6	ND	1.2	1.8	1.9
123789-HxCDD	0.21	3.1	2.6	ND	1.2	3.5	2.0
1234678-HpCDD	5.0	16.7	14.0	13.0	13.0	25.2	19.0
OCDD	34.1	89.4	47.6	ND	96.5	137.6	150.0
2378-TCDF	ND	3.3	2.3	ND	0.81	2.6	2.1
12378-PeCDF	0.12	0.23	ND	ND	0.14	0.12	ND
23478-PeCDF	ND	0.26	0.40	ND	ND	0.16	ND
123478-HxCDF	ND	0.44	1.32	ND	0.23	0.65	ND
123678-HxCDF	0.14	0.23	ND	ND	0.29	0.39	ND
234678-HxCDF	ND	0.30	1.0	1.2	ND	0.53	ND
123789-HxCDF	ND	ND	ND	ND	ND	ND	ND
1234678-HpCDF	1.3	5.3	6.0	4.3	4.7	7.6	16.4
1234789-HpCDF	ND	ND	1.12	ND	ND	ND	ND
OCDF	2.0	7.1	12.4	8.0	7.1	12.4	15.0
TOTAL TCDD	0.25	3.0	1.8	ND	1.7	3.7	2.0
TOTAL PeCDD	0.74	5.1	ND	ND	2.4	7.3	2.7
TOTAL HxCDD	3.4	20.7	16.0	13.7	12.5	29.3	30.0
TOTAL HpCDD	11.6	35.6	28.0	31.7	28.5	58.2	41.0
TOTAL YCDF	1.0	9.7	6.4	ND	2.6	9.6E	6.7
TOTAL PeCDF	1.2	3.1	4.8	3.3	3.9	6.2	5.0
TOTAL HxCDF	0.76	7.9	ND	4.0	5.3	12.0	18.8
TOTAL HpCDF	1.5	13.7	14.4	5.7	10.6	19.5	39.6
% MOISTURE	51.3	20.5	20.3	38.9	63.3	31.6	30.3

Table 6. Dioxin and furans (parts per trillion wet weight) in biota from the Grays Harbor study. ND = not detected; N/A not applicable.

ISOMER	Weyerhaeuser	Weyerhaeuser	Bowerman 1
Juvenile Chinook Salmon	Clems	Amphipods	
2378-TCDD	1.32	ND	23.4
12378-PeCDD	ND	ND	ND
123478-HxCDD	ND	ND	19.4
123678-HxCDD	ND	ND	ND
123789-HxCDD	ND	ND	ND
1234678-HpCDD	1.81	2.03	114
OCDD	9.86	12.2	2268

2378-TCDF	1.55	1.10	27.5
12378-PeCDF	ND	ND	ND
23478-PeCDF	ND	ND	ND
123478-HxCDF	ND	ND	41.1
123678-HxCDF	ND	ND	34.8
234678-HxCDF	ND	ND	ND
123789-HxCDF	ND	ND	ND
1234678-HpCDF	ND	ND	85.1
1234789-HpCDF	ND	ND	ND
OCDF	ND	ND	97.1
TOTAL PCDD	1.23	ND	97.0
TOTAL PeCDD	ND	ND	ND
TOTAL HxCDD	ND	1.72	37.1
TOTAL HpCDD	1.81	4.86	223
TOTAL TCDF	2.99	1.75	575
TOTAL PeCDF	ND	0.787	314
TOTAL HxCDF	ND	ND	162
TOTAL HpCDF	ND	ND	85.1
% LIPIDS	4.77	0.95	N/A

Table 7. Total organic carbon (ppm dry weight) and percent grain size fractions in sediments from the Grays Harbor study.

SITE	Total Organic Carbon (TOC)	%Clay	%Silt	%Sand
Bowerman 1	2.6	17.8	74.7	7.6
Bowerman 2	2.0	20.5	64.0	15.6
Weyerhacuser	0.7	6.4	16.4	77.2
Cow Point A	0.8	6.4	29.2	64.4
Cow Point B	0.7	3.4	14.4	82.2
North Bay	0.3	4.1	7.0	88.9
South Bay 1	0.3	2.6	3.8	93.6
South Channel	1.0	8.2	23.7	68.1
Willapa Bay	2.0	20.9	55.7	23.4

Table 8. Metal threshold criteria for biological effects and proposed marine sediments standards.

Sediments Standards or Criteria	METAL (ppm dry weight)							
	Hg	Pb	As	Cd	Cr	Cu	Ni	Zn
Apparent Effects Threshold for Marine Benthic Effects		450	57	5.1	260	530	>140	410
Apparent Effects threshold for Marine Amphipod Toxicity	2.1	660	93	6.7	270	1,300	>140	960
Proposed Marine Sediment Standards (State of Washington)	.41	450	57	5.1	260	390	140	410

