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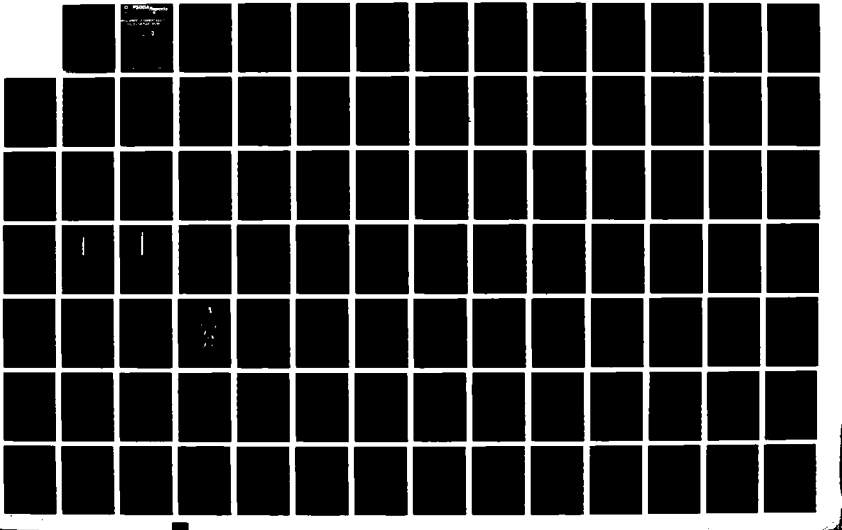

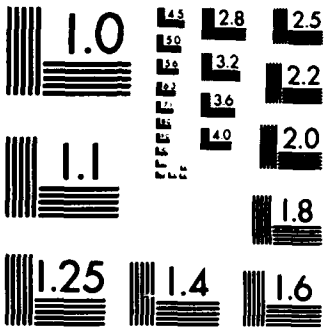

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Puget Sound Dredged Disposal Analysis

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TC3090-02; Task 6
Final Report

DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND

Volume 1

by

Tetra Tech, Inc.

Prepared for

Resource Planning Associates

for

Puget Sound Dredged Disposal Analysis
and Puget Sound Estuary Program

September, 1986

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PREFACE
(Prepared by the sponsoring agencies)

The attached report, Development of Sediment Quality Values for Puget Sound, details the results of the early stages of a joint effort by the Puget Sound Estuary Program (PSEP) and the Puget Sound Dredged Disposal Analysis (PSDDA). The work was performed by Tetra Tech, Inc., with funding and support from the U.S. Environmental Protection Agency, the U.S. Army Corps of Engineers, and the Washington Departments of Ecology and Natural Resources.

The sediment quality values study was commissioned in response to a growing need on the part of federal, state, and local agencies to make decisions concerning the regulation and management of contaminated marine sediments. Recent studies have indicated that sediment contamination may be linked to adverse impacts in marine biota, and that consumption of marine organisms exposed to contaminated sediments may pose risks to human health.

Ideally, the development of sediment quality values would be guided by definitive cause and effect information relating the individual and collective effects of specific contaminants to biological effects in a variety of aquatic species. To date, very little information of this type is available and it is unlikely that it will be available in the near future. The necessary laboratory studies will take many years to complete. In the interim, in the interest of protecting human health and environmental quality, regulatory agencies must proceed with sediment management decisions based on the best information available - information that may be theoretically and/or empirically derived. It is on this premise that the PSDDA and PSEP sediment quality values study has been based.

The goals of the sediment quality values study were to evaluate options for sediment management and to identify numerical values for concentrations of chemicals in sediments that appear to be associated with adverse biological effects in Puget Sound. We feel that these goals have been realized. It is important to note, however, that the results and recommendations presented in the attached report are considered by the sponsoring agencies to be interim. As additional laboratory information concerning chemical/biological cause and effect relationships is developed, and as supplemental field data become available, the numerical concentrations adopted as the recommended sediment quality values, as well as the approaches to establishing and using sediment quality values, are expected to change. In addition, it should also be noted that the sediment quality values presented in the report have been developed using Puget Sound data only. Although the approaches considered in this study may prove useful in developing sediment quality values from other data sets for other locales, application of the Puget Sound values to to other areas would not be advised without specific study.

The first stage of the sediment quality values study is now complete; however, the agencies are by no means finished with their work. The attached

report contains an evaluation of approaches and ranges of chemical values that can be applied in sediment management, but does not identify the specific values that the agencies should adopt for regulation or how these numerical values should be modified for application in specific regulatory programs. Both PSDDA and PSEP technical advisory groups are in the process of evaluating the options presented in the report and defining specific values for different regulatory uses in Puget Sound. In the coming year, it is anticipated that the agencies involved in PSDDA will adopt sediment quality values for use in regulating the disposal of dredged material. PSEP anticipates using sediment quality values as a tool in classifying and prioritizing areas for source control and remedial action, and in establishing discharge limits that can more effectively protect the quality of marine sediment.

The preliminary results of the PSDDA/PSEP sediment quality values study were initially presented in a series of four separate draft reports. These reports were distributed to a variety of technical and management experts at a number of agencies and consulting firms for their review. The draft reports generated significant interest and controversy, and many comments were received. The sponsoring agencies regard all comments as important, useful, and constructive, and have seriously considered all concerns in preparation of the final report. In addition, the agencies, with the assistance of Tetra Tech, have prepared a "response to comments" section, which is included in this final report as Appendix H. The final report represents the revision and synthesis of four draft reports into a single document.

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EXECUTIVE SUMMARY

STUDY PURPOSE

This report presents the results of a joint effort by the Puget Sound Estuary Program (PSEP) and the Puget Sound Dredged Disposal Analysis (PSDDA) to develop sediment quality values for Puget Sound. These values represent concentrations of chemicals in sediments that are expected to be associated with adverse biological effects based either on field evidence or theoretical predictions. Ideally, the development of sediment quality values should be guided by definitive cause and effect information that relates the individual and collective effects of contaminants to a range of biological effects. Very little cause-effect information is available. The sediment quality values discussed in this report are interim estimates that have been developed as only one of several tools to assist managers in making sediment management decisions. The study objectives were to:

1. Compile chemical and biological data from Puget Sound appropriate for use in the development of sediment quality values

2. Evaluate techniques that can be used to develop chemical specific values

3. Evaluate the reasonableness of the values generated using different techniques (i.e., their ability to correctly identify sites with known biological impacts)

4. Evaluate the appropriateness of using the values in different regulatory applications

5. Identify future studies that will be needed to refine or verify the sediment quality values that are generated.

The scope of the fourth objective was refined during the project. Participants at a joint PSDDA/PSEP technical workshop concurred that a range of sediment quality values from several approaches should be provided to enable program managers to determine appropriate values for individual programs. Appropriate uses of the sediment quality values in different regulatory applications are discussed. Results that are pertinent to each objective are summarized in this report.

Material presented in appendices to this report addresses additional objectives related to statistical analyses of a subset of the chemical and biological data using pattern recognition techniques (Appendix D), recommended contaminants of concern (Appendix E), analytical detection limits (Appendix F), and appropriate uses of conventional sediment variables (Appendix G) for the management of dredged material. Responses to comments received on draft reports used to prepare this final report are summarized in Appendix H.

SUMMARY OF RESULTS AND CONCLUSIONS

Eight possible approaches to establishing sediment quality values were evaluated based on (in order of decreasing importance):

- The plausibility and scientific defensibility of their theoretical bases and critical assumptions
- The quantity of data required, and the current availability of data (i.e., for generation of sediment quality values during the present project)
- The range of chemicals for which the approach is appropriate
- The range of biological effects information that can be incorporated into the approach.

Of the eight approaches reviewed, three were selected as the most appropriate for evaluation in this project with available Puget Sound data. These included the sediment-water equilibrium partitioning (EP), apparent effects threshold (AET), and screening level concentration (SLC) approaches.

For a given nonpolar, nonionic organic compound, the sediment-water equilibrium approach establishes a sediment quality value as the sediment concentration [normalized to total organic carbon (TOC) content] corresponding to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant. The relationship between sediment concentrations and interstitial water concentrations is calculated with an estimated sediment organic matter-interstitial water partition coefficient. Field data are not required to generate sediment quality values using this theoretical approach, but are used to validate the approach.

The AET value is the sediment concentration of a contaminant above which statistically significant biological effects (e.g., amphipod mortality, oyster larvae abnormality, depression in the abundance of benthic infauna) would always be expected. The approach was developed for use with any organic or inorganic contaminant, and does not require a priori assumptions concerning the specific mechanism for interactions between contaminants and organisms. AET are empirically derived from matched field data for sediment chemistry and a range of biological effects indicators.

The SLC approach estimates the sediment concentration of a contaminant above which less than 95 percent of the total enumerated species of benthic infauna are present. This approach was originally developed and recommended for use with nonpolar organic compounds normalized to organic carbon content in sediments (Battelle 1986). Possible use of the SLC approach with dry-weight normalized data (and contaminants other than nonpolar organic compounds) was also examined in the current study. This modification was evaluated for the SLC approach because (as with the AET approach, but unlike the equilibrium partitioning approach) a priori assumptions concerning the

specific mechanism for interactions between contaminants and organisms are not necessary. SLC are empirically derived from matched field data for sediment chemistry and the abundance of individual species of benthic infauna. Project constraints permitted the testing of this approach for only three contaminants (naphthalene, high molecular weight polycyclic aromatic hydrocarbons, and mercury), although the approach is not considered to be limited to these contaminants.

The application and evaluation of the selected sediment quality value approaches required that a large database of matched chemical and biological data be compiled. Of 11 Puget Sound data sets reviewed, paired data from 7 studies were included in the final database. These data included recent studies in Commencement Bay (Tetra Tech 1985), eight urban and nonurban embayments of Puget Sound (Battelle 1985a), Everett Harbor (U.S. Department of the Navy 1985), and Duwamish River (Chan et al. 1985a,b). Municipality of Metropolitan Seattle (Metro) data for the Alki Extension project (Osborn et al. 1985; Trial and Michaud 1985) and the Toxicant Pretreatment Planning Study (TPPS; Phase III, Comiskey et al. 1984; Romberg et al. 1984) were also included in the database.

Using the three selected approaches, sediment quality values were calculated for 73 individual or classes of U.S. EPA priority pollutants and other contaminants, and 3 conventional variables (e.g., TOC) and compared, when possible. In general, the magnitude of the sediment quality values for a given contaminant ranked SLC < AET < equilibrium partitioning.

The AET (normalized to sediment dry-weight, organic carbon content, and percent fine-grained material) and equilibrium partitioning approaches were tested with respect to the frequencies at which they correctly identified impacted stations and misidentified nonimpacted stations. Stations were designated as impacted or nonimpacted by independent statistical comparisons of biological data to reference conditions. These impacted/nonimpacted designations were based on four biological indicators: amphipod bioassays, oyster larvae bioassays, Microtox bioassays, and benthic infaunal analyses. A subset of impacted stations was designated as severely impacted based on somewhat arbitrary criteria: >50 percent amphipod mortality or oyster larvae abnormality, or statistically significant depressions in the abundance of more than one major taxonomic group of benthic infauna (including Mollusca, Polychaeta, Crustacea). This subset of severely impacted stations was only used as part of the validation check on sediment quality values, and not to generate sediment quality values.

The 40 sediment quality values from the equilibrium partitioning approach correctly identified between 13 and 43 percent of the impacted stations, and between 0 and 46 percent of severely impacted stations, depending on the biological indicator used for validation. This approach misidentified between 0 and 67 percent of the nonimpacted stations, depending upon the biological indicator used for validation.

The 64 sediment quality values from the AET approach (using dry-weight normalization) correctly identified between 54 and 94 percent of the impacted stations, and between 92 and 100 percent of severely impacted stations,

depending on the biologial indicator used for validation. Corresponding AET values generated from chemical data normalized to TOC or percent fine-grained material in sediments correctly identified between 37 and 88 percent of the impacted stations, and between 62 and 100 percent of the severely impacted stations, depending on the type of normalization, and the biological indicator used for validation. The AET approach misidentified between 0 and 69 percent of the nonimpacted stations, depending upon the type of normalization used for chemical concentrations and biological indicator used for validation.

A detailed evaluation of the accuracy of SLC values was beyond the project scope, because SLC were generated for only three chemicals. It was assumed that such a small number of chemicals could not be expected to correctly identify all impacted stations. Hence, a preliminary evaluation was made only of the number of nonimpacted stations misidentified using each of these three SLC values. The approach misidentified between 15 and 70 percent of the nonimpacted stations, depending on the chemical, type of normalization of chemical concentrations, and biological indicator used for validation.

Of the sediment quality values developed from field data (i.e., AET and SLC), the most accurate values were those generated from chemical data normalized to sediment dry weight. Potential reasons that sediment quality values normalized to organic carbon could be less predictive of biological effects than dry-weight normalized values are discussed in the report. Organic carbon normalization may be less predictive if sediment/interstitial water systems are not at equilibrium in the environment, if all organic matter in sediments does not have uniform affinity for nonpolar, nonionic pollutants, or if interstitial water is not the predominant route of contaminant uptake by organisms.

Precision of sediment quality values developed for each approach was estimated for selected components of uncertainty that could be quantified. The uncertainty of the equilibrium partitioning approach was estimated to range from less than one to six orders of magnitude of the calculated values, primarily because of uncertainty in the estimation of theoretical constants and the applicability of water quality criteria used in the approach. For a given set of field data, the uncertainty of the AET approach was estimated to range from much less than one to two orders of magnitude of the values generated, primarily because of potential misclassification of nonimpacted stations that are used to define the AET. An evaluation of the precision of SLC was beyond the project scope. A statistical evaluation of the precision of SLC has recently been completed by Battelle (1986); 95-percent confidence intervals are calculated for SLC values developed for nine contaminants in marine sediments.

The sediment quality values, in some cases with application of a "safety factor," are recommended for:

- Trigger levels for screening decisions on the need for further testing
- Prioritization of potential problem areas

- Identification of problem chemicals in an impacted sediment
- Identification of acceptable sediments for open-water disposal
- Prioritization of laboratory studies for determining cause-effect relationships.

Additional studies for refining or verifying the sediment quality values generated in this project are also recommended. Elements of these recommended studies would enlarge the database to improve the reliability of field-based sediment quality values, develop new kinds of sediment quality values (i.e., for different biological indicators), and improve the understanding of the interactions between sediment-bound contaminants and biological effects.

STUDY PURPOSE

BACKGROUND

In recent years, high concentrations of U.S. EPA priority pollutants and other toxic chemicals have been identified in the sediments of a number of bays in Puget Sound. Relatively little is known about the ways in which exposure to contaminated sediments affects marine life; however, recent field surveys have found increasing frequencies of biological abnormalities in fish harvested in areas of high sediment contamination. In addition, exposure to contaminated sediments has been linked to adverse environmental impacts such as bioaccumulation in fish and invertebrates, and modified benthic community structure. The risks to human health from consumption of marine organisms exposed to contaminated sediments is also an issue of concern.

Currently, a set of sediment quality values that can be used in judging the significance of chemical contamination and as a basis for regulatory action is needed because it is apparent that national water quality criteria alone are insufficient to ensure protection of estuarine and marine ecosystems consistent with provisions of the Clean Water Act. Sediment quality values represent chemical-specific concentrations in sediments that are expected to be associated with adverse biological effects based either on field or laboratory evidence, or theoretical predictions. Contaminated sediments can serve as an important reservoir for continual recontamination of the overlying water column. Organisms may be harmed as a result of consumption of prey organisms that are intimately associated with sediments. Thus, specific limits for both aqueous and sediment phase contaminant levels are required. When fully developed, sediment quality values that define environmentally acceptable levels of contaminants in sediments will be one of several important tools in environmental decision-making.

OBJECTIVES

The Puget Sound Dredged Disposal Analysis (PSDDA) and Puget Sound Estuary Program (PSEP) jointly sponsored the current work as part of an overall goal to develop a coherent interim management program for contaminated sediments. The specific study objectives were to:

1. Compile chemical and biological data from Puget Sound appropriate for use in the development of sediment quality values

2. Evaluate approaches that can be used to develop chemical-specific sediment quality values and select one or more approaches for evaluation with Puget Sound data

3. Evaluate the reasonableness of the values generated using different techniques (i.e., their ability to correctly identify

sites with known biological impacts) by conducting an uncertainty analyses

4. Evaluate the appropriateness of using the values in different regulatory applications based on the results of the uncertainty analyses, and based on the advantages and limitations of the approaches used for their development

5. Identify future studies that will be needed to refine or verify the sediment quality values that are generated.

The fourth objective was clarified in discussions at a joint meeting of the U.S. EPA Region X Sediment Criteria Work Group and the PSDDA Evaluation Procedures Work Group held in January, 1986. Participants concurred that program managers should be provided with a variety of sediment quality values for several approaches to enable the managers to determine appropriate values for individual programs. Hence, a single sediment quality value for each contaminant is not recommended in this report, although appropriate uses of sediment quality values in different regulatory applications are discussed.

A separate task was conducted as part of the overall work conducted for PSDDA/PSEP to develop a comparative risk assessment document for environmental and health concerns associated with the management of dredged material. The results of this concurrent task are reported elsewhere (Tetra Tech 1986a). A flow chart of all tasks is shown in Figure 1.

REPORT ORGANIZATION

The preliminary results of the PSDDA/PSEP sediment quality values study were presented in a series of four separate draft reports. Comments received from peer review of these reports were used to refine the draft reports into this final report. A summary of comments addressed by PSDDA/PSEP on the draft reports and their responses is given in Appendix H.

Section I of the report addresses the evaluation of different approaches that were considered for development of sediment quality values. Approaches that can use existing data to generate chemical-specific sediment quality values are selected in this section for application in Puget Sound. Section II of the report describes the application of the selected approaches to data compiled from Puget Sound investigations. An uncertainty analysis is also summarized in this section that: (1) evaluates the ability of the sediment quality values generated by different approaches to identify stations known to be impacted according to one or more biological indicators, and (2) estimates confidence intervals for the sediment quality values. Recommendations for uses of sediment quality values and future studies are also summarized.

Several appendices have been incorporated into the final report to summarize Puget Sound data recommended for use in this study (Appendices A-C), and additional tasks undertaken in support of the overall sediment quality values study. These additional tasks included:

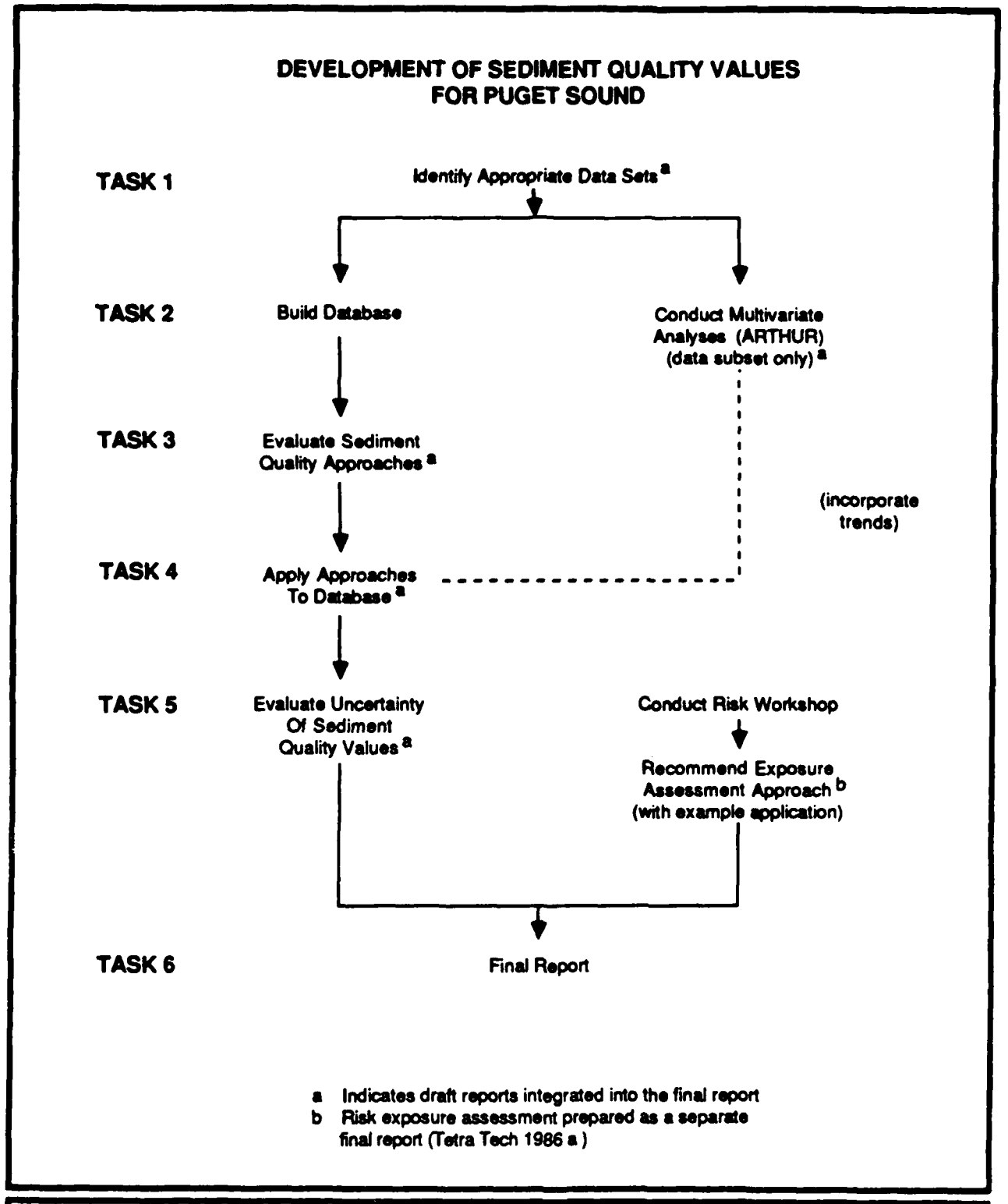


Figure 1. Flow chart of tasks for the development of sediment quality values.

- A statistical evaluation of a data subset using pattern recognition techniques (Appendix D; the objective was to investigate underlying trends among multiple chemical and biological variables that might be considered in the development of sediment quality values)

- A recommendation of contaminants of concern for the management of dredged material (Appendix E) and appropriate detection limits (Appendix F)

- An evaluation of the potential use of conventional chemical variables (e.g., sulfides, volatile solids) in the management of contaminated sediments (Appendix G).

I. EVALUATION OF APPROACHES FOR THE DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND

1.0 INTRODUCTION

In Section I, the conceptual basis for eight approaches to determining sediment quality values is presented (Table 1) and the limitations and advantages of each approach are addressed. Based on a set of selection criteria discussed in Section 3.1, recommendations were made for the application of some of these approaches for the development of chemical-specific sediment quality values for use in Puget Sound.

2.0 APPROACHES TO DETERMINING SEDIMENT QUALITY VALUES

Information from other reviews of approaches to determining sediment quality values was incorporated into this section as appropriate (Battelle 1985b; JRB Associates 1984a,b).

2.1 Reference Approach

2.1.1 General Concept--

In the reference approach, sediment quality values are based on chemical contaminant concentrations in a reference area that is pristine or is considered to have acceptably low levels of contamination and no apparent biological disturbance. This is often referred to as the background approach.

2.1.2 Advantages--

The primary advantage of the reference approach is that it has minimal data requirements. The establishment of reference contaminant concentrations does not require the collection of extensive field data, particularly in areas where historical data are available. In its elementary form, the reference approach does not require analysis of site-specific biological indicators (e.g., sediment toxicity, benthic infaunal abundances) for samples to be compared with reference levels. However, evidence of acceptable biological conditions in the reference area will, in most cases, require some site-specific biological assessments.

The reference approach is the only method for establishing sediment quality values that does not require quantitative toxicological data for priority pollutants and other contaminants of concern in sediments.

2.1.3 Limitations--

The primary limitation of the reference approach is that it is difficult to defend on legal and scientific grounds. The choice of a suitable reference

TABLE 1. APPROACHES REVIEWED FOR ESTABLISHING SEDIMENT QUALITY VALUES

Approach	Concept
Reference Approach	Sediment quality values are based on chemical concentrations in a pristine area or an area with acceptably low levels of contamination.
Water Quality Criteria Approach	Contaminant concentrations in in interstitial water are measured directly and compared with U.S. EPA water quality criteria.
Equilibrium Partitioning (Sediment-Water) Approach	A theoretical model is used to describe the equilibrium partitioning of a contaminant between sedimentary organic matter and interstitial water. A sediment quality value for a given contaminant is the organic carbon normalized concentration that would correspond to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant.
Equilibrium Partitioning (Sediment-Biota) Approach	Acceptable contaminant body burdens for benthic organisms are based on existing regulatory limits. Sedimentary contaminant concentrations that would correspond to these body burdens under thermodynamic equilibrium are established as sediment quality values.
Field Bioassay Approach	Relationships between chemical concentrations and biological responses are established by exposing test organisms to field-collected sediments with measured contaminant concentrations.
Screening Level Concentration (SLC) Approach	The SLC approach estimates the sediment concentration of a contaminant above which less than 95 percent of the total enumerated species of benthic infauna are present. SLC values are empirically derived from paired field data for sediment chemistry and species-specific benthic infaunal abundances.

TABLE 1. (Continued)

Apparent Effects Threshold (AET) Approach	An AET is the sediment concentration of a contaminant above which statistically significant biological effects (e.g., amphipod mortality in bioassays, depressions in the abundance of benthic infauana) would always be expected. AET are empirically derived from paired field data for sediment chemistry and a range of biological effects indicators.
Spiked Bioassay Approach	Dose-response relationships are established by exposing test organisms to sediments that have been spiked with known amounts of chemicals or mixtures of chemicals. Sediment quality values are determined for sediment bioassays in the manner that aqueous bioassays were used to establish U.S. EPA water quality criteria.

area is largely subjective and, depending on the selection criteria, can either overprotect or underprotect against actual environmental impacts:

- The selection of a pristine reference site could enforce unnecessarily restrictive sediment quality values that may not be realistically attainable and that would not account for the assimilative capacity of sediments. Sediment quality values set at some specified factor above reference concentration would be an arbitrary solution to this problem, and would ultimately be difficult to defend on technical grounds. Sediment quality values set as detection limits (when chemicals are not detected in reference sediments) or as multiples of detection limits would also be difficult to defend.

- The choice of a relatively contaminated site as a reference area could be questioned on legal and technical grounds as being too lenient. Such a situation could arise if sediment quality values were established to evaluate dredged material for disposal at an established dredge disposal site (see Section 2.1.4).

2.1.4 Modified Reference (Background) Approach--

The U.S. EPA Region X and the Washington Department of Ecology have established sediment quality values for two Puget Sound dredge disposal sites (Fourmile Rock and Port Gardner) based on a modified reference approach (U.S. EPA/Washington Department of Ecology 1984, 1985). Similar interim criteria have been established for other areas in Puget Sound. A noteworthy attribute of this approach is its inclusion of biological effects (bioassay) data.

Flow diagrams of the approaches for each site are presented in Figures 2 and 3. In both cases, dredged materials are evaluated for their suitability for open-water disposal based on comparisons of chemical (conventional and priority pollutant) and biological (bioassay) results with those of the reference areas (i.e., the disposal sites). This approach, which forbids the open-water disposal of dredged materials that are more chemically contaminated or more biologically detrimental than sediments of the disposal site, is designed to prevent degradation of the disposal site. A modified reference approach was considered appropriate in light of: (1) the immediate necessity for establishing disposal criteria, (2) the lack of an extensive assessment of the biological health of the disposal site, and (3) the lack of toxicological data for the contaminants of concern in sediments.

The use of site-specific bioassay data significantly improves the reference approach because it provides more defensible criteria upon which to base sediment quality values.

A limitation of the modified reference approaches used by U.S. EPA/Washington Department of Ecology is the lack of sufficient data for the reference areas (the Fourmile Rock disposal site, the Port Gardner disposal site, and central Puget Sound) (Thornton 1985). This lack of data limits the

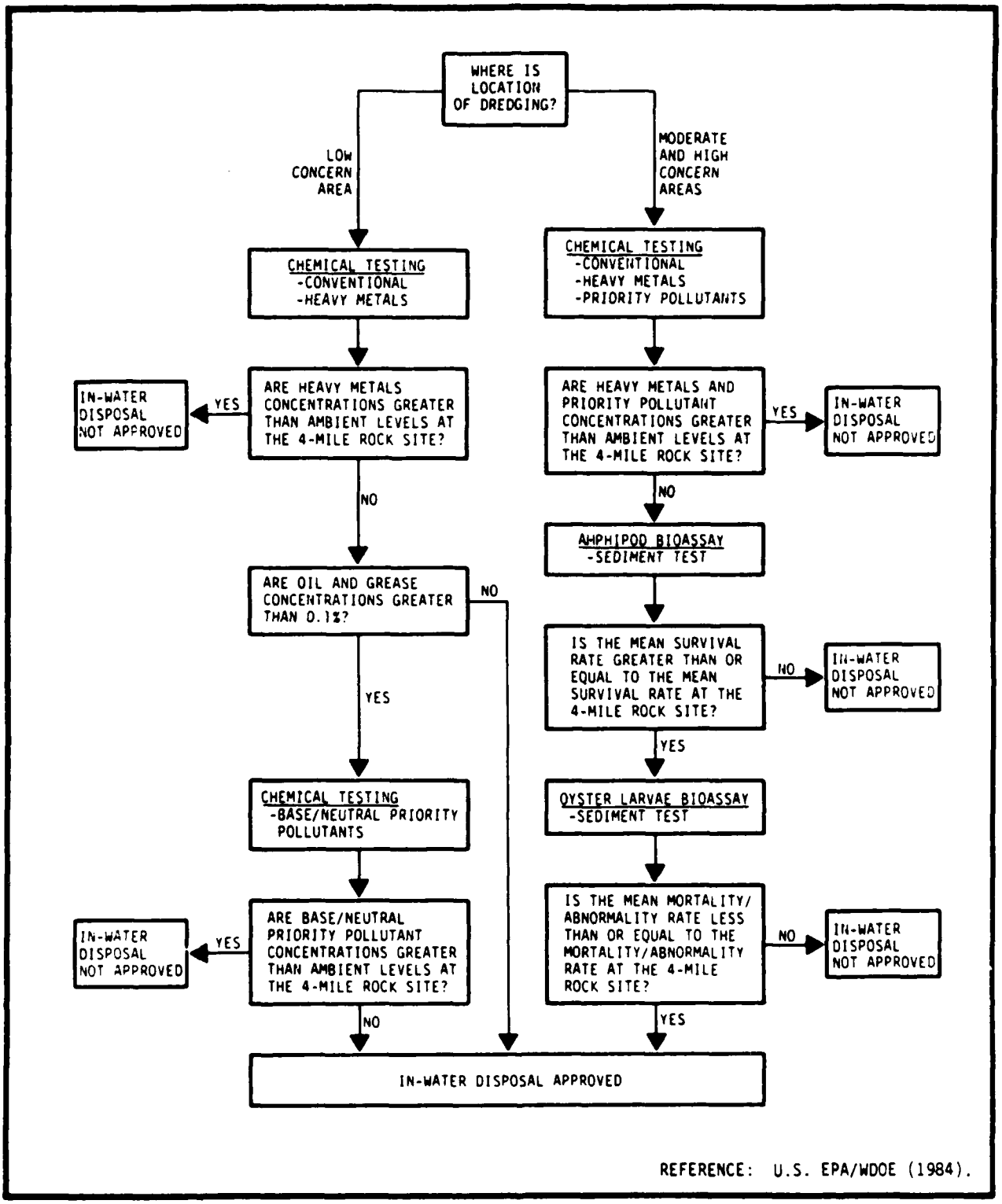


Figure 2. Modified reference approach: Fourmile Rock.

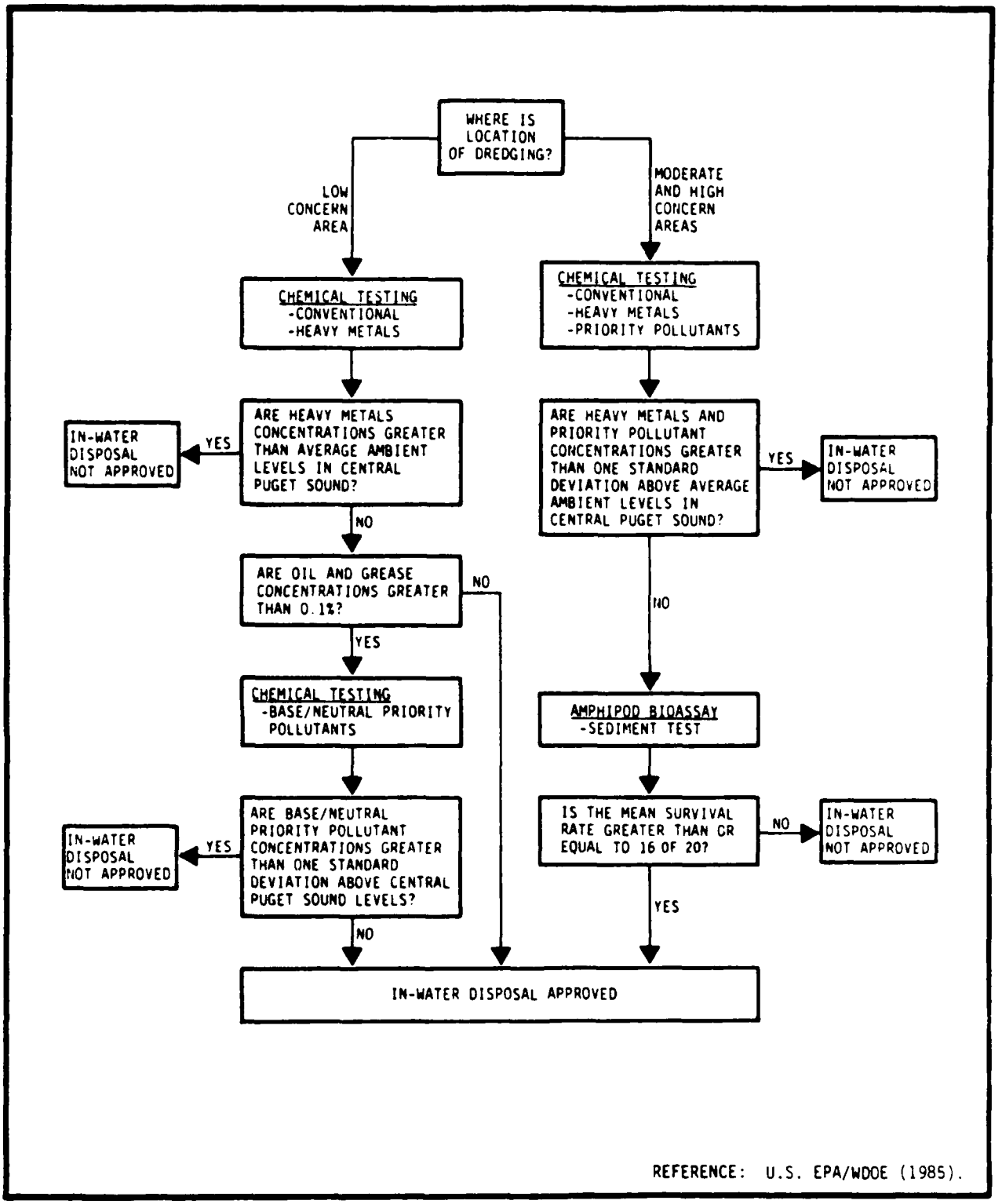


Figure 3. Modified reference approach: Port Gardner.

statistical confidence that available chemical data are truly representative of the reference areas.

2.2 Water Quality Criteria Approach

2.2.1 General Concept--

Contaminant concentrations in interstitial water are measured directly and compared with U.S. EPA water quality criteria.

2.2.2 Background--

U.S. EPA Region VI developed this method to take advantage of the existing toxicological database used to establish national water quality criteria. Relevant criteria consist of 24-h average concentrations and maximum permissible concentrations for the protection of saltwater aquatic organisms.

The only data requirement for this approach is interstitial water contaminant concentrations. Site-specific biological data are not necessary.

2.2.3 Advantages--

The principle advantage of the water quality criteria approach is that it relies on existing toxicological data and only requires site-specific collection of chemical data.

2.2.4 Limitations--

A critical limitation for any approach based on U.S. EPA water quality criteria is that criteria are available for only some of the priority pollutants: 10 inorganic pollutants (arsenic, silver, cadmium, chromium, copper, mercury, nickel, lead, selenium, and zinc) and 9 organic pollutants [PCBs and selected chlorinated hydrocarbon pesticides (chlordane, dieldrin, DDT, endosulfan, endrin, heptachlor, lindane, and toxaphene)]. Polycyclic aromatic hydrocarbons, a significant class of priority pollutants in Puget Sound, are a noteworthy omission from this list.

Practical difficulties exist with the collection and analysis of interstitial water samples. Standardized and validated procedures for interstitial water analysis have not been established. Distinctions between dissolved, colloidal, and suspended phases of a contaminant are operational and therefore are seldom comparable among different laboratory procedures.

Important assumptions of this approach cannot be validated with existing data. These assumptions relate to: (a) the applicability of sediment-free laboratory bioassays to benthic biota under field conditions, and (b) the route of uptake of contaminants in sediments.

2.2.4.1 Applicability of Water Quality Criteria Bioassays to Benthic Biota Under Field Conditions--Sediment-free bioassays conducted largely with nektonic organisms may not be applicable to benthic biota (e.g., deposit-

feeding organisms). The application of toxicological data from a given species to organisms from different phyla with different feeding habits cannot be justified with current biological response data. Although bioassays of marine benthic invertebrates are included in the database for U.S. EPA water quality criteria (Stephan et al. 1983), test organisms were typically nektonic.

Under field conditions, the presence of dissolved or colloidal organic matter may be an important factor in uptake and toxicity. However, dissolved organic matter was not a controlled variable in toxicity tests used to establish U.S. EPA water quality criteria. The effect of dissolved or colloidal organic matter on uptake and toxicity of contaminants has been documented (Jenne and Luoma 1975 and references therein; George and Coombs 1977; Khalid 1980 and references therein; Landrum et al. 1985).

The water quality criteria approach is based on toxicological data for chemicals tested individually. Thus, the approach is not designed to address interactive effects of contaminants. To the extent that interactive effects occur in the environment, uncertainty of these sediment quality values would increase.

2.2.4.2 The Route of Uptake of Contaminants in Sediments--For this approach, interstitial water is assumed to be the primary source of contaminants to benthic biota, or alternatively, benthic systems are assumed to be at equilibrium such that sediment ingestion will not enhance the amount of contaminants available from interstitial water (JRB Associates 1984a).

Comprehensive data regarding compound-specific uptake routes for benthic organisms (e.g., partitioning from interstitial water vs. assimilation by ingestion of sediment) are not available. Biological uptake routes vary with physiochemical properties of contaminants, feeding habits and digestive physiology of benthic organisms, and the nature of contaminant-sediment associations (which in turn can vary according to site-specific environmental conditions, such as organic matter influx, pH, and redox conditions).

Existing studies are indicative of the complex factors involved in the relative biological availability of contaminants in dissolved and particulate form. For example, Roesijadi et al. (1978) found that polychaetes took up polycyclic aromatic hydrocarbons (PAH) more readily from an aqueous than from a sediment phase, whereas Fowler et al. (1978) found that contaminated sediments were a more significant source of polychlorinated biphenyls (PCBs) for polychaetes than water. In a series of laboratory bioassays in which midges were exposed to Kepone-contaminated water, sediment, or food, Adams et al. (1984) concluded that interstitial water and/or water at the sediment/water interface were the sources for pollutant uptake. Jenne and Luoma (1975) and Luoma and Jenne (1975) noted that the bioavailability of a metal is related to the magnitude of its sediment-water distribution coefficient, which in turn is related to the type of phase (e.g., iron oxide or humic matter) with which it is associated. A given metal can have various phase associations depending in part on the chemical environment (e.g., redox conditions) at the sediment/ water interface. In general,

it has been observed that the uptake of pollutants by benthic organisms is more rapid from the aqueous phase. However, sediments can constitute a much larger pool of contaminants than water (on an equal volume basis) because of their higher sorption capacity for many pollutants (Jenne and Luoma 1975; Luoma and Jenne 1975; Neff 1984).

2.3 Equilibrium Partitioning Approach (Sediment-Water)

2.3.1 General Concept--

A simple model is used to describe the equilibrium partitioning of a contaminant between sedimentary organic matter and interstitial water. A sediment quality value for a given contaminant is the sediment concentration (normalized to organic carbon content) that would correspond to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant.

2.3.2 Background--

The equilibrium partitioning approach (Figure 4) uses the same toxicological database as the water quality criteria approach, but avoids the difficulties associated with the direct measurement of contaminant concentrations in interstitial water. The estimation of interstitial water concentrations from sediment concentrations involves the assumption that the distribution of a contaminant between sediment and interstitial water phases is governed by rapid and continuous exchange between these two phases. This assumption of thermodynamic equilibrium at the sediment-water interface implies that the sediment phase/aqueous phase concentration ratio is a constant for a given sediment. The distribution can be represented as:

$$K_D^x = \frac{C_s^x}{C_{iw}^x}$$

where:

K_D^x = is the thermodynamic sediment-water partition coefficient for "contaminant x"

C_s^x = sediment concentration of "contaminant x" (dry wt)

C_{iw}^x = interstitial water concentration of "contaminant x".

Laboratory sorption experiments have demonstrated that K_D values of nonpolar, nonionic organic contaminants are significantly correlated with sedimentary organic carbon content (e.g., Karickhoff et al. 1979; Schwarzenbach and Westall 1981; Means et al. 1980). In support of these findings, field studies (e.g., Choi and Chen 1976; Abdullah et al. 1982) have reported significant correlations of organic carbon content with nonionic organic

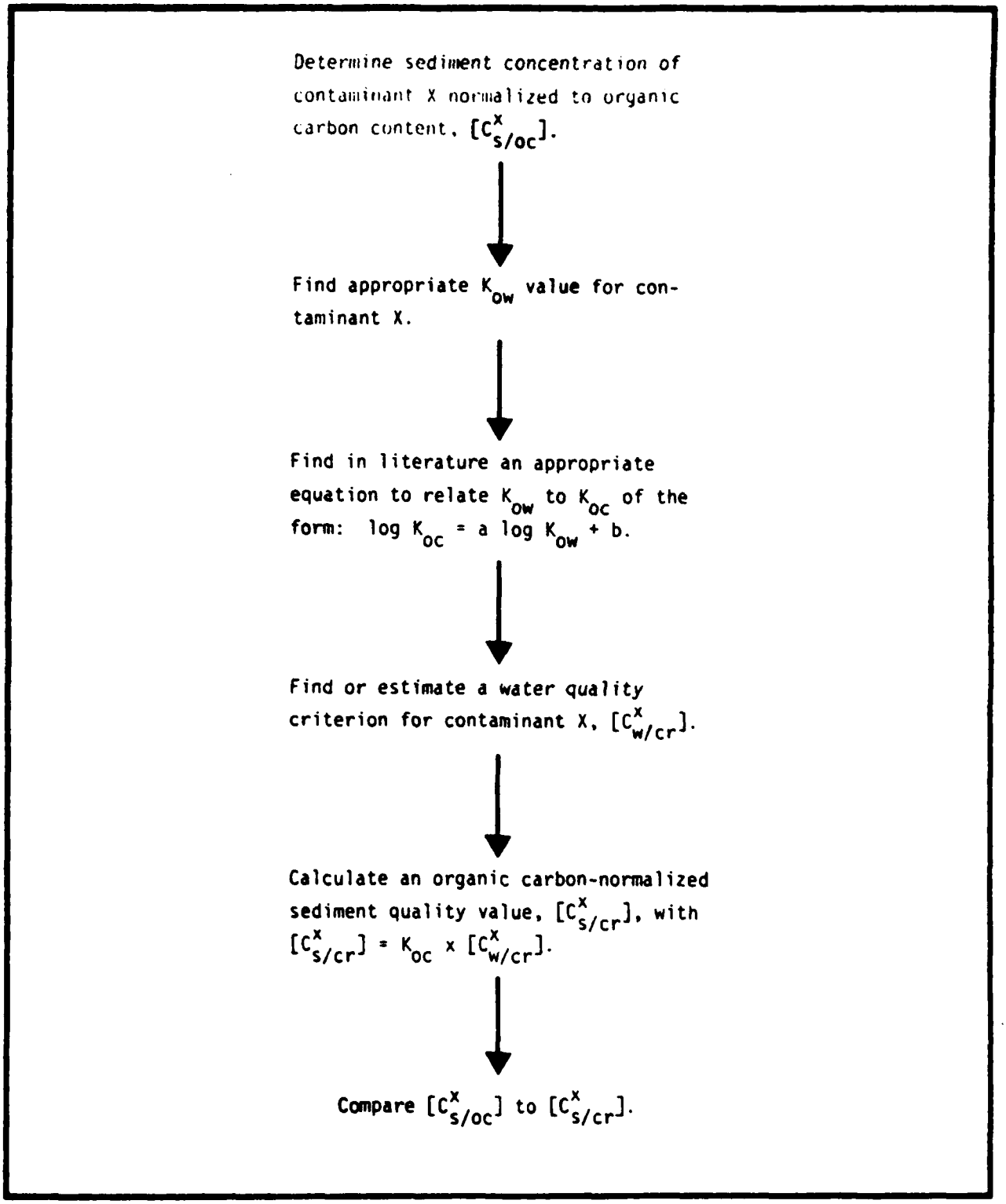


Figure 4. Sediment-water equilibrium partitioning approach. See text for definition of terms.

pollutant concentrations in sediment, although this correlation has not been observed in all field studies (Glooschenko et al. 1976). Because organic matter is apparently the sedimentary fraction that mediates sediment-water distributions, sedimentary concentrations of hydrophobic pollutants are normalized to organic carbon content for the equilibrium partitioning approach. Thus, a thermodynamic partition coefficient for organic carbon-normalized contaminant concentrations is appropriate for nonpolar, nonionic compounds:

$$K_{oc}^{x} = \frac{C_{s}^{x}}{C_{iw}^{x}} \times \frac{1}{f_{oc}} = \frac{K_{D}^{x}}{f_{oc}}$$

where:

K_{oc}^{x} = organic carbon-normalized partition coefficient for contaminant x

f_{oc} = fraction (on a wt/wt basis, in decimal form) of organic carbon in the sediment (dry wt).

If a K_{oc}^{x} value and a water quality criterion ($C_{w/cr}^{x}$) for contaminant x are known, an organic carbon normalized sediment quality value ($C_{s/cr}^{x}$) can be determined as:

$$C_{s/cr}^{x} = K_{oc}^{x} \times C_{w/cr}^{x}.$$

Because K_{OC} values are not available in published literature for all contaminants of concern, more widely available octanol-water partition coefficients (K_{OW} values) are used to estimate K_{OC} values. Several laboratory studies have demonstrated that K_{OW} and K_{OC} values for a given nonpolar, nonionic organic pollutant are highly correlated (Chiou et al. 1983; Karickhoff et al. 1979; Means et al. 1980). This relationship is expressed in the form

$$\log K_{OC} = a \log K_{OW} + b,$$

where a and b are empirically derived constants. This correlation implies that the partitioning of a nonpolar, nonionic organic compound between water and an immiscible organic solvent (octanol) is mechanistically analogous to its distribution between water and sedimentary organic matter (Lambert 1967, 1968; Chiou et al. 1983).

2.3.2.1 Ionizable Organic Compounds--The predictive relationship involving K_{OW} and K_{OC} described for non-polar, nonionic compounds cannot justifiably be applied to polar, ionizable organic compounds. Ionizable organic compounds such as phenols can interact with sedimentary organic matter and mineral surfaces via mechanisms that are not possible for nonionic

organic compounds (e.g., H-bonding, ion exchange, ligand exchange) (Isaacson and Frink 1984; Schellenberg et al. 1984). Although organic carbon can play an important part in ionic organic pollutant-sediment associations, the pH and ionic strength of the aqueous phase are also of great importance and can influence chemical speciation and complicate sorption behavior (Schellenberg et al. 1984; Westall et al. 1985). Thus, organic carbon normalization and use of K_{OW} values to predict interstitial water concentration of ionizable organic compounds is not a scientifically valid approach.

2.3.2.2 Metals and Metalloids--Predictive distribution coefficients are at least as difficult to determine for trace metals as for ionizable organic compounds. Whereas sediment-water distributions of metals can be influenced by organic carbon content, they can also be strongly influenced by iron and manganese oxide and hydrous oxide surfaces (these phases can scavenge metals under oxidizing conditions), sulfides (mercury, zinc, cadmium, copper, and lead form insoluble sulfides under reducing conditions), carbonates, and phosphate ion concentrations (particularly relevant for lead) (Brannon et al. 1976; Crecelius 1975; Davies-Colley et al. 1984; Jenne 1977; Jenne and Luoma 1975; Khalid 1980; Lion et al. 1982; Luoma and Jenne 1975). Associations with oxides, sulfides, and other phases can affect the K_D of a given metal as well as the relative rates of metal adsorption and desorption. For example, an iron oxide or organic matter coating on a sediment particle can impede the desorption rate of a metal, increasing the time required to reach equilibrium (Jenne 1977). On a site-specific basis, redox conditions and pH can influence the relative importance of sedimentary phases (e.g., oxides vs. sulfides) as well as the chemical speciation and/or oxidation state of the metal pollutant. Physiocochemical properties and environmental behavior of a given metal can vary dramatically depending on its species. In summary, sediment-metal associations are too variable on a site-specific basis and too poorly understood to allow for accurate quantitative predictions of sediment-water distribution in the environment.

The remainder of the equilibrium partitioning section is relevant to nonpolar, nonionic organic pollutants, as the necessary predictive relationships cannot be reliably determined for ionizable organic pollutants and trace metals.

2.3.3 Advantages--

The equilibrium partitioning approach takes advantage of an existing toxicological database (U.S. EPA water quality criteria) and does not require the collection of biological data to generate sediment quality values. It requires the collection of only one ancillary chemical variable, organic carbon content. Estimation of sediment-water partitioning based on K_{OW} have a firm theoretical and empirical basis.

2.3.4 Limitations--

The limitations of the water quality criteria approach discussed previously also apply to the equilibrium partitioning approach: the limited number of nonpolar organic compounds for which established U.S. EPA water quality

criteria are available; uncertainty in the applicability of sediment-free laboratory bioassays to benthic biota under field conditions; uncertainty in the route of biological uptake of sedimentary contaminants; the uncertainty introduced by interactive effects of contaminants in the environment. Additional sources of uncertainty are discussed below.

2.3.4.1 The Equilibrium Assumption--The assumption that steady-state equilibrium exists in all aquatic environments is uncertain (Prahl and Carpenter 1983) and can be violated by kinetic factors. Hydrophobic organic contaminants incorporated within a sedimentary organic matter matrix (e.g., fecal pellets or humic substances) may take weeks, months, or longer to attain equilibrium concentrations with an aqueous phase (Freeman and Cheung 1981; DiToro and Horzempa 1982; Karickhoff and Morris 1985a,b). The fact that significant percentages of sediment-associated hydrophobic compounds may be entrapped within refractory organic phases brings the equilibrium assumption into question.

Three factors increase the uncertainty of predictions of interstitial water contaminant concentrations based on K_{OW} relationships: 1) there is considerable variation among K_{OW} values available in the literature for a given compound, 2) colloidal or dissolved organic matter in interstitial water may cause deviations from K_D values predicted from experiments with a "pure" aqueous phase, and 3) laboratory-determined K_D values, from which K_{OC}-K_{OW} relationships derive, are dependent on sediment/water (volume/volume) ratios and may not be quantitatively equivalent to in situ K_D values.

2.3.4.2 Variations in K_{OW} Values--Variations in reported K_{OW} values for a given compound are common in scientific literature (Kenaga and Goring 1980; Rapaport and Eisenreich 1984). In some cases, reported K_{OW} values for a compound can differ by over an order of magnitude. These discrepancies result in part from the use of different techniques for K_{OW} determination. Techniques for K_{OW} determination include the use of shake flasks, generator columns, reverse-phase high-pressure liquid chromatography (RPHPLC; e.g., Rapaport and Eisenreich 1984; Veith et al. 1979b), and approximations based on fragment constants (Hansch and Leo 1979).

2.3.4.3 Effects of Dissolved Organic Matter on Partition Coefficient--The presence of dissolved organic matter in interstitial water could enhance the solubility of hydrophobic organic compounds and contribute to the uncertainty of estimated partition coefficients. Associations of hydrophobic compounds (e.g., DDT, PCBs) with dissolved organic matter have been documented with various analytical procedures (Carter and Suffet 1982; Hassett and Anderson 1979; Landrum et al. 1984). In addition to reducing actual sediment-water partition coefficients, dissolved organic matter could also have unpredictable effects on contaminant toxicity (see water quality criteria approach limitations).

2.3.4.4 Effects of Sediment/Water (vol:vol) Ratios on Partition Coefficients (The "Solids Effect")--Laboratory studies have demonstrated that K_D and K_{OC} values generated in sorption experiments are not constants, but are strongly dependent on the relative volumes of sediment and water in the test systems (O'Connor and Connolly 1980; Voice et al. 1983; Voice

and Weber 1985). Although this finding has been explained as a laboratory artifact (Gschwend and Wu 1985), it has been shown that partition coefficients (K_{OC} values) determined by measuring aqueous and sedimentary PCB concentrations in water column-suspended solid versus interstitial water-sediment samples differed by over an order of magnitude (Voice and Weber 1985). This difference in observed K_{OC} values was consistent with the K_{OC}-solids concentration relationship observed in many laboratory sorption studies. Thus, partition coefficients, which are ultimately based on sorption experiments with relatively low sediment-water ratios, may not compare well to in situ sediment-water partitioning, which involves very high sediment-water ratios.

Other factors that may affect the applicability of laboratory sorption studies to field samples (e.g., salinity, temperature, sediment particle size) have been discussed elsewhere (JRB Associates 1984b) and are considered to be less significant sources of uncertainty.

2.4 Equilibrium Partitioning Approach (Sediment-Biota)

2.4.1 General Concept--

Acceptable contaminant body burdens for benthic organisms are based on existing regulatory limits [e.g., U.S. FDA action limits or U.S. EPA Reference Dose values (RfD)] or, in lieu of established limits for certain compounds, on U.S. EPA water quality criteria. Sedimentary contaminant concentrations that would correspond to these body burdens under thermodynamic equilibrium are established as sediment quality values (Figure 5).

2.4.2 Background--

This approach has been investigated by U.S. EPA/Environmental Research Laboratory-Narragansett, the U.S. Army Corps of Engineers (COE), and Battelle (1985a). McFarland (1984) suggested a sediment-biota approach as a method of screening sediments for bioaccumulation potential of nonpolar organic compounds. Several underlying assumptions of the approach limit its applicability to nonpolar, nonionic organic contaminants. There are a number of assumptions inherent in this approach:

1. Thermodynamic equilibrium exists among sediment, organisms, and interstitial water

2. Hydrophobic pollutants associate predominantly with lipids in all aquatic organisms, and the affinity of lipids for these pollutants is equivalent for all organisms; similarly, hydrophobic pollutants associate predominantly with organic carbon in all sediments and the affinity of organic carbon for these pollutants is equivalent in all sediments

3. The equilibrium distribution of hydrophobic organic pollutants between lipids and sedimentary organic carbon (i.e., the bioconcentration factor) is constant regardless of the type of organism or sediment and regardless of the specific compound; this assumption is not necessary if organism-specific bioconcentration

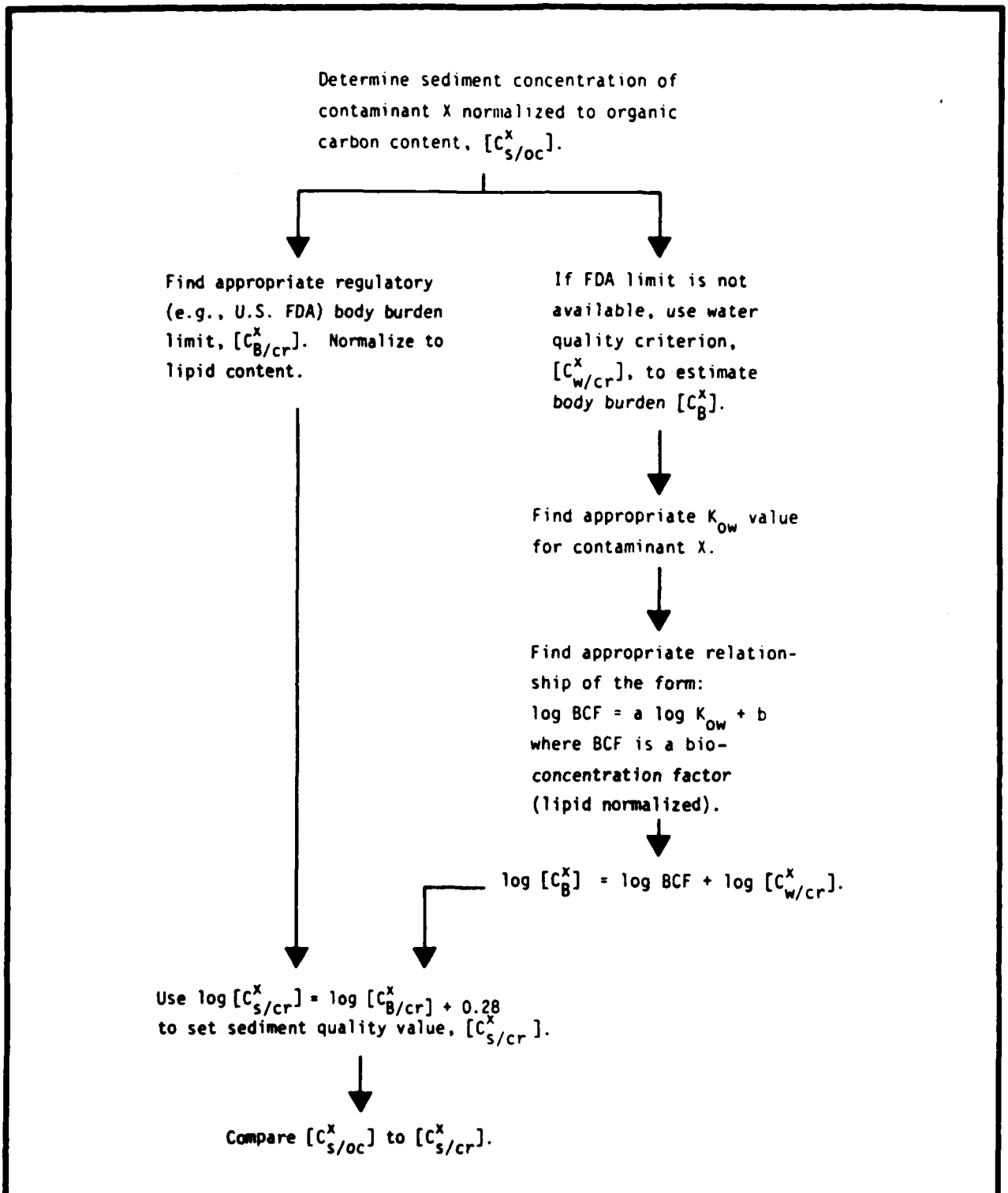


Figure 5. Sediment-biota equilibrium partitioning approach. See text for definition of terms.

factors are established for specific compounds in laboratory studies.