Table 9. Metal concentrations (ppm dry weight) measured in soils and sediments collected from Bowerman Basin for the preacquisition study. A "<

value" indicates sample was less than the detection limit.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
SD1	10.7	0.80	89.4	75.0	<0.02	41.6	28.0	<.30	119
SD2	1.73	0.75	31.9	27.8	<0.02	16.7	<15	<.30	111
SD3	3.51	0.91	57.5	51.2	<0.02	34.1	40.9	<.30	337
SD4	9.68	0.92	75.3	63.4	<0.02	35.3	24.0	0.39	116
SL1	5.97	<0.5	77.3	55.3	<0.02	38.7	34.3	0.40	94.1
SL2	0.38	0.70	178	181	<0.02	88.6	15.9	<.30	111
SL3	5.90	0.65	76.1	52.9	<0.02	36.8	15.3	0.32	99.4
SL4	4.04	<0.5	65.5	30.8	<0.02	31.9	<15	<.30	80.1

As = arsenic Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; Pb = lead; Se = selenium; Zn = zinc

Table 10. Metal concentrations (ppm dry weight) measured in sediments collected for the Grays Harbor special study. A "< value" indicates sample was less than the detection limit.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	6.5	<0.3	43	47.8	0.10	25	20	0.3	76.1
Bowerman 2	8.7	<0.3	46	46.3	0.07	25	23	0.3	79.5
Weyerhaeuser	5.3	<0.3	34	43.2	0.03	29	17	0.2	74.5
Cow Point A	4.9	<0.3	18	44.6	0.04	27	19	<0.1	76.4
Cow Point B	5.0	<0.3	22	44.6	0.03	30	19	0.2	81.9
North Bay	5.2	<0.2	20	11	0.02	14	10	<0.1	46.2
South Bay	5.5	<0.2	22	7.4	0.03	11	9	<0.1	32.6
South Channel	5.8	<0.2	27	21	0.03	18	10	0.2	52.3
Willapa Bay	9.2	<0.3	32	26.9	0.07	20	20	0.2	76.4

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; P
Se = selenium; Zn = zinc

Table 11. Organic carbon normalized metal concentrations (ppm dry weight) in sediments from the Grays Harbor study. Puget Sound Dredged Disposal Analysis (PSSDA) sediment screening level provided for comparison. ND = not detected.

Site	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	2.5	ND	16	18.4	0.04	10	8	0.1	29.3
Bowerman 2	4.3	ND	23	23.2	0.04	12	12	0.1	39.8
Weyerhaeuser	7.6	ND	49	61.7	0.04	41	24	0.3	106.4
Cow Point A	6.1	ND	22	55.8	0.05	34	24	ND	95.5
Cow Point B	7.1	ND	31	63.7	0.04	43	27	0.3	117.0
North Bay	17.3	ND	67	36.7	0.07	47	33	ND	154.0
South Bay	18.3	ND	73	24.7	0.10	37	30	ND	108.7
South Channel	5.8	ND	27	21.0	0.03	18	10	0.2	52.3
Willapa	4.6	ND	16	13.5	0.04	10	10	0.1	38.2
PSSDA Screening Level	57			81	0.21	140	66		160

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; P
Se = selenium; Zn = zinc

Table 12. Metal concentrations (ppm dry weight) in softshell clams from the Grays harbor special study. NCAA Status and Trends (NST) metal concentrations (ppm dry weight) in mussels and oysters presented for comparison. NST values are for both mussels and oysters unless otherwise noted.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	5.5	<0.2		2.0	64.4	0.22	2.0	<4	1.3
Bowerman 2	28.8	0.3		3.7	16.0	0.12	2.0	7.0	1.5
Weyerhaeuser	7.8	<0.2		4.2	23	0.09	2.0	<4	1.8
Cow Point	12.0	0.3		6.0	22.0	0.09	1.0	<4	1.8
North Bay	17.0	<0.2		3.0	16.0	0.15	3.8	<4	1.9
South Channel A	12.0	0.2		6.8	17.0	0.09	4.6	<4	2.0
South Channel B	10.0	<0.2		5.9	17.0	0.09	4.7	<4	1.6
Willapa Bay	31.0	0.3		3.0	18.0	0.15	3.0	6.0	2.6
NOAA NST Gray Harbor Westport Jetty Site (mussels only)	8.83	2.63		1.73	10.33	0.05	2.33	0.44	2.13
NOAA NST Range: 12.5-87.5 Percentile	5.4-110	1.0-5.1		0.25-2.2	62-143 oyster	0.04-0.21	0.97-3.4	0.19-3.13	1.53-3.27
7.6-11 mussel				93-310 oyster					
NOAA NST Maximum	42.7	13		10.9	1603 oyster	0.48	12.6	23.3	8.17
20.3 mussel				310 mussel					

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel; P
Se = selenium; Zn = zinc

Table 13. Metal concentrations (ppm dry weight) measured in amphipods from Grays Harbor and Willapa Bay.

SITE	As	Cd	Cr	Cu	Hg	Ni	Pb	Se	Zn
Bowerman 1	2.2	<0.2	2.0	81.6	0.09	<1.0	10	0.91	65.9
Bowerman 2	2.5	0.6	3.5	124	0.05	2.0	140	0.86	60.6
North Bay	2.2	0.4	<1.0	280	0.05	1.0	72	0.69	82.5
South Bay	2.8	<0.2	<1.0	108	0.09	<1.0	120	0.93	69.4
South Channel	1.8	<0.2	2.0	86.9	0.04	2.0	8.0	0.56	61.1
Willapa Bay	3.4	0.76	2.0	123	0.06	2.0	150	0.98	62.5

As = arsenic; Cd = cadmium; Cr = chromium; Cu = copper; Hg = mercury; Ni = nickel