The equilibrium expression used to establish sediment quality values is based on:

$$BCF_{B-S} = C^x_B / C^x_{s/oc}$$

where:

BCF_{B-S} = bioconcentration factor (partition coefficient) of a contaminant between sediment and biota

C^x_B = contaminant concentration in biota (normalized to lipid content)

$C^x_{s/oc}$ = contaminant concentration in sediment (normalized to organic carbon content)

This can easily be converted to:

$$\log[C^x_{s/oc}] = \log[C^x_B] - \log[BCF_{B-S}].$$

An approximation of BCF_{B-S} was established by McFarland (1984) based on a very limited amount of data. $\text{Log}[BCF_{B-S}]$ was given a constant value of -0.28. Thus, if an FDA body burden limit is available for a given contaminant, the appropriate sediment quality value can be derived from:

$$\log[C^x_{s/cr}] = \log[C^x_{B/cr}] + 0.28$$

where:

$[C^x_{s/cr}]$ = sediment quality value for contaminant x

$[C^x_{B/cr}]$ = U.S. FDA limit for contaminant x.

If BCF_{B-S} is not given a constant value, an empirically derived value for sedimentary organic matter/lipid partitioning would have to be established for all relevant compounds and benthic species. This would require a considerable amount of bioaccumulation research.

Because U.S. FDA limits have been established for few contaminants, a method has been devised to calculate tissue body burden limits from water quality criteria. The operative assumption for this method is that equilibrium body burdens of organisms in interstitial water with acceptable contamination levels will be acceptable. The calculation is based on the expression:

$$BCF_{B-W} = C_B^x / C_W^x \qquad \text{or}$$

$$\log[C_B^x] = \log[BCF_{B-W}] + \log [C_{w/cr}^x]$$

where:

$[C_B^x]$ = lipid-normalized body burden of contaminant x

$[BCF_{B-W}]$ = bioconcentration factor (partition coefficient) of contaminant x between biota and water

$[C_{w/cr}^x]$ = water quality criterion for contaminant x

BCF_{B-W} is often estimated by K_{OW}, as strong linear log-log correlations between BCF_{B-W} and K_{OW} have been reported for some compounds in fish (Neely et al. 1974; Veith et al. 1979b, 1980; Gossett et al. 1983).

2.4.3 Advantages--

Sediment quality values can be established with only FDA guidelines (or water quality criteria and K_{OW} values, if necessary).

2.4.4 Limitations--

The assumptions involved in this approach require extensive validation and study. The equilibrium assumption is difficult to validate in field and laboratory studies. Poor correlations between partition coefficients and bioconcentration factors have been observed with compounds that are rapidly metabolized by fishes (e.g., PAH) (Oliver and Niimi 1985; Connor 1984). Bioconcentration of "bulky" (i.e., sterically hindered) and high molecular weight compounds also deviates from behavior predicted from partition coefficients, presumably because the partitioning behavior of these compounds differs from that of smaller molecular volume, lower weight compounds (Oliver and Niimi 1985; Mackay 1982; Kenaga and Goring 1980).

The assumption that lipids control water-organism partitioning has been supported by laboratory studies of fish bioaccumulation from contaminated water (Chiou 1985; Schnoor 1982), but was not confirmed in a laboratory study of polychaetes in PCB-spiked sediments (McLeese et al. 1980). The

assertion that all lipids have an equal affinity for hydrophobic pollutants and that no other factor (e.g., surface area/volume ratios) significantly influences partitioning need to be supported by further studies.

The applicability of FDA limits to environmental quality is not well founded, as the limits were designed for the protection of human health and also take into account additional socioeconomic factors. The use of water quality criteria to determine acceptable tissue levels of benthic organisms also requires validation. Compounds that do not have established FDA body burden limits or water quality criteria cannot be treated with the sediment-biota approach. U.S. FDA action levels (or tolerance limits) are available for the following nonpolar organic pollutants: aldrin, chlordane, DDT/DDE/DDD, dieldrin, endrin, heptachlor/heptachlor epoxide, hexachlorocyclohexane, Kepone, Mirex, PCBs, and toxaphene.

2.5 Field Bioassay Approach

2.5.1 General Concept--

Relationships between chemical concentrations and biological responses are established by exposing test organisms (e.g., Rhepoxynius abronius, a marine amphipod) to field-collected sediments with measured contaminant concentrations. Mortality or sublethal effects are compared quantitatively to effects observed in reference sediments.

2.5.2 Background--

This empirical assessment of sediment toxicity has been implemented by the U.S. EPA and U.S. Army Corps of Engineers to test the suitability of dredged materials for ocean disposal (U.S. EPA/COE 1977). Bioassay techniques have been developed that provide a high degree of statistical confidence ($P<0.05$) for determining whether or not mortality of test organisms differs from that for a relatively uncontaminated control sediment (Swartz et al. 1985). Sediment quality values could be established at contaminant concentrations that correlate with statistically significant difference in mortality between a test sediment and a control sediment.

In its simplest form, the field bioassay approach cannot set contaminant-specific sediment quality values. The approach treats sediment toxicity as a "black box," in that the total effect of all toxic agents (even those that have not been chemically analyzed and quantified) is being measured. Thus, the approach is useful for identifying problem sediments, but requires integration with another approach to yield chemical-specific sediment quality values (e.g., see Section 2.7).

2.6 Screening Level Concentration Approach

2.6.1 General Concept--

The presence of a given benthic species is related to sedimentary contaminant concentrations to determine the minimum concentration (for a given compound) that was not exceeded in 90 percent of the samples that

contained the species. This process is carried out for numerous species and a "screening level concentration" (SLC) is estimated as the contaminant concentration above which less than 95 percent of the total enumerated species of benthic infauna are present.

2.6.2 Background--

The SLC approach (originally termed toxicity endpoint approach) was suggested as an interim method to establish national sediment criteria for nonpolar organic contaminants (Battelle 1985a). Still in the developmental stage, this approach is currently being evaluated as a screening test for nonpolar organic compounds to distinguish between concentrations that pose a threat to biota and those that do not (Battelle 1986).

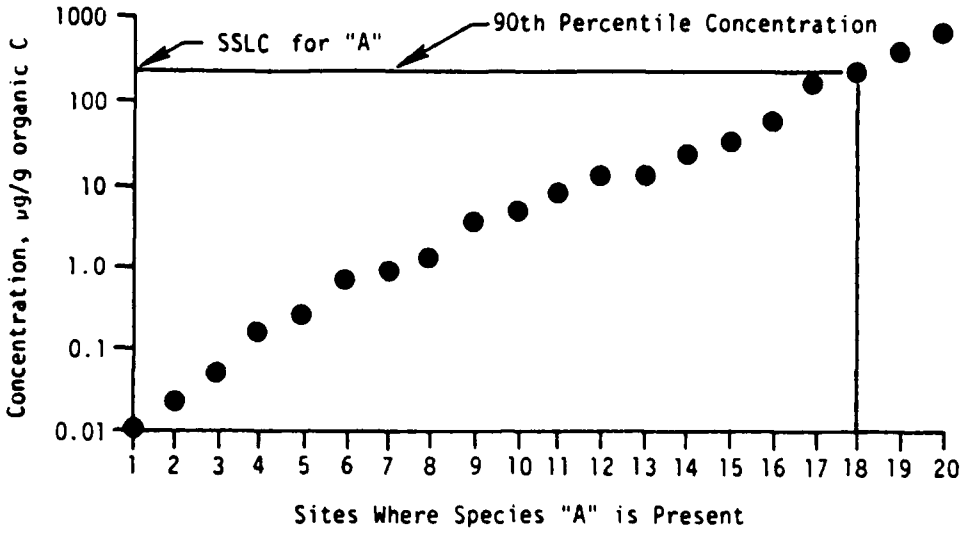
The approach requires that all stations at which a particular benthic invertebrate species is present be arranged sequentially with respect to increasing sediment concentration of the target contaminant. The concentration at the station representing the 90th percentile of the total number of stations at which the species was present is termed the "Species Screening Level Concentration" (SSLC). SSLC values are calculated for a number of species, and arranged sequentially with respect to increasing contaminant concentration. The concentration above which 95 percent of the SSLC are found is termed the "Screening Level Concentration" (SLC). This is consistent with the water quality criteria goal of protecting 95 percent of aquatic biota from adverse effects.

At present, the following minimum data requirements are recommended to calculate the SLC for a compound (Battelle 1986):

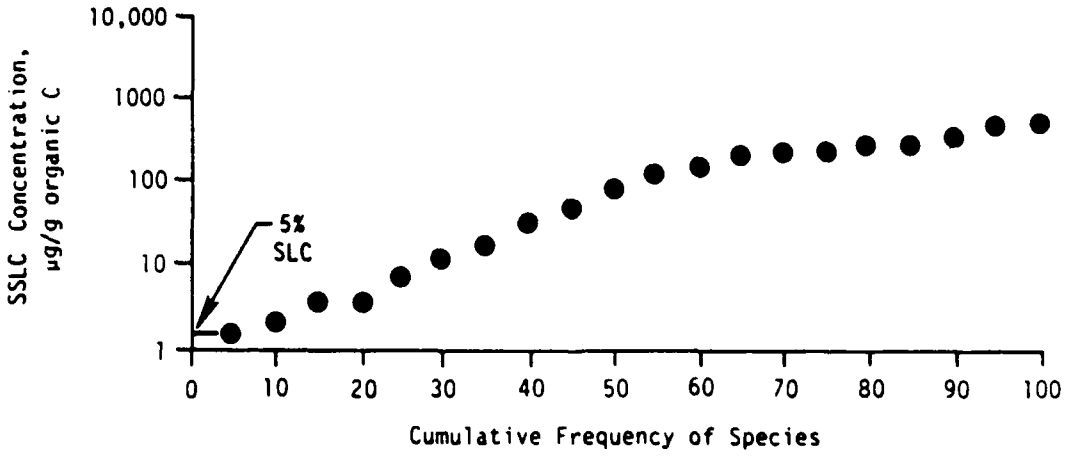
- 20 stations for each SSLC calculation
- 10 taxa (not necessarily species level) for each SLC calculation
- Stations that span a gradient of contamination
- Taxa that are taxonomically homogeneous (e.g., all to species level, all to genus level).

Increasing the number of species and stations beyond the minimum requirements is thought to increase the power of the analysis.

The SLC approach can be displayed graphically, as shown in Figure 6. For each species of interest, concentrations of a given contaminant (normalized to organic carbon content) are plotted in order of increasing concentration for all sample sites where the species was present (Figure 6a). As shown, the SSLC is the minimum contaminant concentration that was not exceeded in sediments from 90 percent of the stations containing the species. SSLC values for selected species are then plotted in a cumulative frequency graph (Figure 6b). The SLC is then determined as the SSLC concentration above which 95 percent of the SSLC values fall.



a. Calculation of Species Screening Level Concentration (SSLC)



b. Calculation of Screening Level Concentration (SLC)

REFERENCE: Battelle (1986)

Figure 6. Calculation of Screeening Level Concentration (SLC) for SLC approach.

2.6.3 Advantages--

The SLC approach uses site-specific field data and is based on an objective method designed to be consistent with the goals of U.S EPA water quality criteria. The approach is not theoretically limited to any one kind of chemical contaminant, although organic carbon normalization (favored by the developers of the approach) limits its use to nonpolar organic compounds. With appropriate normalization, the approach could be applied to metals, polar organic compounds, and nonpolar organic compounds.

2.6.4 Limitations--

The SLC approach requires a considerable amount of field data that span a wide range of contaminant concentrations. It requires that infaunal taxonomic identification be made at the species level, which is a limitation in terms of the time and effort required.

Two implicit assumptions are included in this approach:

- A critical a posteriori interpretation made after generation of SLC values is that the presence/absence of various benthic species is influenced by the toxic effects of contaminants. However, environmental variables (e.g., substrate depth, sediment texture) can be the primary determinants of species presence at a given site. Unless an a priori attempt is made to account for "natural" environmental factors in assessing species presence/absence before calculating SSLC, any a posteriori toxicological interpretation of the final SLC values is complicated.

- It is assumed that the effects of a single contaminant can be discerned from those of all contaminants combined (assuming that presence/absence is truly determined by contaminants).

This approach does not attempt to distinguish between an undisturbed, relatively abundant population and a population that has undergone a severe decline in abundance because of a toxic response (or other factor). Presence/absence is an extreme criterion with which to assess adverse effects. In light of this, it might be more reasonable to consider the number of individuals of each species present rather than their simple presence or absence. Benthic infaunal abundances are generally a more sensitive indicator of disturbance than presence/absence.

Selection criteria for species are not stipulated in this approach. However, the species selected to determine SSLC values can have a great effect on the SLC (i.e., especially when interpreted as a sediment quality value). If over 5 percent of the selected species are sensitive to contaminants, a low and presumably protective SLC value will result (assuming that natural factors have been accounted for). However, if sensitive species constitute a much smaller portion of the total species (i.e., $<<5$ percent) a high SLC could result. Contaminant concentrations sufficient to ensure

the survival of a hardy species may not be acceptable as sediment quality values designed to protect 95 percent of all aquatic life.

The uncertainty of the SLC approach is potentially increased by the existence of interactive effects; the increase in uncertainty will be less pronounced when large data sets collected from diverse areas are used to generate sediment quality values with this approach. Additivity and synergism can produce a comparatively low SSLC for a given chemical by causing species absence at concentrations that would not eliminate a species in the absence of these interactive effects. This would reduce the pool of "nonimpacted" stations used to generate an SSLC. If a large database is used such that chemicals occur over a wide range of concentrations at stations where additivity and synergism are not operative, then the SSLC will be properly set.

Antagonism could potentially increase sediment quality values set by the SLC approach by allowing a species to survive in a sample at a concentration (of a given chemical) that would normally eliminate the species. With a large database and the 90-percent safety factor in SSLC values, such cases would probably have little effect. A final limitation concerning the influence of unmeasured contaminants (common to all of the chemical-specific approaches, and especially empirical approaches that use field data to generate sediment quality values) is discussed in the Limitations section of the AET approach (Section 2.7.4).

2.7 Apparent Effects Threshold (AET) Approach

2.7.1 General Concept--

Chemical data are classified according to the absence or presence of associated biological effects to determine concentrations of contaminants above which statistically significant biological effects (e.g., depressions in benthic infaunal abundances) would always be expected to occur.

2.7.2 Background--

AET were used to determine the contaminants of concern and the regions of highest concern in a Superfund study of Commencement Bay (Tetra Tech 1985). The empirical relationships used to establish AET do not prove a cause-effect relationship between contaminants and effects. The focus of this approach is to identify concentrations of contaminants that are associated exclusively with sediments having statistically significant biological effects (relative to reference sediments).

A pictorial representation of the approach for two chemicals is presented in Figures 7 and 8. Three subpopulations of all sediments analyzed for chemistry and biological effects are represented by bars in the figure, and include:

1. Sediments that did not exhibit significant infaunal depressions

2. Sediments that did not exhibit significant toxicity

3. Sediments that exhibited either toxicity or infaunal depression.

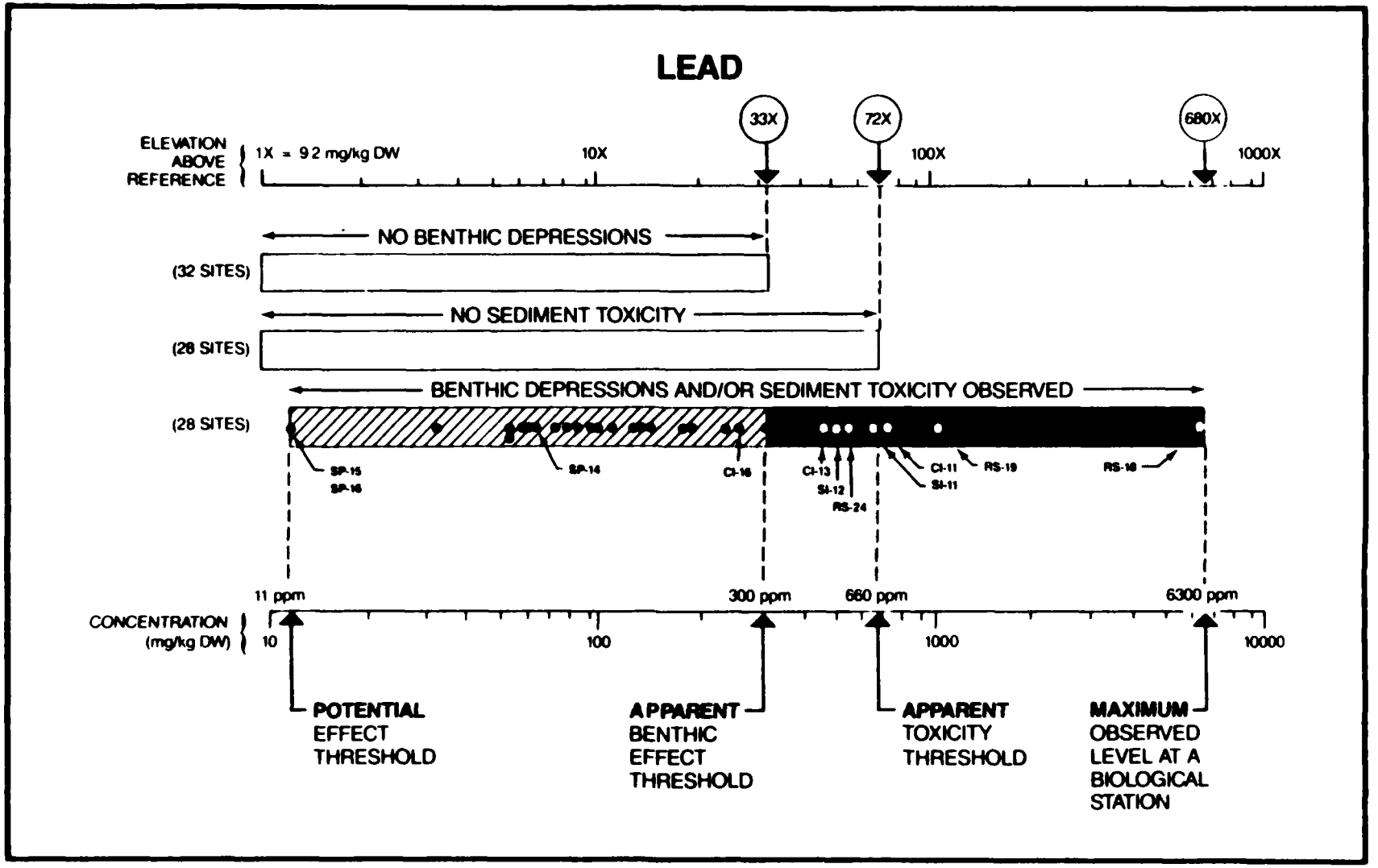


Figure 7. AET approach: Lead (dots in lowest bar designate stations from Tetra Tech, 1985).

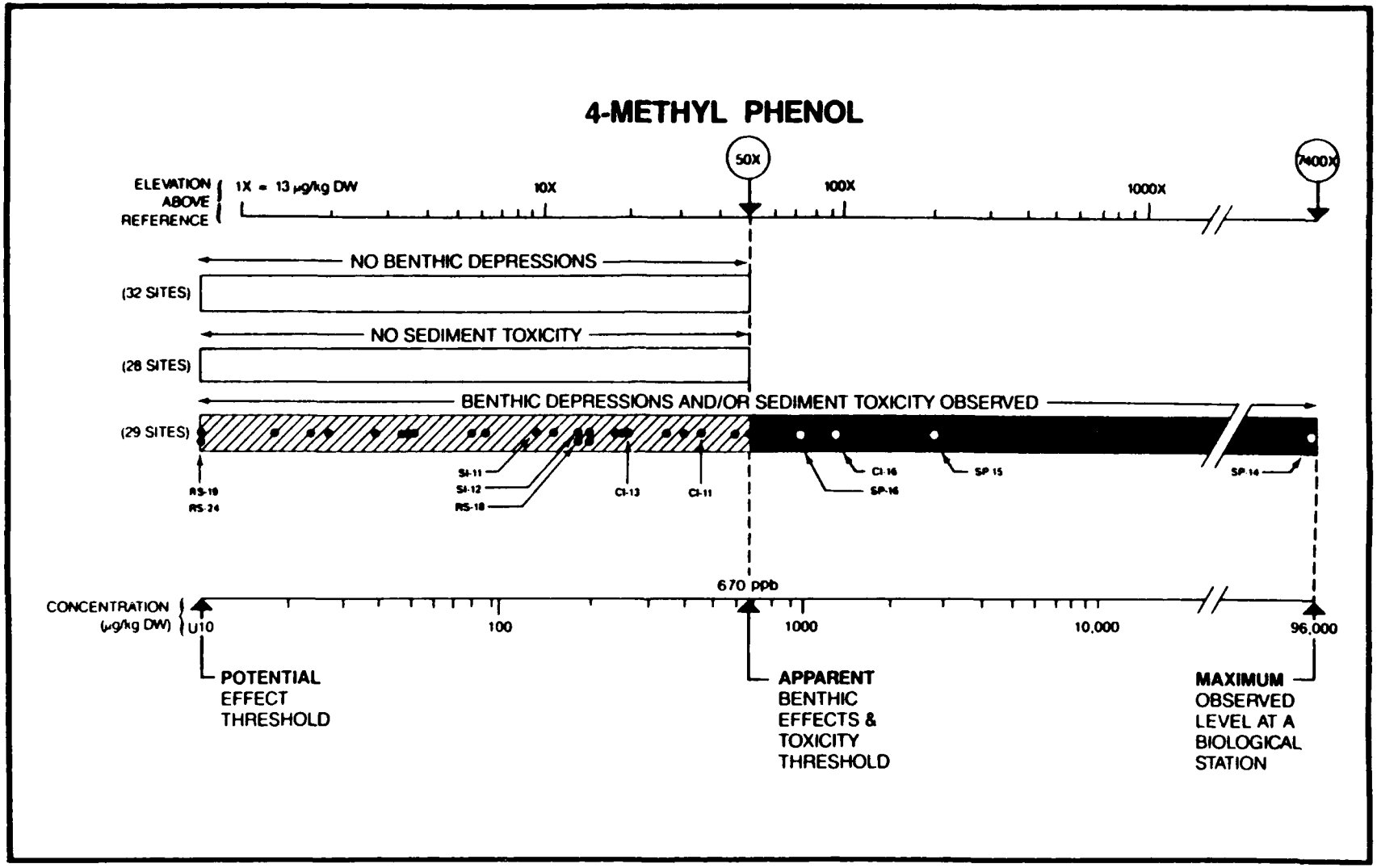


Figure 8. AET approach: 4-Methyl phenol (dots in lowest bar designate stations from Tetra Tech, 1985).

The horizontal axis in each figure represents sedimentary concentrations of the contaminant of concern (i.e., lead or 4-methyl phenol) on a log scale. The AET for lead was based on lead concentration ranges corresponding to sediments that did not exhibit significant biological effects. The AET for 4-methyl phenol were determined analogously.

The potential effect threshold (Figure 7 and 8) is the contaminant concentration below which no statistically significant biological effects were observed in any sample. Note that this threshold for 4-methyl phenol is equal to the detection limit for the compound. The threshold is designated as "potential" because toxicity or benthic effects were found at some, but not all, of the stations with higher lead or 4-methyl phenol concentrations. The toxicity or benthic effects observed at these stations could have resulted from other contaminants or physical conditions (e.g., grain size). Because of these factors, the potential threshold is not used to set sediment quality values.

Apparent benthic effect thresholds and apparent toxicity thresholds correspond to concentrations above which all samples were observed to have infaunal depressions or toxicity, respectively. The purpose of treating data in this manner is to reduce the weight given to samples in which factors other than the contaminant examined (e.g., other contaminants, environmental variables) may be responsible for sediment toxicity. An application of the AET approach to 56 Commencement Bay samples (Tetra Tech 1985) (Figures 7 and 8) illustrates how potential effects of compounds may be distinguished from one another. For example, sediment from Station SP-14 exhibited severe toxicity and depressed infaunal abundances, potentially related to a greatly elevated level of 4-methyl phenol (7,400 times reference levels; Figure 8). The same sediment from Station SP-14 contained a low concentration of lead that was not critical in establishing the AET for lead (Figure 7). Despite the toxic effects displayed by the sample, sediments with higher lead concentrations exhibited no statistically significant biological effects. These results were interpreted to suggest that the effects at Station SP-14 were more likely associated with 4-methyl phenol (or a covarying substance) than with lead. A converse argument can be made for lead and 4-methyl phenol in sediments from Station RS-18. Hence, the AET approach helps to identify different contaminants that are most likely associated with observed effects at each biologically impacted site. Based on the results for these two contaminants, effects at four of the 29 sites may be associated with elevated concentrations of 4-methyl phenol and effects at seven other sites may be associated with elevated lead concentrations.

AET are not limited to site-specific biological indicators [such as infaunal abundances and sediment toxicity (e.g., amphipod, oyster larvae, or bacterial luminescence bioassays)]. They can also be established from biological effects data that are not site-specific, such as fish histopathology or fish bioaccumulation data. Biological indicators that are not site-specific (e.g., fish histopathology data) will introduce additional uncertainty to AET because they will require averaging of chemical data over large areas. Hence, associations between chemical and biological data would

be weaker than for site-specific chemical and biological data (e.g., amphipod bioassays), which can be based on aliquots of the same sediment homogenate.

The AET approach does not intrinsically require normalization (although use of dry-weight normalized data to correct for sediment moisture content is assumed to be desirable). There are a number of reasons that normalization of data to organic carbon content, metal hydroxide content, or grain size may contribute to a better understanding of sediment quality values [e.g., sediment toxicity may be reduced by the "binding" of contaminants to sediment organic carbon, Adams et al. (1984)]. The comparison of sites with similar grain size distributions could minimize potential biological effects of natural environmental factors. At present, there are insufficient data to recommend the use of one normalization method over another.

2.7.3 Advantages--

Like the field bioassay approach, the AET approach relies on empirical biological data to establish sediment quality values. However, the AET approach is an attempt to alleviate a major limitation of the field bioassay approach, namely, that contaminant-specific biological effects cannot be discerned from overall contaminant effects in bioassays of field samples. There are no constraints on the type of contaminant (e.g., metals vs. organic compounds) for which AET can be established. A variety of biological effects indicators (e.g., fish or benthic invertebrate histopathology, bioaccumulation, sediment toxicity) can be used to determine AET for a given chemical. A chemical's AET determined for a diverse set of biological indicators can be compared to yield a more comprehensive perspective on appropriate sediment quality values. By definition, observed biological effects always occur above the AET (for the given data set), hence the approach provides a sediment quality value that is based on non-contradictory evidence of environmental effects.

2.7.4 Limitations--

The AET approach requires the collection of extensive field data for chemical variables and at least one biological indicator. If toxic and benthic effects thresholds are to be established, synoptic bioassay and infaunal abundance data are required in addition to chemical data.

The AET approach allows for the possibility that sediment quality values could be set at a level higher than required for complete environmental protection. This is because biological effects can be observed at levels well below the AET (that is, the potential effect threshold can be much lower than the AET).

AET uncertainty is increased by the possibility of interactive effects; the increase in uncertainty will be less pronounced when large data sets collected from diverse areas are used to generate AET. Additivity and synergism can produce a comparatively low AET for a given chemical by causing impacts at concentrations that would not cause impacts in the absence of these interactive effects. This would effectively reduce the pool of non-impacted stations used to generate AET. This effect is reduced if a large

database is used such that chemicals occur over a wide range of concentrations at stations where additivity and synergism are not operative. Antagonism will produce comparatively high AET if the AET is established at a station where antagonism occurs. A large database could not rectify this elevation of AET because the station at which antagonism occurred would tend to be the nonimpacted station with the highest concentration.

Major sources of uncertainty in determining AET include:

1. The statistical error ($P<0.05$) associated with the significance of bioassay and benthic infauna results (i.e., a classification error)

2. The analytical error associated with the quantification of chemical results

3. The uncertainty associated with the difference between the maximum concentration not associated with an effect and the next highest concentration that is associated with an effect (e.g., the concentration range between the AET and the 4-methyl phenol concentration at Station SP-16 in Figure 8)

4. The uncertainty that adequate sampling has been performed to ensure that a wide range of chemical concentrations and effects has been evaluated.

As with any field-based approach, or even a verification study for a theoretical approach, collection of extensive field data enhances the reliability of the results.

Another source of uncertainty common to all of the chemical-specific approaches (especially approaches that generate sediment quality values based on field data), is the possibility of effects being caused by unmeasured, covarying chemicals. Such chemicals would not be expected to substantially decrease the ability of AET to predict biologically impacted stations (excluding interactive effects already discussed). If an unmeasured chemical (or group of chemicals) varies consistently in the environment with a measured chemical, then the AET established for the measured contaminant will (indirectly) apply to or result in management of the unmeasured contaminant. In such cases, a measured contaminant would be used as an "indicator" for an unmeasured contaminant (or group of unmeasured contaminants). Because all potential contaminants cannot be measured routinely, management strategies must rely to some extent on "indicator" chemicals.

If an unmeasured chemical (or group of chemicals) does not always covary with a measured chemical (e.g., if a certain industrial process releases an unusual mixture of contaminants), the effect should be discerned if a sufficiently large data set is used to establish AET. Use of a large data set comprising samples from a variety of areas with wide-ranging chemical concentrations would decrease the likelihood that an unrealistically low AET would be set. Because AET are set by the highest concentration of a given chemical in samples without observed biological impacts, AET will

not be affected by less contaminated samples in which unmeasured contaminants cause biological impacts.

If an unmeasured toxic chemical does not covary with any of the measured chemicals, it is likely that neither the AET nor any of the other chemical-specific approaches reviewed could predict impacts at stations where the chemical is inducing toxic effects. However, the predictive success can be tested in a validation of each chemical-specific approach using field data. Approaches that rely upon biological testing alone (e.g., the field bioassay approach; Section 2.5) could indicate the impact, but would not indicate the chemical of concern.

2.8 Spiked Bioassay Approach

2.8.1 General Concept--

Dose-response relationships are determined by exposing test organisms (e.g., Rhepoxynius abronius) to sediments that have been spiked with known amounts of chemicals (or mixtures of chemicals). Sediment quality values can be determined for sediment bioassays in the manner that aqueous bioassays were used to establish U.S. EPA water quality criteria.

2.8.2 Background--

Research on spiked sediment bioassays is being conducted for certain chemicals by the U.S. EPA/Office of Research and Development and by Battelle. The research includes investigations of the effect of sedimentary organic matter on chemical toxicity.

2.8.3 Advantages--

In contrast to the field-based approaches considered in this project (e.g., AET, SLC), the spiked bioassay approach can establish cause-and-effect relationships between chemicals and toxic biological responses. Chemicals can be tested individually or in combination. The spiked bioassay is the only systematic and reliable method available for identifying and quantifying interactive effects (e.g., additivity, synergism, and antagonism).

2.8.4 Limitations--

The major limitation of the spiked bioassay approach is the amount of research effort required to test the range of contaminants potentially occurring in Puget Sound, both individually and in combinations. To establish sediment quality values based on spiked bioassays, a wide range of test organisms would require testing. To enhance the reliability of the sediment quality values, a range of sediment types (e.g., with varying organic carbon content and particle size distributions) would also be required.

A source of uncertainty for the spiked bioassay approach concerns the degree to which spiked chemical-sediment associations resemble chemical-sediment association that exist in the environment (e.g., in sediments

that have been extensively reworked by benthic organisms and microbes). This issue is difficult to research and is not currently well understood.

3.0 FINAL SELECTION OF APPROACHES FOR TESTING WITH PUGET SOUND DATA

Of the eight approaches discussed in the previous sections, three [the water quality criteria (Section 2.2), field bioassay (Section 2.5), and spiked bioassay (Section 2.8) approaches] are not evaluated further for application or testing in this project for the following reasons:

- U.S. EPA water quality criteria are integrated into the sediment-water and, for some compounds, the sediment-biota equilibrium partitioning approaches.

- Because the focus of this project is on approaches that can generate chemical-specific sediment quality values, the field bioassay approach will be considered a part of the AET approach in this discussion. The field bioassay approach in its simplest form is not designed to generate chemical-specific sediment quality values.

- The spiked bioassay approach has not yet generated sufficient data to establish sediment quality values and cannot be evaluated in the present project. However, its potential role in future work is discussed in Section 8.5.

The remaining five approaches (reference, sediment-water and sediment-biota equilibrium partitioning, SLC, and AET) were evaluated with regard to their most appropriate uses for establishing sediment quality values.

3.1 Rationale for Selection

Approaches were evaluated with regard to the following criteria (in approximate order of decreasing importance):

- The plausibility and scientific defensibility of the theoretical basis and critical assumptions associated with each approach

- The quantity of data required for each approach, and the current availability of data (i.e., for generation of sediment quality values during the present project)

- The range of chemicals for which each approach is appropriate (i.e., metals; nonpolar, nonionic organic compounds; and polar, ionizable organic compounds)

- The range of biological effects information that can be incorporated into each approach.

3.1.1 Reference Approach--

The reference approach (Section 2.1) provides a toxicologically sound way to establish sediment quality values if: (1) the reference site is determined to have no detrimental effects and (2) the goal of the program is to ensure the absence of toxic effects by considering any contamination above reference levels as unacceptable.

The most practical use of the reference approach is as a screening tool; sediments with contamination above that of an acceptable reference site can easily be identified. After screening, specific contaminant levels requiring remedial action would be established by another approach. This screening approach has minimal data requirements (i.e., only chemistry data are required). The approach is appropriate for a wide range of chemicals. It is not expected that application of this screening approach to Puget Sound biological/chemical data would yield any additional information on its most appropriate use. Therefore, this approach is not recommended for testing with Puget Sound data in this project.

3.1.2 Sediment-Water Equilibrium Partitioning Approach--

The sediment-water equilibrium partitioning approach (Section 2.3) involves plausible assumptions for estimating interstitial water concentrations of hydrophobic pollutants based on sedimentary concentrations. The toxicological assumptions require validation by comparison of calculated sediment quality values to observed site-specific biological effects. Such tests were conducted with existing Puget Sound data in this project (Section 7.1.1). An appealing aspect of this approach is that it has few data requirements (sedimentary contaminant concentration and organic carbon content). Biological data are not required (except for validation of the approach). To use this approach for more than the nine nonpolar, nonionic organic compounds or mixtures for which water quality criteria exist, a method was used to estimate appropriate criteria when established criteria were unavailable (Section 5.2.3.3).

3.1.3 Sediment-Biota Equilibrium Partitioning Approach--

The sediment-biota approach (Section 2.4) is not recommended for use in this project because sufficient data do not exist to validate the approach and to generate definitive sediment quality values.

The minimal data requirements of the sediment-biota equilibrium partitioning approach (only sedimentary contaminant concentrations are required) derive from the series of assumptions used to estimate tissue concentrations and their toxicological significance. As discussed previously, data are not available to confirm certain critical assumptions of the approach (e.g., thermodynamic equilibrium exists between organisms, sediment, and interstitial water; sediment organic matter-lipid distribution coefficients are constant for all hydrophobic compounds, all benthic organisms, and all sediments; and U.S. FDA body burden limits and the U.S. EPA water quality criteria used to estimate body burdens are sufficient to determine potential biological

effects for aquatic organisms). The toxicological assumptions of the sediment-biota approach can only be tested with bioaccumulation data that can be related to toxicological data. Comprehensive data of this type are not available and could be difficult to interpret (e.g., it is unclear whether metabolites and conjugated compounds should be measured along with parent compounds in tissue). Metabolites can be the most toxicologically active forms of pollutants. In contrast to the sediment-biota approach, the sediment-water approach has more laboratory and field evidence that supports some of its critical assumptions. The unproven toxicological assumptions of the sediment-water approach are testable when bioassay or benthic infaunal data are available.

3.1.4 Screening Level Concentration Approach--

The SLC approach (Section 2.6) is still under development but can be applied with available data. Four aspects of the approach limit its defensibility:

1. The interpretation that species presence/absence (without accounting for natural factors) is indicative of toxic effects of contaminants is uncertain

2. Presence/absence is an insensitive measure of the health of a population

3. Selection criteria for species are not established, thus, sensitive species may not be represented

4. There is no mechanism to help discern the effects of individual contaminants from the combined effects of all contaminants present.

The approach could be modified to address the first three of these limitations. The recommended modifications would constitute a major change in the overall approach:

- Data could be grouped according to important natural variables (e.g., grain size, depth) to reduce the effects of these variables on biological observations

- Instead of presence/absence, a quantitative measure of infaunal abundance relative to that at an appropriate reference site is suggested as a new criterion (e.g., sample sites that displayed <80 percent depression in the abundance of a species could be used to determine the SSLC)

- A minimum number of sensitive species (e.g., a minimum of 5 percent of the total species considered) is recommended for determination of SSLC values.

The possible effects of the suggested modifications on the determination of sediment quality values have not been previously tested. The fourth

limitation discussed above is not readily overcome. A limited test of the modified approach was conducted in this project (Section 7.1.4).

3.1.5 Apparent Effects Threshold Approach--

The AET approach is based on empirical evidence of biological effects, and is primarily limited by the quantity of data required to interpret apparent concentration-effects relationships properly. The approach can be used for any chemical contaminant and for any observable biological effects (e.g., bioassays, infaunal abundances, fish histopathology, bioaccumulation). The potential for the AET approach to disregard impacted stations and other aspects of AET uncertainty was tested in this project with matched biological/chemical data from Puget Sound (Section 7.1.1).

3.2 Summary of Approaches Selected for Testing with Puget Sound Data

The sediment-water equilibrium partitioning and AET approaches were selected for testing with Puget Sound data. Test results are presented in Section II. The equilibrium partitioning sediment-water approach was used to generate sediment quality values only for nonpolar, nonionic pollutants. Sediment quality values from this approach were normalized to organic carbon content as specified in equilibrium partitioning theory. The compiled Puget Sound database was used to test the success of these values in predicting biological effects. AET sediment quality values were generated and tested with the same compiled Puget Sound data used to test the equilibrium partitioning approach. AET were generated for four site-specific biological indicators for which data are available (amphipod bioassay, oyster larvae bioassay, benthic infaunal abundances, and Microtox bioassay). Chemical data were normalized to dry weight sediment, organic carbon content, and to percent of fine-grained material (<63 um).

A limited test was performed for three sediment quality values derived with the SLC approach, after the approach was modified according to the factors discussed in Section 3.1.4. The test was limited because the approach is time consuming to apply and computerized species-level infauna data were available for only a few studies (e.g., Commencement Bay). Nonpolar, nonionic compound concentrations were normalized to organic carbon content. Metals were normalized to dry weight sediment. A summary of the results is given in Section 6.2.

II. APPLICATION OF RECOMMENDED SEDIMENT QUALITY VALUE APPROACHES TO PUGET SOUND DATA

4.0 INTRODUCTION

In this section, sediment quality values are developed for the three approaches selected in Section 3.2 (i.e., sediment-water equilibrium partitioning, AET, and SLC approaches). Ideally, the development of sediment quality values should be guided by definitive cause and effect information that relates the individual and collective effects of contaminants to a range of biological effects. However, very little cause-effect information is available. The sediment quality values discussed in this section are interim estimates that have been developed from or validated with chemical and biological data from Puget Sound field investigations.

A large Puget Sound database that comprises matched biological and chemical data from 190 stations was assembled from seven different studies to generate and test sediment quality values for the three selected approaches (see Appendices A and C). The site-specific biological indicators used to assess the sediment quality values include sediment bioassays [amphipod mortality, oyster larvae abnormality, and bacterial luminescence (Microtox)], and depressions in the abundance of major benthic taxonomic groups (e.g., Mollusca, Crustacea, and Polychaeta) or total benthos. Abundances of individual benthic infaunal species were used only with the SLC approach, although these data could be used in the AET approach as well.

The methods used to apply each approach are described in detail in Section 5.0. Chemical-specific sediment quality values derived for each approach are tabulated in Section 6.0. A comparison of the magnitude of these values with the distribution of chemical concentrations in the compiled Puget Sound database (e.g., 50th, 75th, and 90th percentile concentrations) is presented in Section 6.3. This comparison places the sediment quality values in perspective with the level of contamination observed in Puget Sound sediments. Existing Puget Sound interim sediment quality criteria for the Fourmile Rock disposal site are also summarized in Section 6.3 for comparison with the sediment quality values generated in this project.

In Section 7.0, the contaminant-specific sediment quality values generated by the sediment-water equilibrium partitioning (EP) and AET approaches are evaluated with two measures of uncertainty:

- "Accuracy," defined as the ability to predict biologically impacted sediments based on contaminant concentrations in the sediments
- "Precision," defined as the expected variability of sediment quality values given the particular constraints in the design and use of each approach.

The most appropriate use of the proposed sediment quality values for managing contaminated sediments will be influenced by the results of this uncertainty analysis. The analysis focuses on quantifiable uncertainty, although each of the approaches has unquantifiable components of uncertainty. The SLC approach was evaluated separately from the EP and AET approaches because its application was restricted to a small subset of the database and sediment quality values for only a limited number of chemicals were generated.

The overall accuracies of the sediment quality values generated by the EP and AET approaches were evaluated with the same techniques and the same data sets. To more fully test the predictive success of AET, additional accuracy analyses were carried out for AET generated and evaluated with independent data sets (Section 7.1.2). The success of selected sediment quality values generated by the EP and AET approaches in individually predicting biological effects was also examined (e.g., a comparison of the AET value for PCBs and the EP value for PCBs; Section 7.1.3).

Precision analyses of the EP and AET approaches resulted in estimated confidence limits for contaminant-specific sediment quality values. A precision analysis of the SLC approach was beyond the scope of this project; however, confidence intervals for nine SLC values generated from a national database have been determined by Battelle (1986a).

In Section 8.0, the applicability of the sediment quality values generated in this project to a range of sediment management issues is discussed. Recommendations for their use in decision-making and for further studies to refine the values are also summarized (Section 8.0).

5.0 METHODS

5.1 Compilation of Matched Chemical/Biological Data From Puget Sound

A large database consisting of matched chemical/biological data (i.e., chemical and biological data representing the same station) was compiled for the application and testing of the selected sediment quality value approaches. The database was compiled for two reasons:

- To generate sediment quality values for field-based approaches (i.e., the AET and SLC approaches)
- To test the success of sediment quality values (from each of the approaches) at predicting biological impacts in Puget Sound sediments from chemical concentrations in the sediments.

Potential biases related to generating and testing AET with the same database are addressed in detail in Section 7.1.2, in which the predictive success is evaluated for AET generated and tested with independent data sets.

Available Puget Sound data sets containing field measurements of sediment chemistry and at least one site-specific indicator of biological effects were identified and reviewed for use in this project. Data sets from the following Puget Sound studies were identified (for the sake of brevity, incomplete names for studies are used below; the full study names are included in the references):

- Alki Extension (Osborn et al. 1985; Trial and Michaud 1985)
- Commencement Bay (Tetra Tech 1985)
- Duwamish Head (Stober and Chew 1984a)
- Duwamish River I (Chan et al. 1985b)
- Duwamish River II (Chan et al. 1985a)
- Eagle Harbor (not completed in time for this project)
- Eight Bay (Detailed Survey) (Battelle 1985a)
- Everett Harbor (U.S. Department of the Navy 1985)
- OMPA 2, 19 (Malins et al. 1980, 1982)
- Seahurst (Dinnell et al. 1984; Landolt et al. 1984; Nevissi et al. 1984; Stober and Chew 1983, 1984b; Word et al. 1984)
- TPPS (Phase III) (Comiskey et al. 1984, Romberg et al. 1984)

5.1.1 Review of Available Data--

A general review of the available data sets was carried out in three basic steps:

- All available data sets were reviewed for synoptic collection of data, and only synoptically collected chemical and biological data were considered further. [Note: a synoptic data set was defined in this project as one for which toxicity data were collected on the same sediment homogenate used for sediment chemistry, and replicate benthic infaunal samples were collected at the identical station location and time, or at nearly the same time, as sediment chemistry samples.)
- Each data set was reviewed for documentation of quality assurance (QA) methods and summaries of QA review (such documentation was typically provided in the reports in which the data were presented)
- Data were subjected to a more detailed review that focused on issues related to data comparability.

Synoptically collected data were used to reduce the possibility that "patchy" (spatially variable) sediment contamination could result in biological and chemical data based on dissimilar sediment samples representing the same "station." Because the toxic responses of "stationary" organisms (e.g., bioassay organisms confined to a test sediment, or infaunal organisms largely confined to a small area) were assumed to be affected by direct association with contaminants in the surrounding environment, it was considered essential that chemical and biological data be collected from nearly identical subsamples from a given station. Overall, synoptic data were considered to provide the most reliable basis for deriving or validating sediment quality values with site-specific biological field data.

A detailed QA review of all data that were considered for inclusion in the database was beyond the scope of this project. However, the chemical and biological methods were reviewed for every data set considered in an attempt to ensure comparability of chemical, bioassay, and benthic infaunal data from all studies.

In this QA review, analytical techniques, detection limits, and the chemical scope of pollutants analyzed (e.g., polar and nonpolar semivolatile organic compounds, metals, volatile organic compounds) were all considered. The scope of chemicals analyzed in a data set is especially important for sediment quality value approaches that are based on field data (e.g., the SLC and AET approaches). The availability of a wide diversity of chemical data increases the probability that toxic agents (or chemicals that covary with toxic agents) can be identified in sediments with observed biological impacts. No entire data sets were excluded from the database as a result of the review of chemical data.

The QA review of benthic infaunal data focused on sampling methods, and in particular, on subsampling techniques (e.g., cores taken from grab samples), and on the level of replication. The QA review of toxicological data focused on sediment storage (fresh vs. frozen) and on the general acceptance of bioassay methods used.

More detailed treatment of the review and of rationales for excluding data are included in Appendix C.

5.1.2 Summary of Data Used in this Project--

The data sets that were included in the compiled Puget Sound database are summarized in Table 2. The geographical distribution of these data in Puget Sound is presented in Table 3 and Figure 9. More detailed maps with sample locations are included in Appendix A. The compiled chemical data and variables used for normalization [i.e., total organic carbon content, percent of fine-grained material (percent silt and clay)] are tabulated in Appendix A.

TABLE 2. SUMMARY OF DATA SETS USED IN THIS PROJECT

Study	Number of Stations				
			Bioassay		
	Chemistry	Benthic Infauna	Amphipod	Oyster Larvae	Microtox
Alki Extension	11	11	--	--	--
Commencement Bay	56	54	56	56	50
Duwamish River I	9	--	9	--	--
Duwamish River II	31	--	31	--	--
Eight Bay	48	--	48	--	--
Everett Harbor	6	--	6	--	--
TPPS (Phase III A&B)	29	29	--	--	--
Total	190	94	150	56	50

TABLE 3. GEOGRAPHIC DISTRIBUTION OF COMPILED PUGET SOUND DATA

Study Area	Available Data Chemistry	Benthic Infauna	Bioassay	Reference[a]
Alki Point	X	X		4,7
Bellingham Bay	X		X	1
Carr Inlet	X	X	X	6
Case Inlet	X		X	1
Commencement Bay	X		X	6
Dabob Bay	X		X	1
Duwamish River	X		X	2
Elliott Bay	X		X	1
	X	X		3,5
Everett Harbor/ Port Gardner	X		X	1
	X		X	8
Samish Bay	X		X	1
Sequim Bay	X		X	1
Sinclair Inlet	X		X	1
East Passage and Central Basin	X	X		3,5

[a] References:

1. (Battelle 1985b).
2. (Chan et al. 1985a,b).
3. (Comiskey et al. 1984).
4. (Osborn et al. 1985).
5. (Romberg et al. 1984).
6. (Tetra Tech 1985).
7. (Trial and Michaud 1985).
8. (U.S. Dept. of the Navy 1985).

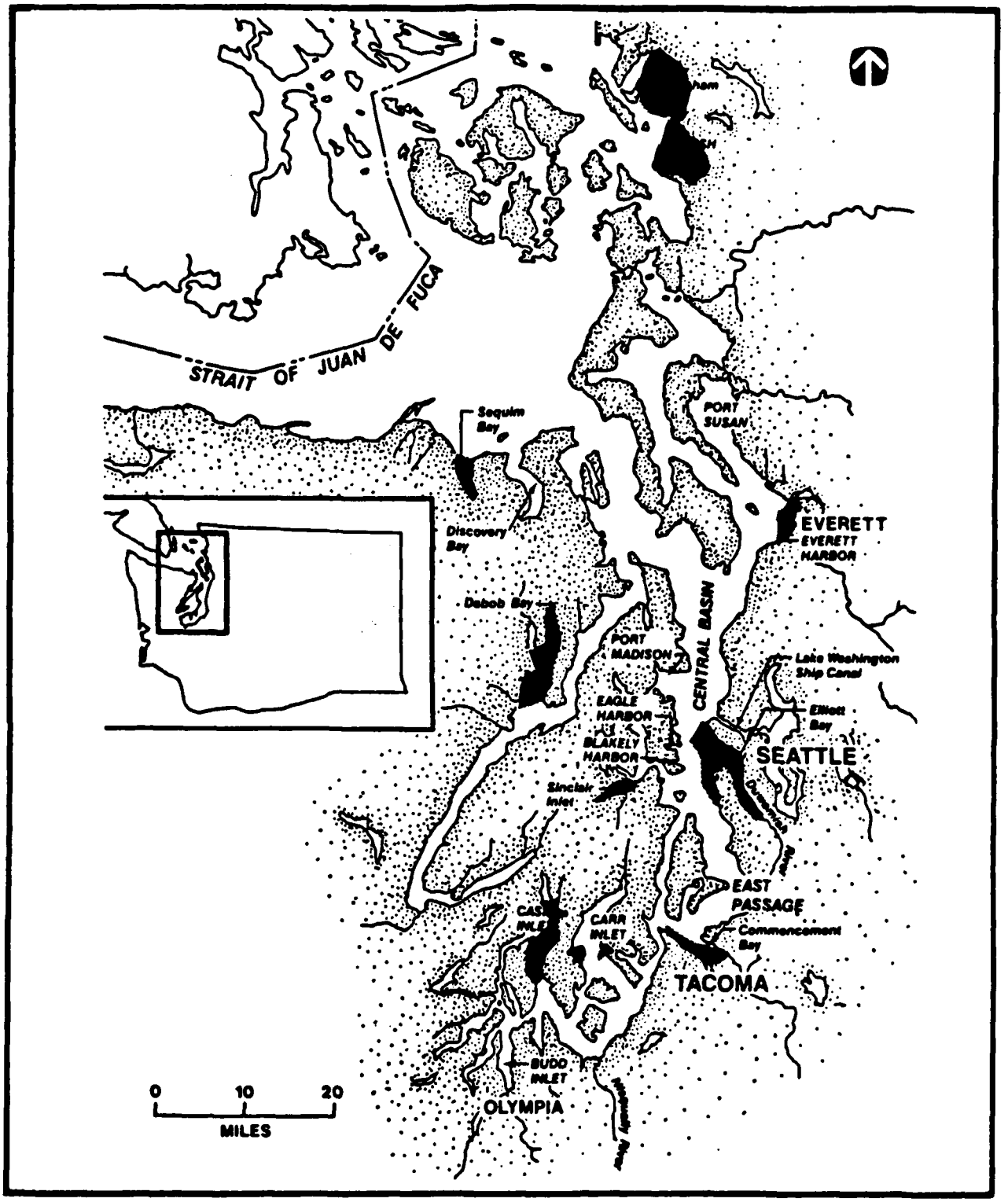


Figure 9. Location of chemical and biological samples included in Puget Sound database.

5.2 Application of the Equilibrium Partitioning Approach

5.2.1 Synopsis of Approach--

A simple model is used to describe the equilibrium partitioning of a contaminant between sedimentary organic matter and interstitial water (see Section 2.3). A sediment quality value for a given contaminant is the sediment concentration (normalized to organic carbon content) that would correspond to an interstitial water concentration equivalent to the U.S. EPA water quality criterion for the contaminant.

5.2.2 Chemicals Used for Application of the EP Approach--

The theoretically based requirements of the EP approach (e.g., the need for a quantitative, environmentally invariant partition coefficient) restrict its application to nonpolar, nonionic (neutral) organic compounds (Section 2.3.2).

Forty nonpolar, nonionic priority pollutants were used in the application of the EP approach for this project (Table 4). Neutral organic priority pollutants that were reported as not detected in the Puget Sound data compiled for this project were not used in the EP application (e.g., hexachlorocyclopentadiene, halogenated ethers, a number of volatile organic compounds, and several chlorinated pesticides).

5.2.3 Literature Data Used for the EP Application--

Sediment quality values for each contaminant were generated using three types of information obtained from the literature (Table 4):

1. Octanol-water partition coefficients (K_{OW})

2. Equations to approximate K_{OC} (a sediment organic carbon-water partition coefficient) from K_{OW}

3. U.S. EPA water quality criteria for saltwater organisms (or estimates of criteria) for each contaminant.

The literature values and sources used for this project are indicated in Table 4.

5.2.3.1 K_{OW} Values--Recently determined K_{OW} values were used when available. Direct determinations of K_{OW} values were preferred. For some compounds, estimations based on reverse-phase high pressure liquid chromatography were the most reliable values available. Calculated K_{OW} values [e.g., those estimated with fragment constants (Hansch and Leo 1979)] were used only if empirically determined values were not available.

5.2.3.2 K_{OW}-K_{OC} Equations--Three K_{OW}-K_{OC} equations were used for this project. These are regression equations of the form $\log K_{OC} = a \log K_{OW} + b$, where a and b are empirically derived constants. An attempt was made to

TABLE 4. DATA USED FOR APPLICATION OF EP APPROACH

Chemical	log K_{ow}[1]	WQC[2] (ppb)	K_{ow}-K_{oc} equation[3]
Low molecular weight PAH			
naphthalene	3.36[a]	1175[r]	t
acenaphthylene	4.07[b]	150[r,s]	t
acenaphthene	3.92[c]	355[p]	t
fluorene	4.23[d]	150[r,s]	t
phenanthrene	4.57[a]	150[r,s]	t
anthracene	4.54[a]	150[r,s]	t
High molecular weight PAH			
fluoranthene	5.22[e]	8[p]	t
pyrene	5.18[a]	150[r,s]	t
benzo(a)anthracene	5.91[e]	150[r,s]	t
chrysene	5.79[e]	150[r,s]	t
benzofluoranthenes	6.57[b,f]	150[r,s]	t
benzo(a)pyrene	6.42[d]	150[r,s]	t
indeno(1,2,3-c,d)pyrene	7.66[b]	150[r,s]	t
dibenzo(a,h)anthracene	6.50[g]	150[r,s]	t
benzo(g,h,i)perylene	7.05[d]	150[r,s]	t
Total PCBs	6.46[h,i,j]	0.03[s,o]	u
Total chlorinated benzenes			
1,3-dichlorobenzene	3.48[k]	65[s,p]	v
1,4-dichlorobenzene	3.38[k]	65[s,p]	v
1,2-dichlorobenzene	3.38[k]	65[s,p]	v
1,2,4-trichlorobenzene	3.98[k]	65[s,p]	v
hexachlorobenzene (HCB)	5.47[k]	65[s,p]	v
Total phthalates			
dimethyl phthalate	1.61[c]	1472[r,s]	u
diethyl phthalate	1.40[c]	1472[r,s]	u
di-n-butyl phthalate	4.13[L]	1472[r,s]	u
butyl benzyl phthalate	4.05[c]	1472[r,s]	u
bis(2-ethylhexyl)phthalate	4.20[h]	1472[r,s]	u
di-n-octyl phthalate	8.06[L]	1472[r,s]	u
Pesticides			
p,p'-DDE	5.69[h]	7[r]	u
p,p'-DDD	6.02[i]	1.8[r]	u
p,p'-DDT	6.36[m]	0.001[o]	u
aldrin	7.4[n]	1.3[q]	u
chlordane	6.00[h]	0.004[o]	u
dieldrin	6.2[n]	0.0019[o]	u
heptachlor	5.44[h]	0.0036[o]	u
gamma-HCH (lindane)	3.72[a]	0.16[q]	u

TABLE 4. (Continued)

Chemical	log K_{ow}[1]	WQC[2] (ppb)	K_{ow}-K_{oc} equation[3]
Miscellaneous extractables			
hexachloroethane	3.93[c]	470[r]	u
hexachlorobutadiene	4.28[h]	16[r]	u
Volatile organics			
trichloroethene	2.42[c]	1000[r]	u
tetrachloroethene	2.53[c]	225[p]	u
ethylbenzene	3.15[b]	215[r]	v

[1] Sources and notes for log K_{ow} values:

[a] Karickhoff (1981)
[b] Callahan et al. (1979)
[c] Veith et al. (1980)
[d] Rapaport and Eisenreich (1984)
[e] Miller et al. (1985)
[f] Average of the benzofluoranthene isomers (b and k)
[g] Means et al. (1980)
[h] Veith et al. (1979b)
[i] Veith et al. (1979a)
[j] Average of log K_{ow}s for Aroclors 1242, 1254,and 1260
[k] Miller et al. (1984)
[l] McDuffie (1981)
[m] Chiou et al. (1981)
[n] Briggs (1981)

[2] Water quality criteria (U.S. EPA 1980) are derived from the following tests all values apply to bioassays conducted with saltwater organisms):

[o] Chronic (24 hr. average) criterion
[p] Estimated chronic criterion (0.5 times the lowest concentration at which chronic effects were observed)
[q] Acute (maximum permissible) criterion
[r] Estimated acute criterion (0.5 times the lowest concentration at which acute effects were observed)
[s] Class value; used for PCBs and individual compounds for which specific criteria are not available.

[3] Regression equations used and their sources are:

[t] $\log K_{oc} = 0.989 \log K_{ow} - 0.346$ (Karickhoff 1981)
[u] $\log K_{oc}^{oc} = 0.843 \log K_{ow}^{ow} + 0.158$ (JRB Associates 1984b)
[v] $\log K_{oc}^{oc} = 0.72 \log K_{ow}^{ow} + 0.49$ (Schwarzenbach and Westall 1981).

use equations that were specific to the chemical classes to which they were applied. For example, the equation used for substituted benzene priority pollutants (Table 4), was developed from laboratory data for 12 substituted benzenes (e.g., representatives of mono- through tetramethylbenzenes and mono- through tetrachlorobenzenes). Similarly, the equation used for PAH was developed from laboratory data for a series of PAH (Table 4). Sufficient phthalate data were not available to develop an equation specifically for phthalates. Thus, an equation developed for priority pollutants with widely ranging K_{OW} values was considered the most appropriate for phthalates (Table 4; JRB Associates 1984b).

5.2.3.3 Water Quality Criteria--U.S. EPA water quality criteria are available for nine organic priority pollutants (PCBs, DDT, chlordane, dieldrin, endosulfan, endrin, heptachlor, lindane, and toxaphene). Of these nine pollutants, chronic saltwater criteria are available for PCBs, DDT, chlordane, dieldrin, and heptachlor. It is desirable to apply the EP approach to as wide a range of nonionic organic chemicals as possible to account for the occurrence of pollutants in the environment from a variety of sources. When published water quality criteria were unavailable for the relevant priority pollutants, water quality criteria were estimated according to a procedure used by developers of the EP approach (JRB Associates 1984b). The procedure involves estimating a water quality criterion as one-half the lowest concentration observed to cause biological effects on saltwater organisms [biological effects data were taken from U.S. EPA (1980)]. This procedure is consistent with the most recent U.S. EPA guidelines for developing water quality criteria (Continuous Maximum Concentrations) from Final Acute Values (Stephan et al. 1985).

Actual water quality criteria, when eventually established by U.S. EPA for compounds that currently have no established criteria, are likely to be different (probably lower) than the values estimated in the present study. Because EP sediment quality values are expected to be most reliable when based on established water quality criteria, compound-specific uncertainty analyses were conducted for compounds with established chronic water quality criteria (Sections 7.1.3 and 7.2.1).

Actual and estimated water quality criteria used in this project are listed in Table 4. Chronic (24-h average) criteria were used when available because they were considered to be more environmentally protective than acute (maximum permissible) criteria. Chronic effects are potentially important in sediments, which are long-term reservoirs for many nonpolar organic pollutants. Developers of the equilibrium partitioning approach have recommended the use of chronic criteria when available (JRB Associates 1984b). When chronic water quality criteria were not available, the following values were used as water quality criteria based on available data in U.S. EPA (1980) (in order of preference):

- Estimates of chronic criteria (based on chronic toxicity data)
- Acute criteria

- Estimates of acute criteria (based on acute toxicity data)
- Estimates of chronic criteria for a chemical group (e.g., chlorinated benzenes)
- Estimates of acute criteria for a chemical group.

Class criteria were applied to individual compounds within a chemical group [consistent with the recommendations of U.S. EPA (1980)] except for the PCB class criterion, which was intended to be used for the entire PCB class, not for individual PCB congeners (U.S. EPA 1980).

Octanol-water partition coefficients (K_{OW}), K_{OW}-K_{OC} regression equations, and water quality criteria were used to calculate sediment quality values with the following equation:

$$C^x_{s/cr} = 10^{[a(\log K_{OW})+b]} \times C^x_{w/cr}$$

where:

$C^x_{s/cr}$ = the sediment quality value (ug contaminant x/kg organic carbon)

$C^x_{w/cr}$ = the water quality criterion (ug contaminant x/L).

5.3 Application of the Apparent Effects Threshold Approach

5.3.1 Synopsis of Approach--

For a given data set, the AET approach identifies concentrations of contaminants that are associated exclusively with sediments that exhibit statistically significant biological effects (compared with reference conditions) (Section 2.7). Chemical data are classified according to the absence or presence of associated biological effects to determine the concentrations of contaminants above which statistically significant biological effects (e.g., depressions in benthic infaunal abundances) would always be expected. AET can be established for any biological indicator.

5.3.2 Chemicals Used for AET Application--

AET may be established for any type of chemical. Sixty-four chemicals or chemical groups (including metals, and polar and nonpolar organic compounds) and three conventional sediment variables were used in the AET application. In general, the frequency of occurrence and range of detected concentrations of chemicals limit their appropriateness for establishing AET. Thus, chemicals seldom detected in the Puget Sound data set (e.g., hexachloroethane, heptachlor) were not used because they did not cover a wide range of concentrations. The range of beryllium and chromium concentrations in the compiled Puget Sound database does not exceed the range for nine different Puget Sound reference areas [as summarized in Tetra Tech (1985)]. Hence, AET for these metals were not used in the AET evaluation [although they are presented in Section 6.0 (Results) as ancillary information].

5.3.3 Data Used for the AET Application--

5.3.3.1 Chemical Data--AET were developed for chemical concentrations (Appendix A) normalized to three variables: sediment dry weight, sediment organic carbon content (expressed as percent of dry weight sediment), and fine-grained particle content (expressed as the percent of silt and clay, or <63 um particulate material, in dry weight of sediment). A discussion of these normalization parameters is included in Appendix G (Ancillary Sediment Variables).

5.3.3.2 Biological Data--AET were developed for four biological effects indicators: amphipod bioassays (with raw data presented as percent mortality), oyster larvae bioassays (with raw data expressed as percent abnormality), benthic infaunal abundances, and bacterial luminescence bioassays (Microtox bioassay; with raw data expressed as percent decrease in luminescence). The selection of indicators was limited by available biological data.

5.3.4 Treatment of Biological Data for AET Application--

The AET approach relies on a binary assessment of biological effects data for a given indicator: a station is classified as either having or not having statistically significant effects. For the sake of brevity, stations with significant effects will be termed "impacted" and those with no statistically significant effects will be termed "nonimpacted." A discussion of the impacted/nonimpacted designation of biological effects for each indicator is presented in this section.

The primary test used to evaluate bioassay and benthic impacts was the t-test, a test that is mathematically equivalent to the single-classification ANOVA based on two groups (Sokal and Rohlf 1981). Although one assumption of ANOVA is that the data are distributed normally, the consequences of non-normality are not too serious; only very skewed distributions have a marked effect on test results (Snedecor and Cochran 1967; Zar 1974; Sokal and Rohlf 1981).

In the amphipod bioassay, for example, there was no reason to expect distributions to be markedly skewed. The five replicate values for each test were generated from subsamples of a homogeneous composite under carefully controlled conditions. These test conditions suggest that the values of all five replicates should be very similar and that the random error encountered among replicates should be relatively small. Transformation of the bioassay results therefore were not considered necessary.

For benthic results, there was considerable reason to believe that the abundance data were strongly skewed, as that pattern is typical of benthic infaunal assemblages (Gray 1981). Accordingly, data for abundance of infauna were $\log_{10}$-transformed before statistical analyses were conducted.

5.3.4.1 Amphipod Bioassay--Significant mortalities of the amphipod Rhepoxynius abronius were determined by statistically comparing results of tests on sediments from potentially impacted sites with those from a

reference area. All comparisons were made within respective studies (i.e., data were not compared among studies). The reference areas used for the different studies included Carr Inlet and Sequim Bay.

Stations with amphipod bioassay data were evaluated for statistically significant mortality as follows:

- All replicates from all stations in the reference area used for each study were pooled, and a mean mortality and standard deviation were calculated
- Results from each potentially impacted site were then compared statistically with the reference conditions using pairwise analysis
- An F_{max}-test (Sokal and Rohlf 1969) was used to test for homogeneity of variances between each pair of mean values
- If variances were homogeneous, a t-test was used to compare the two means
- If variances were not homogeneous, an approximate t-test (Sokal and Rohlf 1969) was used to compare means
- Error rates for significance were adjusted for multiple comparisons using Bonferroni's technique (Miller 1981). That is, an experimentwise error rate of 0.05 for each study was achieved by testing each pairwise comparison at an error rate equal to 0.05 divided by the total number of comparisons made for each study.

5.3.4.2 Oyster Larvae Bioassay--Significant abnormalities in the larvae of the Pacific oyster, Crassostrea gigas, were determined by statistically comparing results of tests on sediments from potentially impacted sites with those from a reference area. Oyster larvae data were available from Tetra Tech (1985). The reference area for that study was Carr Inlet.

Stations with oyster bioassay data were evaluated for statistically significant abnormality as follows:

- All replicates from all stations in the reference area were pooled, and a mean abnormality and standard deviation were calculated
- Results from each potentially impacted site were then compared statistically with the reference conditions using a t-test.
- Error rates for significance were adjusted for multiple comparisons using Bonferroni's technique (Miller 1981). That is, an experimentwise error rate of 0.05 for each study was achieved by testing each pairwise comparison at an error

rate equal to 0.05 divided by the total number of comparisons made for each study.

5.3.4.3 Benthic Infaunal Analysis--Significant depressions of the total abundance of benthic infauna, and of abundances of polychaetes, molluscs, and crustaceans were determined separately by comparing values from potentially impacted sites with those from reference areas. Comparisons were made within respective studies unless reference data were not available for a particular study. In those cases, comparisons were made among studies.

Although the AET approach can be used with species-level data for benthic infauna, higher level taxa (i.e., Polychaeta, Mollusca, Crustacea) were used to set AET values in this project for two major reasons. First, because the AET approach is based on pair-wise statistical comparisons with reference conditions, the benthic taxa must either be abundant enough or have a low enough variance to allow major depressions to be discriminated statistically. If these criteria are not met, it may be very difficult to distinguish a depression and, in some cases, complete absence of a taxon may not be indicated as a significant impact. Therefore, use of taxa that are either rare or highly variable may result in a relatively insensitive indicator of environmental impact.

The second major reason for using higher taxa was that comparisons with bioassay results (i.e., amphipod mortality and oyster larvae abnormality) as part of the Commencement Bay Nearshore/Tideflats Remedial Investigation (Tetra Tech 1985) showed that impacted or non-impacted designations made by benthic and bioassay indicators agreed at 67-79 percent of the 48 stations evaluated. This level of agreeement is significant ($P<0.05$, binomial test), and suggests that benthic comparisons based on higher taxa were as sensitive as the bioassays and were responding to similar stimuli. This independent corroboration of the use of higher level taxa contributed to its acceptance for setting benthic infauna AET.

Reference data for each potentially impacted site were selected based on samples collected during the same season, at a similar depth, and in sediments with similar particle size characteristics (i.e., percent silt plus clay) as those of the potentially impacted site. In this manner, all comparisons were stratified by three of the major natural variables known to influence the abundance and distribution of benthic macroinvertebrates. The reference areas used for different studies included Carr Inlet, Blair Waterway (Commencement Bay), and central Puget Sound (Pt. Williams to Pt. Robinson). Although not a pristine reference area, Blair Waterway stations sampled in the Commencement Bay Nearshore/Tideflats Remedial Investigation (Tetra Tech 1985) exhibited relatively low chemical contamination, no toxicity (except one station), and sediment characteristics similar to those found throughout the other waterways. Thus, Blair Waterway was used as a best estimate of unimpacted waterway conditions in fine-grained sediments of Commencement Bay.

Stations with infaunal data were evaluated for statistically significant benthic depressions as follows:

- All abundances were $\log_{10}$-transformed
- All replicates from each set of reference conditions were pooled, and a mean and standard deviation were calculated for each of the four benthic groups (i.e., total benthos, Polychaeta, Mollusca, and Crustacea)
- The $\log_{10}$-transformed abundance of each benthic group at each potentially impacted site was then compared statistically with the appropriate reference conditions using pairwise analysis
- An F_{max}-test (Sokal and Rohlf 1969) was used to test for homogeneity of variances between each pair of values
- If variances were homogeneous, a t-test was used to compare the two means
- If variances were not homogeneous, an approximate t-test (Sokal and Rohlf 1969) was used to compare means
- Error rates for significance were adjusted for multiple comparisons using a Bonferroni's technique (Miller 1981). That is, an experimentwise error rate of 0.05 for each benthic group in each study was achieved by testing each pairwise comparison at an error rate equal to 0.05 divided by the total number of comparisons made for each study.

Appropriate reference data (i.e., with respect to season, depth, and sediment texture) were available for most potentially impacted sites. However appropriate reference data could not be found for 17 Phase IIIA and 6 Phase IIIB Metro TPPS stations. Thus, biological effects could not be assessed for these stations.

5.3.4.4 Microtox Bioassay--Significant Microtox toxicity for samples from Commencement Bay (Tetra Tech 1985) was assessed by statistically comparing the predicted decrease in luminescence in the presence of a 15-g sediment sample to that observed for sediments from a reference area (Carr Inlet). The following procedure was used (Williams et al. 1986):

- For each sample, decrease in luminescence for a 15-g sample was predicted with a least-squares regression of the percent decrease in luminescence vs. the logarithm of the standardized sample dilution, where five serial dilutions of supernatants from samples of 13.0 to 26.4 g were used as values for the independent variable
- Statistical significance of the predicted luminescent response as compared to that of control sediment was determined using a t-test with a comparisonwise error rate of 0.001, which yields an experimentwise error rate of 0.05 (Zar 1974).

5.4 Application of the Screening Level Concentration Approach

5.4.1 Synopsis of Approach--

In the SLC approach, the presence of a given benthic species is correlated to sedimentary contaminant concentrations to determine the minimum concentration (for a given compound) that was not exceeded in 90 percent of the samples containing the species (Section 2.6). This process is carried out for numerous species and a "screening level concentration" (SLC) is estimated as the contaminant concentration above which no more than 95 percent of the total enumerated species of benthic infauna are present (see Section 2.6.2).

5.4.2 Modifications of the Original Approach--

Before the SLC approach was applied on a limited scale to data from Commencement Bay, several modifications to the original approach were made to respond to the constraints identified in Section 3.1.4. Because the characteristics of benthic invertebrate assemblages are influenced by depth (e.g., Sanders et al. 1965; Jumars and Fauchald 1977) and sediment character (e.g., Gray 1974; Rhoads 1974), effects of these natural variables may confound or obscure effects from chemical contamination. The stations used in the limited application were therefore stratified by depth and percent silt plus clay (i.e., an index of sediment character).

The species list used to generate each SLC is developed in part using data from contaminated stations. Hence, it is possible that >95 percent of the SSLC values (explained in Section 2.6.2) will be calculated for pollution-tolerant species. In such a case, the resulting SLC would be established by a pollution-tolerant species and thereby may not be sufficiently protective if applied beyond the immediate data set. To avoid the potential influence of pollution-tolerant species, the species list used in this limited application was developed from data collected in a Puget Sound reference area (with similar physical conditions as at the contaminated stations). This list therefore represents the species expected to be present at the contaminated stations in the absence of contamination.

The use of presence as a measure of the health of a population may be a relatively insensitive measure. For example, it is uncertain whether a single individual at a station implies that a species has not been unreasonably affected by chemical contamination. Presence may also be overly sensitive to methodological errors. For instance, if a single individual was introduced to a station (e.g., through inadequate cleaning of the sieves between stations) or was identified incorrectly (e.g., because it was damaged), the designation of the entire station could change from impacted to nonimpacted with respect to that species. To evaluate the use of presence as the index of species health, an 80 percent depression in abundance from that observed at the reference stations was used as an alternative index of impact (i.e., 80 percent depression corresponds to absence). The 80 percent level was derived from Tetra Tech (1985), in which most (i.e., 33 of 37) statistically significant ($P<0.05$) depressions in the abundance of major taxonomic groups (i.e., total benthos, Polychaeta, Mollusca, Crustacea) from Commencement Bay stations exceeded

an 80 percent depression from reference abundances (see also discussion in Appendix H).

5.4.3 Data Used for the Limited Application--

The data used for the limited application of the toxicity endpoint approach were taken from the Commencement Bay Nearshore/Tideflats Superfund Remedial Investigation (Tetra Tech 1985). Twenty-nine stations (4 reference, 25 contaminated) were selected within the depth range of 5-18 m and the range of percent silt plus clay of 55-89 percent. The station group included representatives from all seven industrial waterways and spanned relatively wide ranges of degree and kind of chemical contamination.

Twenty taxa (15 species, 1 species group, 3 genera, 1 family) were sufficiently abundant (i.e., $\geq$ 5.0 individuals per station) to calculate an 80 percent depression that would require a minimum of one individual per station. The taxa spanned a wide taxonomic range, including 4 phyla and at least 5 classes (Table 5). Several taxa identified to the family and genus level were included with the species-specific data because the taxonomic laboratory could not routinely identify those taxa to lower levels. Inclusion of these taxa presumably increased the power of the limited application by providing four additional SSLC values. In addition, one of the higher level taxa (i.e., Amphiuridae) is thought to be pollution-sensitive (Word et al. 1977; Thompson 1982).

The reference taxa were quite representative of the species captured at all 52 stations in Commencement Bay (Tetra Tech 1985), as 7 were included within the 10 most abundant taxa of the 52-station data set and all but Syllis heterochaeta were included in the 63 most abundant taxa of the 52 station data set. Pollution-sensitive species accounted for at least 25 percent of the reference taxa. Four of these species (i.e., Praxillella gracilis, Axinopsida serricata, Nucula tenuis, Euphilomedes producta) were identified as potential pollution-sensitive taxa in pattern recognition analyses of Commencement Bay data (Appendix D), and a fifth taxon (i.e., Amphiuridae has been identified as apparently pollution-sensitive by Word et al. (1977) and Thompson (1982).

Using the 20 reference species and the 25 contaminated sites described earlier, SLC were calculated for high molecular weight polycyclic aromatic hydrocarbons (HPAH), naphthalene, and mercury. SLC were calculated for HPAH and naphthalene on both a dry-weight and an organic carbon normalized basis. The SLC approach was orginally developed and recommended for use with nonpolar organic compounds normalized to organic carbon content in sediments (Battelle 1986). The reason for also testing dry-weight normalization was that the SLC approach (as with AET, but unlike the equilibrium partitioning approach) requires no a priori assumptions concerning the specific mechanism for interactions between contaminants and organisms.

TABLE 5. REFERENCE AREA TAXA USED FOR THE LIMITED APPLICATION OF THE SLC APPROACH

Taxon	Taxon Code[a]	Reference Abundance[b]	Number of Stations[c] 80 Percent	Presence
Annelida				
Polychaeta				
Chaetozone spp.	1	13.8	20	23
Eteone longa	2	9.8	6	18
Euchone spp.	3	10.5	10	16
Glycera capitata	4	15.5	17	21
Lumbrineris sp. gr. 1	5	149.5	19	23
Nephtys ferruginea	6	8.3	14	19
Notomastus tenuis	7	10.8	6	16
Praxillella gracilis[d]	8	32.5	3	10
Syllis heterochaeta	9	5.8	[illegible]	[illegible]
Tharyx multifilis	10	710.8	21	24
Mollusca				
Gastropoda				
Mitrella gouldi	11	10.3	8	14
Pelecypoda				
Axinopsida serricata[d]	12	1,266.8	[illegible]	14
Compsomyax subdiaphana	13	6.[illegible]	[illegible]	[illegible]
Macoma carlottensis	14	39.[illegible]	[illegible]	14
Nucula tenuis[d]	[illegible]	[illegible]	[illegible]	4
Pseplidia [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Arthropoda				
Crustacea				
Euphilomedes carcharodonta	[illegible]	[illegible]	[illegible]	
Euphilomedes producta[d]	[illegible]	[illegible]		
[illegible] sp.	[illegible]		4	[illegible]
[illegible]odermata				
[illegible]eroidea				
Amphiuridae[e]		[illegible]		

[a] [illegible] number [illegible] taxon [illegible] each [illegible]

[b] Mean abundance [illegible] each taxon at the [illegible] stations [illegible] of each taxon at each reference [illegible] grab samples

[c] Number [illegible] stations at which the abundance [illegible] was [illegible] depressed [illegible] the reference [illegible] was present

TABLE 5. (Continued)

[d] Identified as a potential pollution-sensitive species in Commencement Bay in Appendix D.

[e] Identified as a pollution-sensitive taxon by Word et al. (1977) and Thompson (1982).

6.0 RESULTS

6.1 Sediment Quality Values Generated by the Equilibrium Partitioning and Apparent Effects Threshold Approaches

Contaminant-specific sediment quality values are presented in Tables 6 through 8. For comparative purposes, the values are grouped according to their normalization. EP sediment quality values can be compared roughly to dry-weight AET if an organic carbon content is assumed (Table 6). As noted in Table 6, a 1 percent organic carbon content is assumed; however, to adjust the sediment quality values for a different organic carbon content, multiply by the percent organic carbon. (The mean and median organic carbon content of the compiled Puget Sound database are 2.0 and 1.3, respectively.) EP and AET sediment quality values normalized to organic carbon content are presented together in Table 7. Fines-normalized AET are presented in Table 8. The "greater than (>)" AET values in Tables 6-8 indicate that a definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations. These "greater than" values were not used in testing the AET approach (Section 7.0), although they indicate a minimum potential value for the AET of the particular chemical.

Sediment quality values generated by the EP approach generally are higher, in some cases by orders of magnitude, than corresponding AET values generated for various biological effects indicators (Tables 6 and 7). However, EP values for several chemicals are comparable to or considerably less than the corresponding AET (e.g., p,p'-DDT and PCBs). Because EP sediment quality values are established largely by K_{ow} values and water quality criteria, relatively low water quality criteria (e.g., established chronic water quality criteria for certain chlorinated pesticides and PCBs; Table 4) or low K_{ow} values (e.g., for dimethyl phthalate; Table 4) will set relatively low sediment quality values for these chemicals.

6.1.1 Comparison with Historical Values--

6.1.1.1 Equilibrium Partitioning--The EP sediment quality values presented in Table 7 are comparable to corresponding values generated in a recent report that developed the sediment-water equilibrium partitioning approach for Puget Sound (JRB Associates 1984b). Differences between the two sets of values are attributable to the use of different K_{ow} values (K_{ow} values reported in more recent literature were used when possible in the present report) or different K_{ow}-K_{oc} equations (chemical class specific K_{ow} K_{oc} equations were used when possible in the present report).

The EP values in Table 7 differ from EP values generated by Quinlan et al. (1985). In their report, the equilibrium partitioning approach included use of observed sediment-water partition values (K_d), K_{ow} K_{oc} equations, K_{oc}-aqueous solubility equations, U.S. EPA water quality criteria, and aqueous bioassay toxicity data from unspecified sources. Values were presented on a dry weight basis assuming a 2 percent organic carbon content. Of the 10 compounds for which EP values were established in both Quinlan et al. (1985) and the present report, 4 compounds or compound groups (PCBs,

TABLE 6. EP AND AET SEDIMENT QUALITY VALUES (DRY WEIGHT)[a,b]
(ug/kg dry weight for organics; mg/kg dry weight for metals)

Chemical	EP[c,d]	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Low molecular weight PAH		5200	5200	6100	5200
naphthalene	11000	2100	2100	2100	2100
acenaphthylene	7200	560	>560	640	>560
acenaphthene	12000	630	500	500	500
fluorene	10000	540	540	640	540
phenanthrene	22000	2100	1500	3200	1500
anthracene	21000	960	960	1300	960
High molecular weight PAH		18000	17000	>51000	12000
fluoranthene	5200	3900	2500	6300	1700
pyrene	89800	4300	3300	>7300	2600
benzo(a)anthracene	470000	1600	1600	4500	1300
chrysene	360000	2800	2800	6700	1400
benzofluoranthenes	2100000	3700	3600	8000	3200
benzo(a)pyrene	1500000	2400	1600	6800	1600
indeno(1,2,3-c,d)pyrene	26000000	690	690	>5200	600
dibenzo(a,h)anthracene	1800000	260	230	1200	230
benzo(g,h,i)perylene	6300000	740	720	5400	670
Total PCBs	120	2500	1100	1100	130
Total chlorinated benzenes		680	400	400	170
1,3-dichlorobenzene	640	>170	>170	>170	>170
1,4-dichlorobenzene	550	260	120	120	110
1,2-dichlorobenzene	550	>350	50	50	35
1,2,4-trichlorobenzene	1500	51	64	64	31
hexachlorobenzene (HCB)	17000	130	230	230	70
Total phthalates		>5200	3400	>70000	3300
dimethyl phthalate	480	160	160	160	71
diethyl phthalate	320	>73	>73	97	>48
di-n-butyl phthalate	64000	>5100	1400	>5100	1400
butyl benzyl phthalate	55000	>470	>470	470	63
bis(2-ethylhexyl)phthalate	74000	>3100	1900	1900	1900
di-n-octyl phthalate	130000000	>590	>420	>68000	
Pesticides					
p,p'-DDE	6300	15	--	9	
p,p'-DDD	3100	43	--	2	--
p,p'-DDT	3.3	3.9	>6	11	--
aldrin	32000	--	--	--	--
chlordane	6.6	--	--	--	--
dieldrin	4.6	--	--	--	--
heptachlor	2.0	--	--	--	--
gamma-HCH (lindane)	3.2	--	--	--	--

TABLE 6. (Continued)

Chemical	EP[c,d]	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Phenols					
phenol	--	560	420	1200	1200
2-methylphenol	--	63	63	>72	>72
4-methylphenol	--	1200	670	670	670
2,4-dimethylphenol	--	>50	29	29	29
pentachlorophenol	--	>140	>140	>140	>140
Miscellaneous extractables					
hexachloroethane	14000	--	--	--	--
hexachlorobutadiene	930	290	270	270	120
1-methylphenanthrene	--	310	370	370	370
2-methylnaphthalene	--	670	670	670	670
biphenyl	--	260	260	270	270
dibenzothiophene	--	240	240	250	250
dibenzofuran	--	540	540	540	540
benzyl alcohol	--	73	73	73	57
benzoic acid	--	>690	650	650	650
N-nitrosodiphenylamine	--	220	130	75	40
Volatile organics					
trichloroethene	1600	--	--	--	--
tetrachloroethene	440	>210	140	140	140
ethylbenzene	1200	>50	37	37	33
total xylenes	--	>160	120	120	100
Metals					
antimony	--	5.3	26	3.2	26
arsenic	--	93	700	85	700
beryllium	--	>5.5	0.45	>0.50	0.36
cadmium	--	6.7	9.6	5.8	9.6
chromium	--	>130	>37	59	27
copper	--	800	390	310	390
iron	--	27000	37000	37000	37000
lead	--	700	660	300	530
manganese	--	230	480	>1000	480
mercury	--	2.1	0.59	0.88	0.41
nickel	--	>120	39	49	28
selenium	--	>1.0		>63	
silver	--	>3.7	>0.56	5.2	>0.56
thallium	--	0.4	0.24	0.24	0.24
zinc	--	870	1600	260	1600
Conventional variables					
total organic carbon	--	15%	15%	15%	15%
total volatile solids	--	27%	22%	22%	22%
percent fine-grained	--	>98%	>89%	>97%	88%

TABLE 6. (Continued)

[a] Dashes in EP column indicate chemicals not appropriate for approach (because of chemical characteristics) or chemicals for which water quality criteria are not available or easily estimated.

[b] ">" in AET columns indicate that a definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations.

[c] Equilibrium Partitioning approach.

[d] Assumes a constant organic carbon content of 1 percent for comparison purposes. To adjust the value for a different organic carbon content, multiply by the percent organic carbon.

TABLE 7. EP AND AET SEDIMENT QUALITY VALUES (ORGANIC CARBON NORMALIZED)[a,b]
(mg/kg organic carbon for organics and metals)

Chemical	EP[c]	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Low molecular weight PAH		396	370	>6100	>530
naphthalene	1100	>200	99	>330	>170
acenaphthylene	720	27	>27	640	>27
acenaphthene	1200	>72	16	>100	>57
fluorene	1000	58	23	>640	>71
phenanthrene	2200	180	120	>3200	>160
anthracene	2100	>79	>79	1300	>79
High molecular weight PAH		960	960	>51000	1500
fluoranthene	520	160	160	>6300	>190
pyrene	8980	>210	>210	>7300	>210
benzo(a)anthracene	47000	110	110	>4500	>160
chrysene	36000	110	110	>6700	>200
benzofluoranthenes	210000	230	230	>8000	>430
benzo(a)pyrene	150000	99	99	>6800	>140
indeno(1,2,3-c,d)pyrene	2600000	33	33	>5200	>87
dibenzo(a,h)anthracene	180000	120	120	>1200	33
benzo(g,h,i)perylene	630000	>31	31	>5400	>67
Total PCBs	12	130	>46	270	12
Total chlorinated benzenes		21	21	21	18
1,3 dichlorobenzene	64	>15	>15	>15	>15
1,4 dichlorobenzene	55	6.5	3.1	>16	>16
1,2 dichlorobenzene	55	>3.2	2.3	2.3	2.3
1,2,4 trichlorobenzene	150	>2.8	2.7	2.7	0.81
hexachlorobenzene (HCB)	1700	5.4	9.6	9.6	2.3
Total phthalates		>310	>310	>12000	220
dimethyl phthalate	48	>22	>22	>22	>19
diethyl phthalate	32	>5.3	>5.3	>78	>5.3
di n butyl phthalate	6400	260	260	>3400	220
butyl benzyl phthalate	5500	>9.2	>9.2	64	4.9
bis(2 ethylhexyl)phthalate	7400	78	59.6	59.6	47
di n octyl phthalate	13000000	>57	>57	>12000	
Pesticides					
p,p' DDE	630	0.9		>5.0	
p,p' DDD	310	2.2		2.0	
p,p' DDT	0.33	>1.2	>0.39	>3.7	
aldrin	3200				
chlordane	0.66				
dieldrin	0.46				
heptachlor	0.20				
gamma HCH (lindane)	0.32				

TABLE 7. (Continued)

Chemical	EP[c]	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Organic acids					
phenol	--	>39	>39	>39	33
2-methylphenol	--	3.1	3.1	>10	>10
4-methylphenol	--	37	37	81	81
2,4-dimethylphenol	--	>1.3	>1.3	>1.3	0.63
pentachlorophenol	--	>11	>11	>11	>11
Miscellaneous extractables					
hexachloroethane	1400	--	--	--	--
hexachlorobutadiene	93	16	11	11	3.9
1-methylphenanthrene	--	22	22	>29	>29
2-methylnaphthalene	--	38	38	>64	>64
biphenyl	--	9.4	7.0	12	12
dibenzothiophene	--	>19	8.2	14	14
dibenzofuran	--	15	15	>58	>58
benzyl alcohol	--	5.0	5.0	5.0	5.0
benzoic acid	--	>170	>170	>170	>170
N-nitrosodiphenylamine	--	>11	>11	11	>11
Volatile organics					
trichloroethene	160	--	--	--	--
tetrachloroethene	44	>22	>22	>22	>22
ethylbenzene	120	>3.8	>3.8	>3.8	>3.8
total xylenes	--	>12	>12	>12	>12
Metals					
antimony	--	1900	3300	550	3300
arsenic	--	32000	88000	6300	88000
beryllium	--	>470	>64	>350	42
cadmium	--	1100	1200	580	1200
chromium	--	>5900	>5400	>35000	5100
copper	--	49000	49000	17000	48000
iron	--	>5700000	>5700000	22000000	4600000
lead	-	84000	66000	22000	66000
manganese	-	>83000	>83000	>1100000	61000
mercury	--	210	210	>780	77
nickel	-	>6800	>6800	>32000	6300
selenium	--	44	--	>8400	
silver	--	>130	>100	490	100
thallium	-	>105	>105	>105	>105
zinc	-	72000	>200000	53000	>200000

[a] Dashes in EP column indicate chemicals not appropriate for approach (because of chemical characteristics) or chemicals for which water quality criteria are not available or easily estimated.

TABLE 7. (Continued)

[b] ">" in AET columns indicate that a definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations.

[c] Equilibrium Partitioning approach.

TABLE 8. AET SEDIMENT QUALITY VALUES (FINE-GRAINED SEDIMENT NORMALIZED)[a,b]
(ug/kg fines for organics; mg/kg fines for metals)

Chemical	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Low molecular weight PAH	16000	16000	>92000	29000
naphthalene	4300	4300	>9500	>9500
acenaphthylene	1200	>1200	>9600	>1200
acenaphthene	2300	890	3100	3100
fluorene	2300	1000	>9600	3900
phenanthrene	7100	5400	>47000	8800
anthracene	3400	3400	>19000	3400
High molecular weight PAH	42000	42000	>770000	82000
fluoranthene	7100	7100	>94000	10000
pyrene	9300	9300	>110000	9500
benzo(a)anthracene	4600	4600	>67000	8800
chrysene	5800	5800	>100000	11000
benzofluoranthenes	9990	9990	>120000	>24000
benzo(a)pyrene	4300	4300	>100000	7800
indeno(1,2,3-c,d)pyrene	1600	1600	>78000	>4800
dibenzo(a,h)anthracene	580	580	>17000	1800
benzo(g,h,i)perylene	1500	1500	>80000	>3700
Total PCBs	4300	1400	4800	230
Total chlorinated benzenes	930	510	>12000	1000
1,3-dichlorobenzene	>270	>270	>270	>270
1,4-dichlorobenzene	350	160	>5100	>880
1,2-dichlorobenzene	>480	62	130	130
1,2,4-trichlorobenzene	90	90	90	51
hexachlorobenzene (HCB)	230	290	290	110
Total phthalates	21000	21000	77000	18000
dimethyl phthalate	>420	>420	>420	>3900
diethyl phthalate	>130	>130	>1100	>130
di-n-butyl phthalate	18000	18000	>59000	18000
butyl benzyl phthalate	>580	>580	580	110
bis(2-ethylhexyl)phthalate	4000	3400	3400	3400
di-n-octyl phthalate	1100	1100	75000	
Pesticides				
p,p'-DDE	26	--	51	
p,p'-DDD	74	--	30	
p,p'-DDT	5.6	>8.2	>200	
aldrin	--	--	--	
chlordane	--	--	--	
dieldrin	--	--	--	
heptachlor	--	--	--	
gamma-HCH (lindane)	--	--	--	

TABLE 8. (Continued)

Chemical	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Organic acids				
phenol	>3800	>3800	>14000	>3800
2-methylphenol	140	140	>570	>570
4-methylphenol	1600	1600	4500	4500
2,4-dimethylphenol	>68	32	36	36
pentachlorophenol	>250	>250	>250	>250
Miscellaneous extractables				
hexachloroethane	--	--	--	--
hexachlorobutadiene	370	350	350	200
1-methylphenanthrene	960	960	1600	1600
2-methylnaphthalene	1600	1600	3500	3500
biphenyl	460	460	640	640
dibenzothiophene	430	430	780	780
dibenzofuran	960	960	3200	3200
benzyl alcohol	120	120	170	170
benzoic acid	>3400	>3400	>3400	>3400
N-nitrosodiphenylamine	500	500	500	500
Volatile organics				
trichloroethene	--	--	--	
tetrachloroethene	>1000	>1000	>1000	>1000
ethylbenzene	>180	>180	>180	180
total xylenes	>530	>530	>530	>530
Metals				
antimony	410	410	25	410
arsenic	6600	6600	1600	6600
beryllium	>19	>7.8	>6.7	>7.8
cadmium	170	170	25	170
chromium	>590	>590	>4300	>590
copper	6800	6800	970	6800
iron	>800000	>80000	500000	>800000
lead	7700	7700	970	7700
manganese	>7700	>7700	>18000	>7700
mercury	11	11	8	
nickel	>780	>780	>3300	>780
selenium	1.5	--	66	
silver	>22	>22	>65	--
thallium	2.6	2.6	2.6	2.6
zinc	16000	16000	4100	>1600

[a] Dashes in EP column indicate chemicals not appropriate for approach because of chemical characteristics or chemicals for which water quality criteria are not available or easily estimated.

TABLE 8. (Continued)

[b] ">" in AET columns indicate that a definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations.

DDT, butyl benzyl phthalate, tetrachloroethene) have similar values. Calculated EP values for other compounds differ by one to three orders of magnitude [the Quinlan et al. (1985) values are consistently lower]. These differences are attributable largely to the differences in toxicity data used in the reports. Toxicity values were often orders of magnitude lower in the Quinlan et al. (1985) report than in the U.S. EPA (1980) report used for the present project.

6.1.1.2 AET--Fifty-six samples from the compiled Puget Sound data set were used previously to generate toxicity AET (amphipod and oyster larvae bioassays) and benthic AET as part of the Commencement Bay Nearshore/ Tideflats Superfund Remedial Investigation (Tetra Tech 1985). In some cases, AET generated from the Puget Sound data set (Tables 6, 7, and 8) are higher than those generated from the reduced data set. (AET can only increase when the chemical/biological data set is expanded, because AET are established by the highest concentration associated with a station without biological impacts.)

Major increases in AET generated in this project compared with those determined in the Commencement Bay study were noted for three chemical groups: PCBs (amphipod and/or benthic AET increased, depending on normalization), HPAH (benthic AET increased), and total phthalates (benthic AET increased; the changes were driven by dioctyl phthalate). For example, the amphipod AET for PCBs increased from 420 ug/kg (dry weight) to 2,500 ug/kg. The benthic AET for HPAH increased from 17,000 ug/kg (dry weight) to >51,000 ug/kg. The benthic AET for total phthalates increased from 5,200 ug/kg (dry weight) to >70,000 ug/kg. The benthic AET for silver increased from >0.56 to 5.2 mg/kg (dry weight).

It is noteworthy that the benthic AET for LPAH, HPAH, and most of the 16 priority pollutant PAH were set by a single station (7WP-11 from the Metro IPPS study, Appendix Table A5). Concentrations of PAH in sediment from this west Point station were far above those of the other nonimpacted benthic stations in the Puget Sound data set. The effect of having one "anomalous" station establish AET values are discussed further in the uncertainty analysis for AET (Section 7.2.2.2; Classification Errors).

6.2 Sediment Quality Values Generated by the Screening Level Concentration Approach

SSLC values are graphed in Figures 10-12 for each of three chemicals or chemical groups for which the SLC approach was applied. To generate these values, the minimum number of stations at which a species must either be <80 percent depressed or present (depending upon the index used) was arbitrarily set at six. As shown in Table 5, Syllis heterochaeta was thereby eliminated from both analyses and Praxillella gracilis was eliminated from the analysis based on the 80 percent depression index. In most cases, the number of impacted stations based on the presence index exceeded the number based on the 80 percent depression index. When <10 stations were available for a species, a 90th percentile concentration could not be used as the SSLC. In such cases, the second highest contaminant concentration was used as the SSLC, even though it represented <90 percent of the stations.

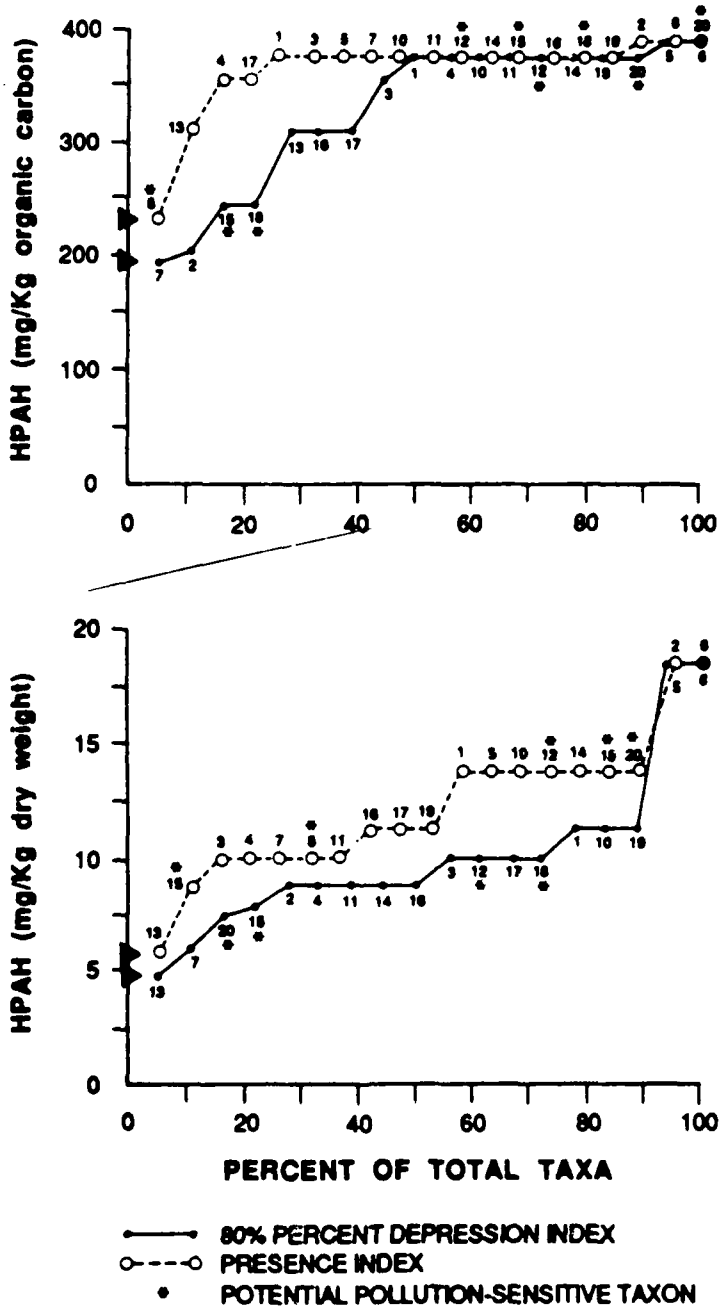


Figure 10. SSLC values for HPAH. Numbers near points are taxon codes (Table 5). Arrows on ordinates indicate SLC values.

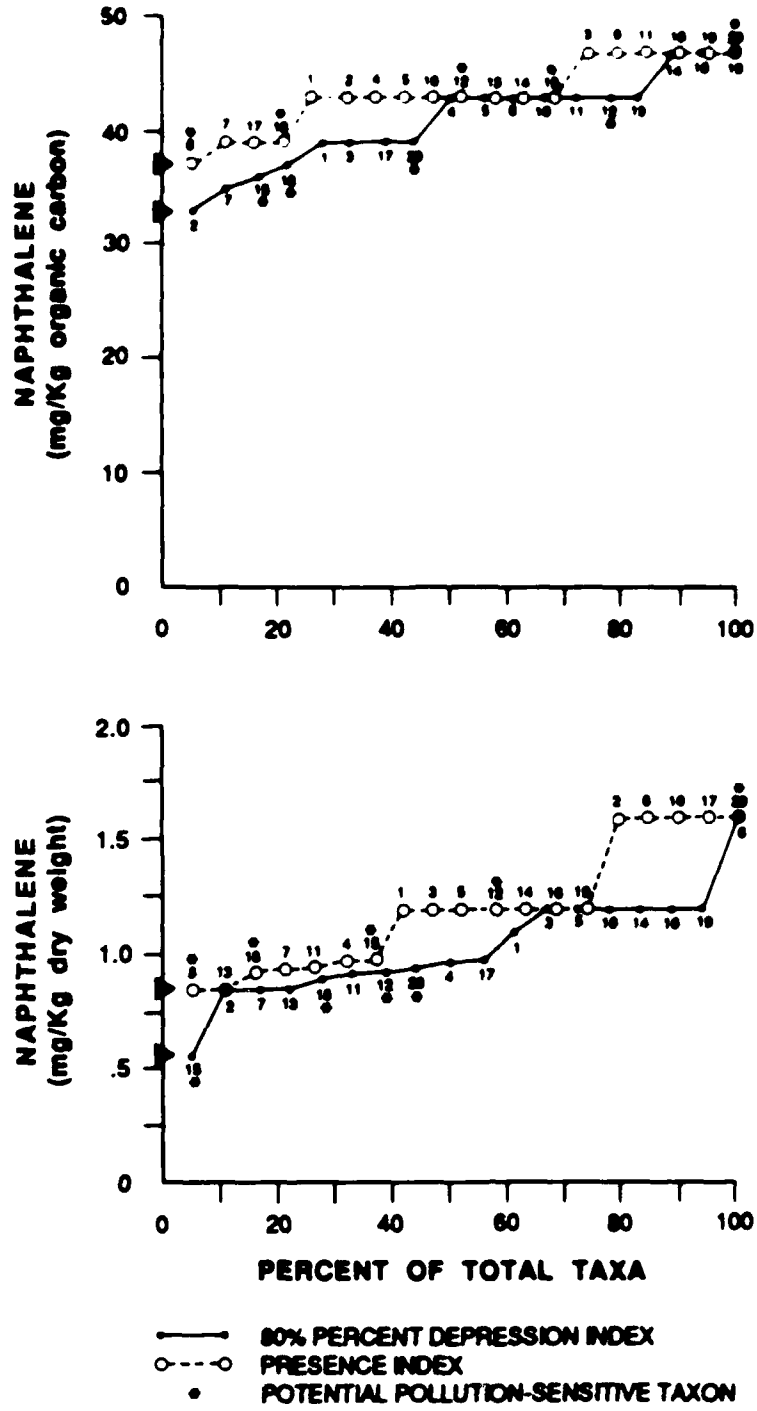


Figure 11. SSLC values for naphthalene. Numbers near points are taxon codes (Table 5). Arrows on ordinate indicate SLC values.

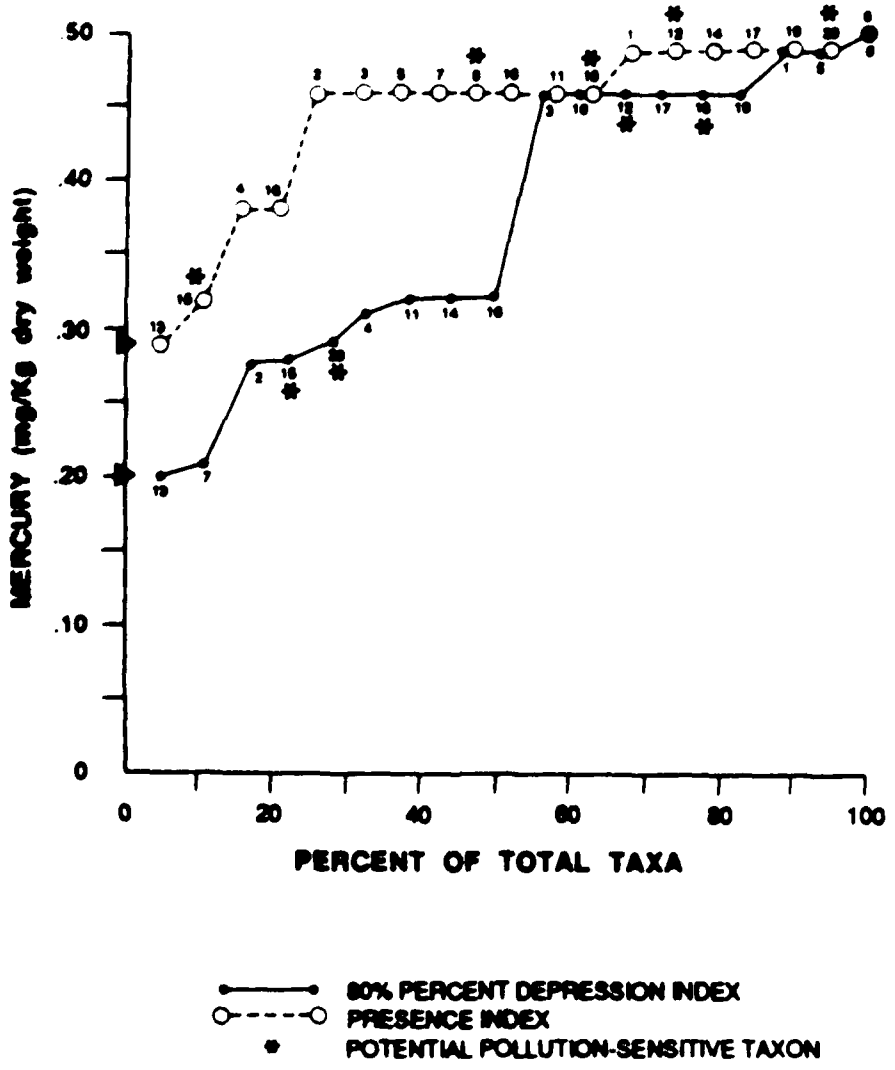


Figure 12. SSLC values for mercury. Numbers near points are taxon codes (Table 5). Arrows on ordinate indicate SLC values.

SLC values based on Figures 10-12 are presented in Table 9. Because 18 and 19 species were used for the 80 percent depression and presence analyses, respectively, the species having the lowest SSLC for each compound represented approximately 5 percent of the total number of species and therefore set the SLC. Each of these species is identified in Table 9.

6.2.1 Patterns Observed Using the Limited Application--

The SSLC index based on species presence appeared to be less sensitive than the index based on an 80 percent depression from reference abundances. Most SSLC values based on presence exceeded those based on an 80 percent depression for all compound/normalization combinations. In addition, SLC values based on presence exceeded those based on an 80 percent depression by 12-56 percent for all compound/normalization combinations (Table 9). One major effect of using an 80 percent depression as the index was a substantial reduction in the number of stations used for many SSLC analyses relative to the number of stations available when presence was used. However, this potential limitation did not appear to alter the relative sensitivities of the two indices.

The SSLC plots were characterized by an initially increasing line followed by a series of plateaus at higher chemical concentrations, and rarely approached linearity. Most wide plateaus (i.e., comprising many stations) were found at the highest observed SSLC values, suggesting that those concentrations act as a common limitation, or "ceiling," for many of the less sensitive taxa. Wide plateaus were not found for the lowest observed SSLC values, suggesting that the most sensitive taxa exhibited a graded response to increasing chemical concentrations.

The relative magnitude of the SSLC for several taxa sometimes varied substantially depending upon which index (i.e., presence or 80 percent depression) was used. The most common pattern in the SSLC plots was for some of the lowest SSLC values calculated using the 80 percent depression index to increase when recalculated using the presence index. The most sensitive taxa in this respect were Eteone longa (Code=2) and Amphiuridae (Code=20). For most compound/normalization combinations, SSLC values for these two taxa rose from among the lowest observed when based on the 80 percent depression index, to among the highest observed when based on the presence index. SSLC values for Notomastus tenuis (Code=7) also showed this pattern, but to a lesser degree. In contrast, the lowest SSLC values based on the presence index rarely increased substantially when recalculated using the 80 percent depression index. These patterns suggest that SSLC values based on species presence may be less stable when evaluating the most sensitive taxa than are SSLC values based on an 80 percent depression of a species.

Taxa thought to be pollution sensitive did not consistently exhibit the lowest SSLC values. SSLC values of the five species identified as potentially pollution sensitive in Table 5 ranged from among the lowest to among the highest observed values for most SSLC plots. Sensitive taxa sometimes having the lowest SSLC, and thereby setting the SLC, included

TABLE 9. SLC VALUES FOR TARGET COMPOUNDS

Compound	SLC[a,b] mg/kg Organic Carbon 80 Percent	mg/kg Organic Carbon Presence	mg/kg Dry Weight 80 Percent	mg/kg Dry Weight Presence
HPAH	200 (7)	230 (8)	4.9 (13)	5.8 (13)
Naphthalene	33 (2)	37 (8)	0.55 (15)	0.86 (13)
Mercury			0.20 (13)	0.29 (13)

[a] The code for the taxon that set each SLC is given in parentheses below each concentration (see Table 5 for a description of each code).

[b] For each method of normalization, organic carbon and dry weight, SLC are given for analyses using indices based on 1) an 80 percent depression from reference abundance and 2) taxon presence.

Praxillella gracilis (three cases) and Nucula tenuis (one case). Both of these species were identified as potentially sensitive to toxic chemicals in a pattern recognition analysis of Commencement Bay chemical and biological data (Appendix D). The species that set the greatest number of SLC values (five) was Compsomyax subdiaphana. This latter species was not identified in the pattern recognition study (Appendix D). Additional comparisons are presented by Battelle (1986a).

6.2.2 Comparison with Other Sediment Quality Value Approaches--

For the three compounds for which SLC values were established, sediment quality values based on the SLC approach were lower than the corresponding AET, which were lower than the corresponding EP values. The consistently low sediment quality values generated for the three chemicals by the SLC approach probably resulted largely from their reliance upon sensitive taxa (generally species level). By contrast, the benthic indicator used in this application of the AET approach is based on higher level taxa (i.e., phylum and class level), without regard to pollution sensitivity. (The AET approach could be applied to species-level benthic data). The differences between sediment quality values generated by the SLC and AET approaches may relate to the data used to set these values: the 29 stations used to establish SLC values had narrower ranges of concentration for the chemicals examined than did the larger set of Puget Sound stations used to establish AET. Determination of SLC values based on a larger data set is recommended. In addition, development of AET for apparently sensitive taxa is recommended. Such AET may enable more sensitive indication of chemical impacts on benthic infaunal communities than AET based on major taxa.

6.3 Comparison of Sediment Quality Values to Sediment Concentrations in Puget Sound

The detection frequency and concentration percentiles (e.g., 50th, 75th, and 90th percentiles) of individual chemicals in the Puget Sound database assembled for this study are shown in Table 10. This range of chemical concentrations in environmental samples (mostly from urban embayments) provides a useful perspective for the sediment quality values generated in this study (e.g., Tables 6 and 9). The following comparison does not necessarily indicate the percentage of all Puget Sound sediment that may exhibit biological effects because biological testing is necessary to confirm such predicted effects, and the existing database is skewed toward more highly contaminated sediments from urban embayments of Puget Sound.

The SLC values generated in this study fell between the 50th and 90th percentile concentrations of the corresponding chemicals in sediment samples contained in the database. It should be noted that these are preliminary SLC values developed from a relatively small data set. In general, AET values were at or above the 90th percentile concentration for most chemicals. All but 7 of the 40 EP sediment quality values (dry weight, 1 percent organic carbon content assumed) exceeded the concentration of the corresponding chemical in 100 percent of the sediment samples in the Puget Sound database.

TABLE 10. DETECTION FREQUENCY AND PERCENTILE VALUES FOR CHEMICAL CONCENTRATIONS USED IN PUGET SOUND DATABASE
(ug/kg dry weight for organics; mg/kg dry weight for metals)

Chemical	Detection Frequency[a]	Concentration Percentiles[b] 50%	75%	90%	Maximum Detected Concentration[c]	Fourmile Rock Interim Sediment Criteria[d]
Low molecular weight PAH	161/212	610	1450	3200	55000	855
naphthalene	150/212	100	340	920	5900	---
acenaphthylene	126/212	40	100	280	3300	---
acenaphthene	96/181	40	100	200	4000	---
fluorene	144/212	60	140	320	4800	---
phenanthrene	185/212	220	540	1200	34000	---
anthracene	163/212	83	200	450	10000	---
High molecular weight PAH	165/181	2800	7000	14000	260000	14000
fluoranthene	191/212	420	880	1900	71000	---
pyrene	190/212	520	1000	2000	63000	---
benzo(a)anthracene	171/212	200	530	920	15000	---
chrysene	175/212	260	720	1600	35000	---
benzofluoranthenes	143/181	410	1600	3300	29000	---
benzo(a)pyrene	160/212	200	640	1400	23000	---
indeno(1,2,3-c,d)pyrene	94/181	140	390	600	9100	---
dibenzo(a,h)anthracene	76/212	34	170	490	4000	---
benzo(g,h,i)perylene	102/181	140	400	800	11000	---
Total PCBs	168/200	91	140	290	5400	760
Total chlorinated benzenes	52/166	49	600	1300	17000	---
1,3-dichlorobenzene	20/175	U 5	U 40	U 100	170	---
1,4-dichlorobenzene	49/175	U 20	U 40	U 100	7700	---
1,2-dichlorobenzene	20/175	U 5	U 40	U 100	9000	---
1,2,4-trichlorobenzene	8/166	U 10	U 40	U 170	260	---
hexachlorobenzene (HCB)	27/206	U 20	U 20	500	730	---
Total phthalates	130/166	660	1400	3600	70000	---
dimethyl phthalate	46/175	U 40	U 50	100	350	---
diethyl phthalate	62/175	U 10	U 40	100	320	---
di-n-butyl phthalate	99/175	U 80	210	850	5100	---
butyl benzyl phthalate	45/166	U 25	U 80	180	1800	---
bis(2-ethylhexyl)phthalate	46/175	U 25	210	750	3100	---
di-n-octyl phthalate	67/166	U 40	260	1500	69000	---
Pesticides						
p,p'-DDE	72/175	U 1	3	8.9	47	---
p,p'-DDD	47/150	U 1	U 1	12	175	---
p,p'-DDT	28/206	U 1	U 25	U 50	77	9[e]
aldrin	---	---	---	---	---	---
chlordane	---	---	---	---	---	---
dieldrin	---	---	---	---	---	---
heptachlor	---	---	---	---	---	---
gamma-HCH (lindane)	---	---	---	---	---	---

TABLE 10. (Continued)

	Detection Frequency[a]	Concentration Percentiles 50%	75%	90%	Maximum Detected Concentration[c]	Fourmile Rock Interim Sediment Criteria
Organic acids						
phenol	63/165	U 40	U 100	280	1700	---
2-methylphenol	26/52	U 10	22	45	72	---
4-methylphenol	47/52	150	290	650	96000	---
2,4-dimethylphenol	9/165	U 10	U 50	U 200	50	---
pentachlorophenol	9/165	U 200	U 200	U 1200	140	---
Miscellaneous extractables						
hexachloroethane	2/166	U 50	U 50	U 200	2800	---
hexachlorobutadiene	31/175	U 25	U 130	320	730	---
1-methylphenanthrene	72/96	29	78	180	1300	---
1-methylnapthalene	86/96	70	190	390	1200	---
biphenyl	69/96	11	56	100	1100	---
dibenzothiophene	37/56	33	110	190	1100	---
dibenzofuran	47/52	120	200	350	2000	---
benzyl alcohol	30/52	14	28	53	140	---
benzoic acid	12/52	U 25	57	370	690	---
N-nitrosodiphenylamine	29/166	U 5	U 500	U 2000	610	---
Volatile organics						
trichloroethene	0/69	U 10	U 20	U 20	U 20	---
tetrachloroethene	13/80	U 10	U 20	U 20	210	---
ethylbenzene	11/80	U 10	U 20	U 20	50	---
total xylenes	7/15	U 20	100	140	160	---
Metals (mg/kg dry weight)						
antimony	115/167	0.34	0.94	1.56	420	---
arsenic	211/211	10	17	38	9700	19
beryllium	156/156	0.29	0.39	3.53	5.5	---
cadmium	193/212	0.48	1.78	3.07	180	0.9
chromium	167/167	35	53	66	129	---
copper	212/212	49	83	167	11400	115
iron	108/108	19000	27000	32000	53000	---
lead	212/212	39	92	190	6250	158
manganese	108/108	200	400	520	1000	---
mercury	204/212	0.20	0.46	0.98	52	1.4
nickel	167/167	27	41	50	118	---
selenium	62/156	U 0.40	1.0	1.0	63	---
silver	153/167	0.30	0.74	2.8	5.4	---
thallium	37/156	U 0.1	U 0.1	0.2	3.2	---
zinc	212/212	91	140	292	3320	450
Conventional variables						
total volatile solids	160/160	6.15%	9.30%	12.9 %	44.7%	10%
total organic carbon[f]	212/212	1.31%	2.30%	4.50%	16.0%	10%
fine-grained material	212/212	61.0 %	81.0 %	90.0 %	98.0%	---

TABLE 10. (Continued)

[a] Detection frequency is the number of samples in which the chemical was detected compared with the total number of samples for which data were reported (only samples with associated biological effects data are included in the total number).

[b] The indicated percentage of samples in the data set had concentrations that fell below the concentrations listed. The percentiles were determined using all data reported (i.e., detection limits were included).

[c] Maximum detected concentration for the number of samples shown in the detection frequency column.

[d] In-water disposal at the Fourmile Rock site is not allowed if any pollutant exceeds listed concentration.

[e] Summation of p,p'-DDD, p,p'-DDE, and p,p'-DDT.

[f] Organic carbon content for the Alki Extension Study samples was estimated from total volatile solids data using a regression equation (Appendix A - Table 5).

The same trend applied to EP values normalized to organic carbon (Table 7) when compared to organic carbon normalized Puget Sound data (e.g., Appendix Table B1). All but 8 of the 40 EP values normalized to organic carbon exceeded the concentration of the corresponding chemical (normalized to organic carbon) in 100 percent of the sediment samples in the database.

Fourmile Rock interim sediment criteria for the disposal of dredged material have been used as guidelines for sediment management by some agencies. "Permissible" sediment concentrations of the 10 U.S. EPA priority pollutants or pollutant groups used as part of these guidelines are also summarized in Table 10 for comparison with the sediment quality values derived in this report. With some exceptions, the Fourmile Rock dry-weight criteria listed in Table 10 are 2-36 times lower than the dry-weight normalized EP, AET, and SLC sediment quality values listed in Tables 6 and 9. Notable exceptions include mercury (the oyster larvae, Microtox, and benthic AET, and the mercury SLC concentration are exceeded by the Fourmile Rock criteria), PCBs (the EP value and Microtox AET for PCBs are exceeded), high molecular weight PAH (the SLC concentration and Microtox AET for HPAH are exceeded), and zinc (only the benthic AET is exceeded).

7.0 UNCERTAINTY ANALYSIS: TEST OF GENERATED SEDIMENT QUALITY VALUES

The goal of testing sediment quality value approaches in this project is to assess their potential use for various aspects of sediment management. The uncertainty analysis comprised two components: **accuracy** (i.e., the ability of an approach to predict biological effects), and **precision** (i.e., the expected variability of sediment quality values given the particular constraints in the design and use of an approach).

Two aspects of accuracy were considered in this analysis (and are defined in detail in Section 7.1). The first aspect, **sensitivity**, represents the ability of sediment quality values to correctly identify all stations in a data set that actually have biological impacts. The second aspect of accuracy, **efficiency**, is independent of sensitivity and represents the ability of sediment quality values to identify only stations that actually have biological impacts. The results of these accuracy tests are presented in four sections:

1. The overall sensitivity and efficiency of the EP and AET approaches when the accuracy test included all possible appropriate chemicals for each approach (Section 7.1.1)

2. A further test of the sensitivity and efficiency of AET values that were generated with one database and tested with an independent database (Section 7.1.2)

3. A comparison of the efficiency (but not sensitivity) of individual EP and AET sediment quality values for selected chemicals that were common to both approaches (Section 7.1.3; the sensitivity of a sediment quality value for only one chemical was not considered a good measure of the predictive success of an approach, because no single chemical is expected to account for all biologically impacted stations in the database)

4. The efficiency (but not sensitivity) of the SLC sediment quality values (Section 7.1.4).

The SLC accuracy test was conducted independently of the EP and AET evaluations because SLC values were generated for only 3 chemicals (selected from over 60 chemicals that were considered appropriate), and were based on a relatively small data subset. A preliminary, less thorough uncertainty evaluation was thus considered appropriate for the SLC approach. Generation of SLC sediment quality values for a large number of chemicals and for a large database would have required a level of effort beyond the scope of the present project.

The accuracy evaluation was considered the best way to evaluate the overall ability of each approach to predict biological impacts. The accuracy analysis could not quantify various elements of uncertainty in each approach, but instead provided an estimate of how the combined uncertainties of an approach would affect its ultimate predictive success. This was considered particularly useful because numerous factors that affected the uncertainty of the AET and EP approaches were not quantifiable, and some may partially offset the effect of others.

The precision evaluation consists of two sections:

1. Estimated Minimum Confidence Limits for EP Sediment Quality Values (Section 7.2.1)

2. Estimated Confidence Limits for AET Sediment Quality Values (Section 7.2.2).

The EP approach, which is theoretically based, requires a number of estimations and assumptions to derive a sediment quality value (e.g., estimation of K_{OC} values from K_{OW} values, assumption of thermodynamic equilibrium; see Section 2.3) . Precision could only be estimated for the EP values for chemicals with established chronic water quality criteria. The uncertainty associated with estimated water quality criteria was not possible to quantify.

Quantifiable and unquantifiable elements of uncertainty are found in all of the sediment quality value approaches (e.g., see discussion of AET approach in Section 2.7, and discussion of SLC approach in Section 2.6). For AET values, confidence limits reflect a consideration of the "weight of evidence" supporting the empirical approach. A method for determining precision of SLC values is discussed by Battelle (1986a).

7.1 Accuracy of Sediment Quality Values (Sensitivity and Efficiency)

Any use of a sediment quality value approach (e.g., to screen areas for further testing and evaluation, to identify problem sediments in a study area) requires that the approach be an accurate predictor of detrimental biological effects. "Accuracy," in this sense, has two aspects:

- Sensitivity--the approach should be capable of identifying a high percentage of sites that exhibit adverse biological effects potentially associated with chemical contamination

- Efficiency--the approach should not identify a large number of stations that do not exhibit any adverse biological effects potentially related to chemical pollution.

The concepts of sensitivity and efficiency are presented in Figure 13.

Sensitivity and efficiency are distinct and can be mutually exclusive. For example, a sediment quality value approach that sets values for a wide range of chemicals near their analytical detection limits will probably be sensitive but inefficient. That is, it will indicate all sediments with severe biological effects but will also identify many biologically unaffected sediments with only slightly elevated chemical concentrations. Thus, the approach would have limited effectiveness at identifying sites of potential concern from a large sample pool.

Conversely, a sediment quality value approach that sets values at the high range of environmental concentrations may be efficient but insensitive. That is, a high percentage of the predicted problem stations identified by the approach may indeed be biologically impacted, but the approach may fail to indicate biologically impacted stations with moderate to high chemical concentrations. Such an approach could be useful for indicating grossly contaminated sediments but would not be adequate for most sediment management purposes.

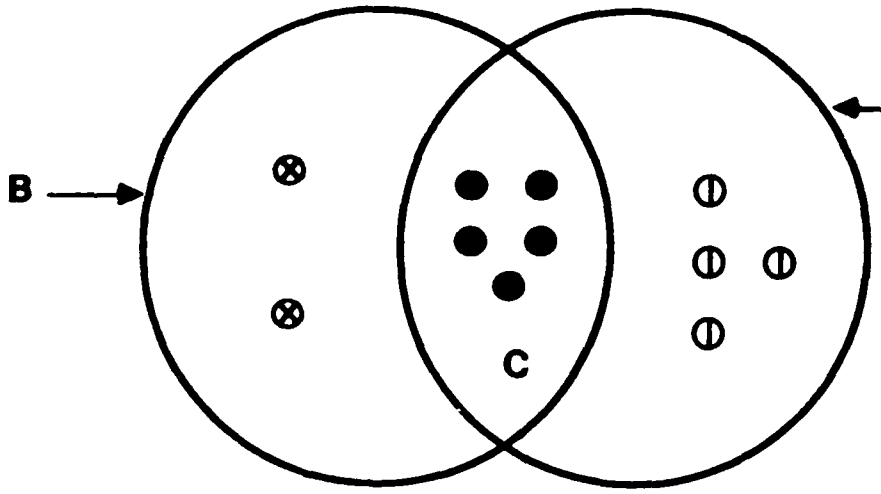
With the matched chemical/biological data compiled for this project, it was possible to quantitatively evaluate the sensitivity and efficiency of the different sediment quality approaches.

7.1.1 Sensitivity and Efficiency of the EP and AET Approaches--

The primary objective of this test was to determine the sensitivity and efficiency of each approach for each biological indicator. The EP and AET approaches were tested using the same procedure and the same sets of chemical/biological data. The test was carried out in three steps, as described below:

1. **The chemical database (Appendix A) was subdivided into groups of stations that were tested for the same biological effects indicators.**

For example, all chemistry stations with associated amphipod bioassay data were grouped together. Thus, four station groupings were established according to available station-specific biological data (amphipod bioassay, oyster larvae bioassay, benthic infaunal, Microtox bioassay). Only Commencement Bay stations were included in all four groups. The oyster larvae and Microtox groups consisted solely of Commencement Bay stations. The numbers of stations included in each group were: amphipod (150), benthic (94), oyster larvae (56),



	BIOLOGICALLY IMPACTED	PREDICTED TO BE IMPACTED
○	NO	NO
◑	NO	YES
⊗	YES	NO
●	YES	YES

A B C

FOR A GIVEN DATA SET WITH PAIRED CHEMICAL/BIOLOGICAL DATA:

A ALL STATIONS PREDICTED BY APPROACH TO BE IMPACTED (i.e., PREDICTED PROBLEM STATIONS).

B ALL STATIONS KNOWN TO BE IMPACTED BASED ON A GIVEN BIOLOGICAL INDICATOR.

C ALL STATIONS SUCCESSFULLY PREDICTED TO BE IMPACTED.

SENSITIVITY = C/B x 100 = 5/7 x 100 = 71%

EFFICIENCY = C/A x 100 = 5/9 x 100 = 56%

Figure 13. Sensitivity and efficiency as measures of accuracy.

and Microtox (50) (Table 2). Specific stations that compose each group can be determined from Appendix A.

2. **The stations of each group were classified as "impacted" or "nonimpacted" based on the appropriate statistical criteria discussed in a previous section** (see "Treatment of Biological Data for AET Application" in Section 5.3.4). **Biologically impacted stations were evaluated further for classification as "severely impacted"** (i.e., having an especially high magnitude of biological effects).

Severe amphipod and oyster impacts were designated as values above 50 percent (absolute) mortality and abnormality, respectively. These severe toxicity values are somewhat arbitrary, but reflect guidelines presented in Tetra Tech (1985) and correspond with "severe toxicity" guidelines proposed by the U.S. COE for the management of dredged material (U.S. COE 1985). The severe impact guideline used for benthic infaunal data was set arbitrarily as the occurrence of benthic depressions in more than one major taxonomic group (i.e., two or more depressions among Mollusca, Crustacea, and Polychaeta). This guideline was chosen based on the consideration that significant depressions in more than one taxonomic group were indicative of impacts across a fairly broad range of organisms and were unlikely to be driven solely by highly sensitive species. A severe impact criterion was not developed for Microtox data.

The results of classifying impacted and severely impacted stations are presented in Tables 11 and 12. The stations with multiple indicator data [i.e., Commencement Bay stations (Table 11)] are presented separately from stations with only single indicators (Table 12). The respective number of impacted and severely impacted stations in each group were: amphipod (43 and 13), benthic (28 and 13), oyster larvae (16 and 4), and Microtox (29; severe impacts not designated).

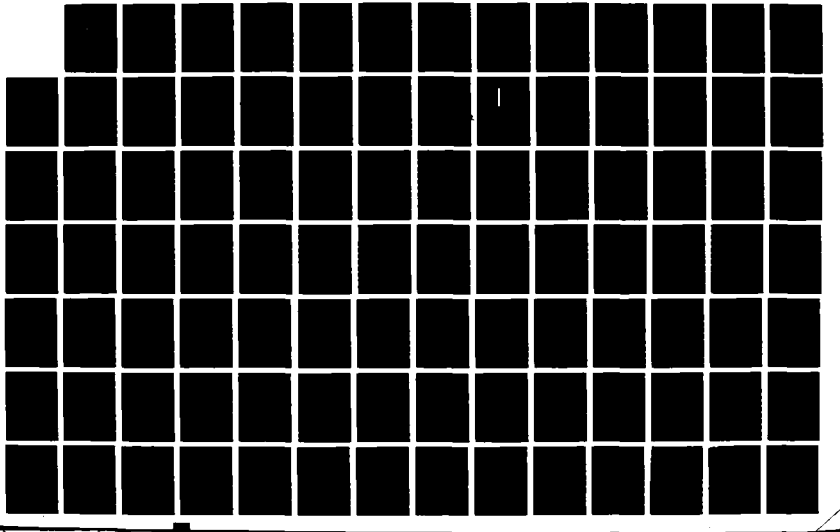
3. For each approach, sediment quality values for all applicable chemicals (40 for the EP approach and 64 for the AET approach) were compared with the corresponding chemical data for each station. **When one or more chemicals exceeded the appropriate sediment quality values at a given station, then biological impacts were considered to be predicted at that station.**

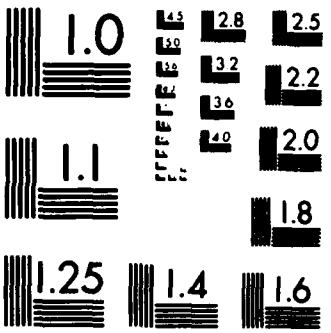
Station-by-station listings of all chemicals that exceeded their sediment quality values for the EP (organic carbon-normalized), AET (dry weight), AET (organic carbon-normalized), and AET (fines-normalized) approaches are presented in Appendix Tables B1 through B4. Note that besides Commencement Bay stations, only some kinds of biological indicator data were available at each station.

Results of the accuracy tests (i.e., quantitative measures of predictive power and efficiency; see Figure 13) of each approach are summarized in Table 13 for the different sets of biological indicator stations. This table can be constructed from the information in Appendix B and the following three formulas:

AD-A184 867 DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND 2/6
VOLUME 1(U) TETRA TECH INC BELLEVUE WA SEP 86
TC3090-02-VOL-1 DACW67-85-D-0029

UNCLASSIFIED F/G 24/3 NL





MICROCOPY RESOLUTION TEST CHART
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TABLE 11. BIOLOGICALLY IMPACTED STATIONS BASED ON MULTIPLE BIOLOGICAL INDICATORS[a]

Station	Amphipod	Oyster	Benthic	Microtox[b]
1 BL-13				X
1 BL-25	X			
1 BL-31				X
1 CI-11	*X	*X	X	X
1 CI-13		X	*X	X
1 CI-16		X	*X	X
1 CI-17				X
1 CI-20	X	X		
1 HY-12		X		X
1 HY-14			X	X
1 HY-17		X	*X	X
1 HY-22	X	X	*X	X
1 HY-23	X	X	*X	X
1 HY-24				X
1 HY-32			*X	
1 HY-37			X	X
1 HY-42	X			X
1 HY-43				X
1 HY-47		X	X	X
1 HY-50				X
1 MI-11	X			
1 MI-13				X
1 MI-15	X			X
1 RS-13	X	X		
1 RS-18	*X	*X	*X	X
1 RS-19	*X	X	X	X
1 RS-20			X	X
1 RS-24	X			
1 SI-11			X	X
1 SI-12	X		X	X
1 SI-15	X			
1 SP-11				X
1 SP-12		X		X
1 SP-14	*X	*X	*X	X
1 SP-15	*X	*X	*X	X
1 SP-16	X	X	X	X
2 B 15	X			

[a] X indicates statistically significant biological impacts.

[b] Severe impacts not estimated for Microtox data.

* Indicates severe biological impacts.

TABLE 12. BIOLOGICALLY IMPACTED STATIONS BASED ON SINGLE BIOLOGICAL INDICATORS

Amphipod Bioassay Station	Benthic Infauna Station
3 BH-05	5 AP-04
3 BH-23*	**6 EB-33***
3 CS-15	6 EB-35
3 CS-17	6 EB-36
3 DB-15	6 WP-16
3 EV-01*	**7 EB-33***
3 EV-02	7 EB-35
3 EV-03	**7 EB-36***
3 EV-04*	**7 EB-38***
3 EV-05*	7 WP-03
3 EV-06	
3 SC-08	
3 SC-14	
3 SC-20	
3 SM-01	
3 SM-03	
3 SM-20	
4 DR-07	
4 DR-08*	
9 DR-10*	
9 DR-11	
9 DR-16	
9 DR-25	
9 DR-26*	
9 DR-27*	

* Severely impacted stations.

TABLE 13. EVALUATION OF ACCURACY OF EP AND AET APPRAOCHES

Approach	Sensitivity (%)[a] (Impacted Stations)	Sensitivity (%)[a] (Severely Impacted Stations)	Efficiency (%)[a]
Equilibrium Partitioning			
Amphipod	30 (13/43)[b]	31 (4/13)	34 (13/38)
Oyster	13 (2/16)	0 (0/4)	33 (2/6)
Benthic	43 (12/28)	46 (6/13)	39 (12/31)
Microtox	14 (4/29)	---[c]	100 (4/4)
AET - DW[d]			
Amphipod	54 (23/43)	92 (12/13)	100[e] (23/23)
Oyster	94 (15/16)	100 (4/4)	100 (15/15)
Benthic	82 (23/28)	92 (12/13)	100 (23/23)
Microtox	90 (26/29)	---	100 (25/25)
AET - OC[d]			
Amphipod	40 (17/43)	62 (8/13)	100 (17/17)
Oyster	63 (10/16)	100 (4/4)	100 (10/10)
Benthic	68 (19/28)	69 (9/13)	100 (19/19)
Microtox	59 (17/29)	---	100 (17/17)
AET - Fines[d]			
Amphipod	37 (16/43)	69 (9/13)	100 (16/16)
Oyster	88 (14/16)	100 (4/4)	100 (14/14)
Benthic	57 (16/28)	62 (8/13)	100 (16/16)
Microtox	55 (16/29)	---	100 (16/16)
AET (DW, OC or Fines)[f]			
Amphipod	58 (25/43)	92 (12/13)	100 (25/25)
Oyster	100 (16/16)	100 (4/4)	100 (16/16)
Benthic	82 (23/28)	92 (12/13)	100 (23/23)
Microtox	93 (27/29)	---	100 (27/27)

[a] Terms defined in text.

[b] Fraction from which percent was calculated.

[c] Severe impacts not determined for Microtox data.

[d] DW = normalized to dry weight; OC = normalized to organic carbon; fines = normalized to percent fine-grained material.

[e] By definition; the approach is designed such that all sediments with concentrations exceeding their AET are biologically impacted.

[f] Stations identified by any of the three normalized AET.

1. $$\text{Sensitivity (impacted stations)} = \frac{\text{correctly predicted stations with impacts}}{\text{all stations with impacts}} \times 100$$

2. $$\text{Sensitivity (severely impacted stations)} = \frac{\text{correctly predicted stations with severe impacts}}{\text{all stations with severe impacts}} \times 100$$

3. $$\text{Efficiency} = \frac{\text{correctly predicted stations with impacts}}{\text{all stations predicted to be impacted}} \times 100$$

Depending on the biological indicator being tested (Table 13), and using these formulas, the EP approach correctly predicted from 13 to 43 percent of the stations with statistically significant biological effects. The EP approach also correctly predicted from 0 to 46 percent of the severely impacted stations. From 33 to 100 percent of all stations predicted by the EP approach to be impacted had observed biological effects. Although the EP approach may be sensitive for untested indicators of biological effects at the apparently unimpacted stations, it did not correctly predict a majority of the impacted or severely impacted stations identified by any of the available biological indicators. Only EP values normalized to organic carbon were tested for accuracy.

The accuracy of the AET approach (dry weight normalization) in correctly predicting stations with observed biological effects ranged from 54 to 94 percent, depending on the biological indicator being tested (Table 13). The approach also correctly predicted from 92 to 100 percent of the severely impacted stations when chemical concentrations were normalized to dry weight. Alternative methods of normalizing AET values resulted in lower sensitivity (Table 13). By definition, 100 percent of the stations predicted by the AET approach to be impacted had observed biological effects. This result was a direct consequence of generating and testing AET with the same database (because the AET is set at the level above which biological effects always occur in the data set used to generate AET). A more realistic assessment of AET efficiency is given in Section 7.1.2, based on AET generated and tested with independent databases.

In contrast to this predetermined result for efficiency, there is nothing in the design of the AET approach that, a priori, ensures high sensitivity (i.e., identification of a high percentage of impacted stations) when generated and subsequently tested with the same database (as in Table 13). Application of the AET approach to develop sediment quality values for a chemical does not ensure that an AET will even be set for a chemical. For example, chemicals that do not produce biological effects or covary with another chemical that produces biological effects may occur in completely overlapping concentration ranges in nonimpacted and biologically impacted sediments, or even in higher concentration in the group of nonimpacted stations. If only such chemicals were used to develop AET, the approach would likely have poor sensitivity regardless of the database used for testing. The sensitivity test was only conducted with chemicals with estab-

lished AET (i.e., the concentration of the chemical was higher in sediment from ≥1 station with statistically significant biological effects than in sediment from any of the nonimpacted stations).

In addition, the number of stations that are predicted to be impacted using any one AET value was typically only a small percentage of all impacted stations. This result was interpreted to mean that biological effects in Puget Sound probably result from a number of chemicals derived from several different sources. However, the setting of AET values for several chemicals could result in the same small subset of impacted stations being predicted to be impacted by each chemical. Even if the same database was used to generate and test these AET, the result would be poor sensitivity. As a further check on the sensitivity of the AET approach, AET generated and tested with independent databases was also performed (see Section 7.1.2).

Several trends in the accuracy of AET are apparent from Table 13:

- The sensitivity of AET for identifying severely impacted stations is comparable to or greater than their sensitivity for identifying impacted stations overall. This trend applies to AET normalized to dry weight, organic carbon, and percent fine-grained sediments and to all four biological indicators assessed.

- The ability of the AET approach to indicate stations with significant amphipod toxicity is less than its ability to indicate stations with significant oyster larvae abnormalities, Microtox bioassay effects, or benthic infaunal depressions. This trend is consistent whether AET are normalized to dry weight, organic carbon, or percent fine-grained sediment

- Dry-weight AET are consistently more sensitive than those normalized to organic carbon or percent fine-grained sediment (this applies to impacted stations and severely impacted stations). In fact, the latter two AET identified very few impacted stations that were not already identified by the dry-weight AET alone [compare "AET-DW" and "AET (DW, OC, or fines)" in Table 13].

The relative sensitivities of dry-weight and organic carbon normalized AET were further tested. The overall sensitivity of dry-weight AET (Table 13) was compared to the sensitivity of AET when nonpolar organic compounds were normalized to organic carbon content and metals and polar organic compounds were normalized to dry weight sediment. Based on current theories of organic carbon normalization, the sensitivity of AET would be expected to improve if nonpolar organic compounds were normalized to organic carbon content. However, the sensitivity of AET when nonpolar organic compounds were normalized to organic carbon was lower than when the same compounds were normalized to sediment dry weight, regardless of the biological indicator. Sensitivity decreased from 54 to 44 percent for amphipod bioassay stations, from 94 to 88 percent for oyster larvae bioassay stations, from 82 to 75 percent for benthic infaunal stations, and from 90 to 76 percent for Microtox

bioassay stations. This analysis can be carried out with the information in Appendix Tables B-2 and B-3 and using the formulas presented in this section.

Although these results do not provide a mechanistic explanation for the predictive success of dry weight normalization relative to organic carbon normalization of AET, they suggest that the mass loading of contaminants in sediments may be the predominant factor influencing toxicity to benthic organisms (although organic carbon interactions may be a secondary factor). For additional discussion of this issue, see Section 8.6 and Appendix H.

The EP and AET approaches were tested further by examining the list of stations that were biologically impacted (according to available indicators) but were not correctly identified as impacted by one or both of the approaches. These stations are listed by biological effects indicator in Table 14. The stations listed for the AET approach were not correctly predicted as by any of the three sets of AET values (normalized to dry weight, organic carbon, and percent fine-grained sediment). If only dry-weight AET had been used in the evaluation, this list would be essentially the same.

The largest percentage of biologically impacted stations that were not correctly predicted by either approach is in the amphipod bioassay data group. Fifteen of the 43 impacted amphipod bioassay stations were not predicted by either approach. Because natural variables (e.g., fine sediment texture) can influence amphipod mortality even in relatively uncontaminated sediments (Ott 1985; Tetra Tech 1985), it is possible that the toxicity observed at these stations was not related to chemical contamination. Of the 18 impacted stations not predicted by the AET approach, 28 percent had over 90 percent fine-grained material, 22 percent had between 85 and 90 percent fine-grained material, and 27 percent had between 75 and 85 percent fine-grained material. Overall, 77 percent of the stations displaying significant amphipod toxicity had fine-grained sediment content of over 75 percent.

These results support, but do not prove, the contention that fine-grained material may have been responsible for impacts observed at many of the amphipod data stations not identified by the AET approach. Alternatively, the toxicity may be attributable to some unidentified chemical with a distribution that does not co-vary with the chemicals studied. Other factors (e.g., viruses) could contribute to unexplained amphipod toxicity. However, five of these 18 stations are from areas that are not highly industrialized or populated (e.g., Dabob Bay, Case Inlet, Samish Bay) and have relatively low concentrations of U.S. EPA priority pollutants.

These characteristics were not shared by most of the remaining stations that exhibited significant amphipod toxicity, but were not identified by the EP approach. For example, three of the stations not predicted by the EP approach (1CI-11, 1RS-18, 1SP-14) were each severely impacted according to three biological indicators and exhibited elevated concentrations of numerous chemicals, including PAH (see Tables 11 and 14, and Appendix A).

TABLE 14. BIOLOGICALLY IMPACTED STATIONS NOT INDICATED BY SEDIMENT QUALITY VALUE APPROACHES

Amphipod		Oyster		Benthic		Microtox	
EP	AET	EP	AET	EP	AET	EP	AET
1 **CI-11***		1 **CI-11***	none	1 **CI-11***		1 BL-13	
1 BL-25	1 BL-25	1 CI-13		1 **CI-13***		1 BL-31	
1 CI-20		1 CI-16		1 **CI-16***		1 CI-11	
					1 HY-14		
1 MI-11	1 MI-11	1 CI-20		1 **HY-17***		1 CI-13	
1 MI-15	1 MI-15	1 HY-12		1 **HY-32***	1 **HY-32***	1 CI-16	
					1 HY-37		
1 RS-13		1 HY-17		1 **RS-18***		1 CI-17	
1 **RS-18***		1 HY-47		1 RS-19		1 HY-12	
1 **RS-19***		1 HY-50		1 RS-20		1 HY-14	
		1 RS-13		1 SI-11		1 HY-17	
1 RS-24		1 **RS-18***		1 SI-12		1 HY-24	
1 SI-12	1 SI-12	1 RS-19		1 **SP-14***		1 HY-43	
1 SI-15		1 SP-12		1 **SP-15***		1 HY-47	
1 **SP-14***		1 **SP-14***		1 SP-16		1 HY-50	
1 **SP-15***		1 **SP-15***		5 AP-04	5 AP-04	1 MI-13	
1 SP-16		1 SP-16			7 WP-03	1 MI-15	1 MI-15
3 BH-05	3 BH-05					1 RS-18	
3 **BH-23***	3 **BH-23***					1 RS-19	
3 CS-15	3 CS-15					1 RS-20	
3 CS-17	3 CS-17					1 SI-11	
3 DB-15	3 DB-15					1 SI-12	
3 **EV-01***						1 SP-11	1 SP-11
3 EV-02	3 EV-02					1 SP-12	
3 EV-03	3 EV-03					1 SP-14	
3 **EV-04***						1 SP-15	
3 **EV-05***						1 SP-16	
3 EV-06	3 EV-06						
	3 SC-08						
	3 SC-14						
3 SC-20							
3 SM-01							
3 SM-03	3 SM-03						
3 SM-20	3 SM-20						
	9 DR-11						
9 DR-16	9 DR-16						

* Severely impacted station as defined in text; all stations listed exhibited statistically significant biological effects.

7.1.2 Sensitivity and Efficiency Analysis of AET Generated and Tested with Independent Data Sets--

In the preceding section, AET were generated and tested with the same data. AET were generated with the entire Puget Sound database because large data sets (with wide-ranging chemical concentrations) are expected to enhance the reliability of field-based sediment quality values (e.g., AET, SLC values). The entire Puget Sound database was also used for evaluation of AET (and EP) values because the reliability of the accuracy analysis was also expected to be highest with a large database.

For this section, AET (dry weight) were generated with Commencement Bay data alone and were tested with chemical data from the 134 remaining stations in the Puget Sound database, for three reasons: (1) to account for potential bias resulting from using the same data for establishing and then testing AET, (2) to examine the accuracy of AET developed from one area and applied to other areas, and (3) to enable AET to be determined from chemical data that are matched with biological effects data for any of the four biological indicators used in this project (the Commencement Bay data set is unique in this respect).

The evaluation procedure was analogous to that described in the preceeding section:

- The chemical database (from the 134 non-Commencement Bay samples) was subdivided into groups of stations tested for the same biological indicators (either amphipod bioassay or benthic infaunal analysis; Microtox and oyster larvae bioassays were not performed for these samples)

- The stations of each group were classified as "impacted" (and "severely impacted") or "nonimpacted" (see Table 12 for listing of impacted and severely impacted stations)

- Commencement Bay AET for all appropriate chemicals were compared to the corresponding data for the non-Commencement Bay stations; stations predicted to have biological impacts were identified as those stations with one or more chemicals exceeding AET

- Measurements of accuracy (sensitivity and efficiency as percent) were calculated for each subgroup of stations as in Section 7.1.1, i.e.:

$$\text{Sensitivity (impacted stations)} = \frac{\text{correctly predicted stations with impacts}}{\text{all stations with impacts}} \times 100$$

$$\text{Sensitivity (severely impacted stations)} = \frac{\text{correctly predicted stations with severe impacts}}{\text{all stations with severe impacts}} \times 100$$

$$\text{Efficiency} = \frac{\text{correctly predicted stations with impacts}}{\text{all stations predicted to be impacted}} \times 100$$

Station-by-station listings of chemicals exceeding Commencement Bay AET are included in Appendix Table B6, along with the Commencement Bay AET themselves (Appendix Table B6-A). The results of this analysis and of the corresponding analysis performed for Table 13 are tabulated in Table 15.

These results suggest that the original accuracy analysis was not biased. In fact, the sensitivity of AET generated and tested with these different databases slightly exceeded the sensitivity observed for AET generated and tested with the one Puget Sound database. However, the efficiency of Commencement Bay AET for both biological indicators (31 and 37 percent) is a more reliable estimate of true performance than the 100 percent efficiency reported in Table 13. Efficiency might improve if two larger independent databases are used in such accuracy analyses, because more reliable AET would be expected from a larger database.

7.1.3 Efficiency of EP and AET Sediment Quality Values for Selected Chemicals--

To apply the EP approach to the maximum number of nonpolar organic compounds in the initial test of accuracy (Section 7.1.1), it was necessary to estimate water quality criteria for the compounds that do not have established criteria. In the present section, the accuracy of individual EP sediment quality values was tested only for chemicals with established U.S. EPA chronic water quality criteria. These sediment quality values were tested individually because they were considered the most reliable EP values available. For comparison, AET accuracy was also tested for the same chemicals.

PCB and p,p'-DDT were selected for this evaluation for two reasons: (1) they are among the few nonpolar organic compounds with established chronic water quality criteria, and (2) they accounted for virtually all of the predicted problem stations indicated by the EP approach. Of the 63 Puget Sound stations at which EP sediment quality values were exceeded, PCBs were exceeded at 58 stations, p,p'-DDT at 10 stations, fluoranthene at 5 stations, diethyl phthalate at 3 stations, lindane, heptachlor, and phenanthrene each at 2 stations, and dieldrin at one station (Appendix Table B1). The EP values for the other nonpolar organic chemicals were never exceeded at any stations in the Puget Sound database.

The only appropriate measure of accuracy for individual chemicals is efficiency. Sensitivity is considered an inappropriate measure of accuracy for individual sediment quality values because a single chemical is not expected to account for biological impacts in all sediment samples. The measure of efficiency was analogous to that defined previously (Sections 7.1.1 and 7.1.2), but was only based on a single chemical (i.e., either PCBs or p,p'-DDT).

The accuracy analysis was carried out as in previous tests, except AET generated with Commencement Bay data were tested with the 134 non-Commence-

TABLE 15. ACCURACY OF AET AS RELATED TO DATA SETS USED FOR GENERATION AND EVALUATION

AET Tested	Sensitivity ("Impacted")	Sensitivity ("Severely Impacted")	Efficiency
Amphipod (DW)[a]	54 (23/43)	92 (12/13)	100[b] (23/23)
Benthic (DW)[a]	82 (23/28)	92 (12/13)	100[b] (23/23)
Amphipod (DW)[c]	72 (18/25)	100 (8/8)	37 (18/49)
Benthic (DW)[c]	90 (9/10)	100 (4/4)	31 (9/29)

[a] From Table 12, AET generated and evaluated with the same data set.

[b] As noted in Table 12, efficiency is 100 percent by definition.

[c] AET generated with data from one data set (Commencement Bay, 56 samples) and evaluated with data from several independent studies (Puget Sound data in the compiled database, excluding Commencement Bay; 134 samples).

ment Bay stations in the database. If the entire Puget Sound database were used to generate and evaluate individual AET, the efficiency would be 100 percent by definition for all chemicals.

The results of this accuracy evaluation are presented in Table 16. The number of gaps in the table preclude detailed interpretation. It is noteworthy that the EP efficiency percentages for PCBs are similar to those listed for the overall EP approach in Table 13 (Section 7.1.1). This is not surprising, as PCBs accounted for over 90 percent of the predicted impacted stations for the EP approach. For either chemical, efficiencies of the EP and AET sediment quality values are roughly comparable when evaluated with the amphipod bioassay station group. For the benthic infaunal station group, efficiency of the AET for PCBs was greater than the EP value for PCBs (100 percent vs. 43 percent, respectively).

It should again be noted that sensitivity and efficiency can be mutually exclusive; this evaluation for individual chemicals does not yield information on the overall sensitivity of either approach.

7.1.4 Efficiency of SLC Sediment Quality Values: Preliminary Evaluation--

The evaluation of the SLC approach could not be conducted as thoroughly as that of the EP and AET approaches because SLC values were not developed for all appropriate chemicals and did not incorporate data from a large number of stations. It was not considered appropriate to test the overall sensitivity and efficiency of the approach because sediment quality values for only three contaminants were developed. These three contaminants (naphthalene, HPAH, and mercury) could not be expected to account for biological impacts potentially associated with other contaminants. Hence, the same measure of efficiency was used based only on a single chemical (i.e., either HPAH, naphthalene, or mercury) as in the previous section:

$$\text{Efficiency (percent based on chemical x)} = \frac{\text{correctly predicted stations with impacts}}{\text{all stations predicted to be impacted}} \times 100$$

The efficiencies of SLC values for HPAH, naphthalene, and mercury (based on stations grouped by biological indicator) are presented in Table 17). For the range of compound/normalization combinations, SLC values were most accurate relative to the Microtox bioassay (i.e., 50-70 percent agreement) and least accurate relative to the oyster abnormality bioassay (i.e., 15-30 percent agreement). Efficiencies with respect to benthic depressions (i.e., 36-48 percent agreement) and the amphipod mortality bioassay (i.e., 32-52 percent agreement) were intermediate in magnitude. For both HPAH and naphthalene, efficiencies of all four biological indicators were higher for dry-weight normalizations than for organic-carbon normalizations.

7.2 Precision of Sediment Quality Values

The effective management of contaminated sediments requires knowledge of the confidence limits for the estimates of sediment quality values. These confidence limits reflect a degree of uncertainty in the derivation

TABLE 16. EFFICIENCY OF EP AND AET VALUES FOR PCBs AND p,p'-DDT

	Efficiency[a]	
	PCB	p,p'-DDT
Equilibrium Partitioning		
Amphipod	29 (10/34)	100 (2/2)
Oyster	50 (2/4)	0 (0/2)
Benthic	43 (12/28)	25 (2/8)
Microtox	100 (4/4)	(Not exceeded)
AET (dry weight)		
Amphipod	38 (9/24)	100 (1/1)
Oyster	NA[b]	NA[b]
Benthic	100 (3/3)	--[c]
Microtox	NA[b]	NA[b]
AET (organic carbon)		
Amphipod	26 (7/27)	100 (2/2)
Oyster	NA[b]	NA[b]
Benthic	--[c]	--[c]
Microtox	NA[b]	NA[b]

[a] Efficiency =

$$\frac{\text{Stations Correctly Predicted (based on Chemical X) to be Impacted}}{\text{All Stations Predicted to be Impacted (based on Chemical X)}} \times 100.$$

[b] Not applicable: oyster larvae and Microtox bioassays were only performed on Commencement Bay samples.

[c] Definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations.

TABLE 17. PERCENT EFFICIENCY OF SLC SEDIMENT QUALITY VALUES

Compound	Normalization	Biological Indicators[a,b]			
			Sediment Bioassay		
		Benthic	Amphipod	Oyster	Microtox
HPAH	OC	36 (19/53)	35 (12/34)	18 (6/34)	61 (14/23)
HPAH	DW	42 (16/38)	38 (12/32)	25 (8/32)	65 (15/23)
Naphthalene	OC	38 (6/16)	45 (9/20)	15 (3/20)	50 (6/12)
Naphthalene	DW	48 (10/21)	52 (17/33)	30 (10/33)	70 (14/20)
Mercury	DW	48 (21/44)	32 (23/72)	17 (12/72)	64 (16/25)

[a] Indicators included depressed abundances of at least one major benthic group (i.e., total benthos, Polychaeta, Mollusca, Crustacea), amphipod mortality, oyster abnormality, and change in bacterial luminescence (i.e., Microtox bioassay).

[b] Efficiency (percent) =

$$\frac{\text{Stations Correctly Predicted (Based on Chemical X) with Impacts}}{\text{All Stations Predicted to be Impacted (Based on Chemical X)}} \times 100.$$

of the values. All of the approaches used to derive sediment quality values have sources of error that affect the reproducibility of the values. Some components of variability can be reasonably estimated (e.g., analytical error of chemical and biological results, or the standard error in a regression curve). Other components of variability are poorly defined (e.g., the true representativeness of empirical data used in the AET and SLC approaches, or the uncertainty in interstitial water concentrations predicted by the EP approach). Because of the unquantifiable nature of these latter sources of error, confidence limits presented in this section are only rough estimates of the true precision of sediment quality values. A statistical confidence that incorporates all aspects of uncertainty cannot be assigned.

7.2.1 Estimated Minimum Confidence Limits for EP Values--

As discussed in the Section 5.2, sediment quality values for the equilibrium partitioning approach are generated with the equation:

$$\text{EP value} = K_{OC} \times \text{water quality criterion}$$

For many chemicals, K_{OC} values and water quality criteria are unavailable and must be estimated. Both of the variables have various degrees of quantifiable uncertainty and unquantifiable uncertainty. In this section, estimates are made of the minimum uncertainty associated with EP values for nonpolar, nonionic chemicals for which chronic (24-h) criteria have been established by the U.S. EPA (i.e., PCBs, p,p'-DDT, chlordane, dieldrin, and heptachlor). EP values based on established chronic water quality criteria are considered to be the most reliable sediment quality values for the approach.

7.2.1.1 K_{OC} Values--Three major factors contribute to the uncertainty of interstitial water contaminant concentrations predicted from K_{OC} values:

- The uncertainty in measured and estimated K_{OW} and K_{OC} values
- The possibility that laboratory determinations of K_{OC} values do not accurately simulate conditions in nature [e.g., because sediment:water (volume:volume) ratios and dissolved organic matter concentrations can be markedly different under laboratory and natural conditions; discussed in Section 2.3.4]
- Possible violation of the assumption that sediment-interstitial water partitioning is at equilibrium under conditions in nature (discussed in Section 2.3.4).

In this report, only the first factor will be discussed because quantitative estimates of the uncertainty associated with the latter two factors are difficult to make with available data. Because K_{OC} values are not widely available in published literature for many nonpolar chemicals, more widely available K_{OW} values are used to estimate K_{OC} according to the linear relationship:

$$\log K_{OC} = a \log K_{OW} + b$$

where a and b are empirically derived constants. Two major sources of uncertainty characterize this relationship: uncertainty in measured or estimated K_{ow} and uncertainty in the K_{ow}-K_{oc} regression relationship. Variation in reported K_{ow} values in the scientific literature are common and result in part from the variety of techniques by which they are measured or estimated (e.g., generator columns, shake flasks, approximations based on reverse-phase high-pressure liquid chromatography, estimations based on fragment constants). In some cases, reported K_{ow} values for a compound can vary by over one order of magnitude (e.g., Kenga and Goring 1980; Rapaport and Eisenreich 1984).

For nonpolar compounds, K_{oc} values predicted by a K_{ow}-K_{oc} regression equation are generally within 0.5 log units of measured K_{oc} values (Karickhoff 1981). Accordingly, the regression equation used to estimate K_{oc} for PCBs, p,p'-DDT, chlordane, dieldrin, and heptachlor in this study was found to have a standard error of approximately 0.5 log units (JRB Associates 1984b). However, for some substances, deviations from measured K_{oc} values may be greater than 2 log units (Lyman et al. 1982). The variation associated with each measured K_{oc} or K_{ow} value is not included in the regression analysis. Consequently, regression statistics will provide a minimum estimate of the amount of variation (expressed as a standard deviation or 95 percent confidence interval) in predicted K_{oc} values.

7.2.1.2 Water Quality Criteria--Major uncertainties in establishing the precision of chronic water quality criteria are:

- Adequacy of the existing aquatic toxicity database for establishing a criterion according to U.S. EPA (1980) guidelines and for determining a statistical estimate of uncertainty

- Comparability of criterion values for the various contaminants, which were determined using a stratified evaluation of two kinds of toxicological data (i.e., systemic toxicity and bioaccumulation potential)

- Validity of the assumption that the sediment-free bioassay or bioaccumulation data for primarily nektonic organisms are applicable to benthic biota (e.g., deposit-feeding infauna) under field conditions (discussed in Section 2.2.4)

- Validity of the assumption that interstitial water is the sole source of contaminants to benthic biota, or alternatively, that benthic systems follow sediment-biota equilibrium partitioning and are unaffected by the route of contaminant exposure (e.g., dermal absorption vs. ingestion of sediments) (discussed in Section 2.2.4)

Only the first factor above will be quantified in this report because the other three factors are not quantifiable with available data. However, uncertainties associated with assumptions of the approach will influence the degree of accuracy of the approach when tested with field data.

According to U.S. EPA (1980) guidelines, chronic water quality criteria for each priority pollutant are determined using a stratified evaluation of systemic toxicity and bioaccumulation in tissues. Factors considered in evaluation of systemic toxicity include chronic effects in animals and plant toxicity. Where there are insufficient chronic data in biotic groups (e.g., major phyletic groups that have not been tested), chronic toxicity for the group may be estimated by dividing the acute toxicity criterion (i.e., the maximum allowable concentration) by a geometric mean acute toxicity/chronic toxicity ratio. Acute/chronic ratios may range from 2 to 100 (Welch 1980). Contaminant concentrations in water that may result in bioaccumulation considered harmful to humans through the ingestion of seafood or to sensitive wildlife are determined by:

$$C_{wqc} = A/(L \times BCF_n)$$

where:

C_{wqc} = concentration in water

A = U.S. Food and Drug Administration (FDA) action level (e.g., 5 mg/kg PCBs) or a maximum permissible tissue concentration in a sensitive species (e.g., 0.15 mg/kg DDT in brown pelicans)

L = average percent lipids in seafood (i.e., 16 percent expressed as a decimal) or in the prey of a sensitive species

BCF_n = lipid-normalized geometric mean bioconcentration factor for aquatic organisms.

The final chronic water quality criterion is the minimum of the various chronic animal toxicity, plant toxicity, and bioaccumulation values. Geometric mean BCF_n values in combination with FDA action levels or maximum permissible tissue concentrations were used to establish chronic water quality criteria for the five nonpolar, nonionic substances discussed above. Thus, data available in the U.S. EPA (1980) water quality criteria may be used to calculate the standard deviation of the mean log BCF_n as a measure of the minimum uncertainty for each substance:

- PCBs (mean log BCF_n=4.02, SD=0.34, N=5)
- DDT (mean log BCF_n=4.25, SD=0.59, N=32)
- Chlordane (mean log BCF_n=3.67, SD=0.03, N=2)
- Dieldrin (mean log BCF_n=3.19, SD=0.18, N=2)
- Heptachlor (mean log BCF_n=3.72, SD=not determined, N=1).

A major limitation of this approach is that uncertainty in determination of U.S. FDA action levels, maximum permissible tissue concentrations, and average percent lipid content in seafood or the prey of sensitive wildlife is not taken into consideration. U.S. FDA action levels are determined

by a combination of human-health risk assessment, economic impact analysis, and regulatory policy- and decision-making procedures. Consequently, uncertainty estimates for U.S. FDA action levels are not feasible since they are determined in part by unquantified professional judgement.

As indicated above, where data were insufficient to determine chronic water quality criteria, estimates of water quality criteria were determined from the minimum chronic toxicity value available (cf. Table 4). In general, the data are too limited to quantify uncertainty for chronic water quality criteria estimated from minimum chronic toxicity values. With the exception of particularly sensitive commercially important species, maximum allowable water quality criteria are defined as the EC_{50} concentration for the 5th percentile of species ranked in decreasing order of sensitivity. Thus, where acute toxicity data are sufficient to determine a maximum allowable water quality criterion, it is possible to evaluate uncertainty using linear estimation techniques (e.g., regression of probit-transformed cumulative percent frequency of species tested on log transformed EC_{50} values). This method would provide a minimum estimate of variance associated with the acute EC_{50} criterion concentration. This method also requires extensive data evaluation and is beyond the scope of the present project.

A major limitation in determination of sediment quality values is the uncertain comparability of the two kinds of toxicological data (i.e., systemic toxicity and bioaccumulation potential) used to derive chronic water quality criteria. In general, sediment quality values determined from acute toxicity data approximate the sediment concentration needed to be protective of aquatic biota. Sediment quality values determined from chronic toxicity data approximate the sediment concentration needed to be protective of human health or sensitive wildlife. Given the guidelines (U.S. EPA 1980) used to establish water quality criteria, sediment quality values determined from BCF_n may be more conservative than those estimated from acute toxicity values by approximately one order of magnitude.

7.2.1.3 Estimated Uncertainty in EP Sediment Quality Values--As a first step in approximating the miniumum amount of uncertainty, EP values were estimated for the five chemicals for which there are chronic water quality criteria using the relationship:

$$\log \text{EP value} = \log K_{OC} + \log C^{x}_{w/cr} \qquad \text{[Eq. 1]}$$

where:

EP value = sediment quality concentration normalized to organic carbon content for chemical x ($C^{x}_{s/cr}$)

K^{x}_{OC} = sediment organic carbon-water partition coefficient for chemical x

$C^{x}_{w/cr}$ = water quality criteria concentration for chemical x.

An estimate of the variance of each predicted log K_{OC} was determined from the standard error (0.48 log units) reported for the appropriate K_{OW}-K_{OC} regression equation (JRB Associates 1984b). Estimates of the variance of each log $C^{x}_{w/cr}$ value was determined from the standard deviation of the mean of the log BCF_n values reported by the U.S. EPA (1980). Each variable (i.e., EP value, K_{OC}, $C^{x}_{w/cr}$) was assumed to be log-normally distributed (Gumbel 1958). The total variance in the EP value was estimated as:

$$V_s = V_k + V_w \qquad \text{[Eq. 2]}$$

where:

V_s = variance of log EP value

V_k = variance of log K_{OC} = (std. dev. of predicted log K_{OC} value)^2

V_w = variance of the log BCF_n value described above.

The arithmetic mean and standard deviation given the uncertainties in the derivation of each EP value were then determined by propagation of errors using the equations:

$$\text{mean EP value} = \frac{[\exp(aU_s) \times \exp(aS_s)^2]}{2}$$

and

$$\text{standard deviation of EP} = \exp(aU_s) \times [\exp 2(aS_s)^2 - \exp(aS_s)^2]^{0.5}$$

where:

$a = \ln 10 = 2.303$

U_s = mean log EP value from Eq. 1

$S_s = (V_s)^{0.5}$.

Values used to estimate the uncertainty of EP sediment quality values for each of the five substances are shown in Table 18. The combined uncertainty for these substances may be expressed as the coefficient of variation (i.e., the standard deviation divided by the mean, expressed as a percent). Coefficients of variation ranged from 1.5 for heptachlor to 4.5 for p,p'-DDT. These are extreme minimum estimates of uncertainty based on consideration of only two factors that may affect determination of uncertainty in the EP sediment quality values. For the substances listed in Table 18, there are a number of factors that could contribute to uncertainty estimates (see Section 2.3.4). Although uncertainty for many of these factors remains unquantified, it is likely that the true error associated with predicted EP values is in the range of one to six orders of magnitude of the generated value.

TABLE 18. MINIMUM ESTIMATE OF PRECISION OF EP SEDIMENT QUALITY VALUES

Chemical	$SE_{K_{OC}}$ [a]	SD_{WQC} [b]	CV [c]	95 Percent Confidence Interval [d] Lower		Upper
PCB	0.48	0.34	2.3	0	-	66,000
p,p'-DDT	0.48	0.59	4.5	0	-	2,300
chlordane	0.48	0.03	1.6	0	-	2,700
dieldrin	0.48	0.18	1.7	0	-	490
heptachlor	0.48	--	1.5	0	-	800

[a] Standard error of regression equation $\log K_{OC} = 0.843 \log K_{OW} + 0.158$ ($n=19; r=0.96$) (JRB Associates 1984b).

[b] Standard deviation of U.S. EPA chronic water quality criterion.

[c] Coefficient of variation of EP sediment quality value [i.e., (SD/mean)*100].

[d] 95 percent confidence intervals were established as the EP sediment quality value (Table 4) ± 1.96(CV*EP sediment quality value); assuming a normal distribution of mean predicted EP sediment quality values for a given chemical. Units are ug/kg organic carbon.

7.2.2 Estimated Confidence Intervals for AET Values--

For a given data set, major sources of uncertainty in determining AET include:

- The uncertainty defined by the concentration range between the AET (determined by a nonimpacted station) and the next highest concentration that is associated with a statistically significant effect
- A classification error associated with the statistical significance of biological indicator results (i.e., whether a station is properly classified as impacted or nonimpacted)
- The weight of evidence or number of observations supporting a given AET value
- The analytical error associated with quantification of chemical results (this error is also implicit in the derivation of EP values, but was not quantified).

7.2.2.1 Uncertainty Above the AET Concentration--The most obvious uncertainty in the AET value is the concentration range between the AET and the next highest concentration in the data set (e.g., Figure 14). By definition, this next highest concentration is always associated with a statistically significant effect. It is assumed that the AET could be anywhere within the range because there are no data on the potential effects associated with sediment concentrations within this range. For the available data set, adjusting AET within this concentration range (up to but not including the next highest concentration) will have no effect on the apparent "accuracy" of the AET approach. The upper limit of AET should include this range of concentrations.

7.2.2.2 Classification Errors--Impacted stations (for each biological indicator) were defined as those exhibiting biological effects that were statistically significant relative to reference conditions. The potential error in misclassifying impacted and nonimpacted stations is defined by two statistical errors: 1) the probability that a station determined to be impacted was actually nonimpacted (a Type I error) and 2) the probability that a station determined to be nonimpacted was actually impacted (a Type II error). If a Type I error was made for a station at which sediment concentrations of a contaminant exceeded the AET, the correct AET will be higher. If a Type II error was made for the station that set the AET, the correct AET will be lower.

The Type I error (set experimentwise) for each study and each biological indicator is $P<0.05$. The probability (P) of falsely classifying any one of the impacted stations with contaminant concentrations above AET ranged from 0.1 to 0.8 percent, depending on the exact number of stations tested in each of the studies. The probability of falsely classifying more than one of the impacted stations is even lower (i.e., equal to P^n, where n

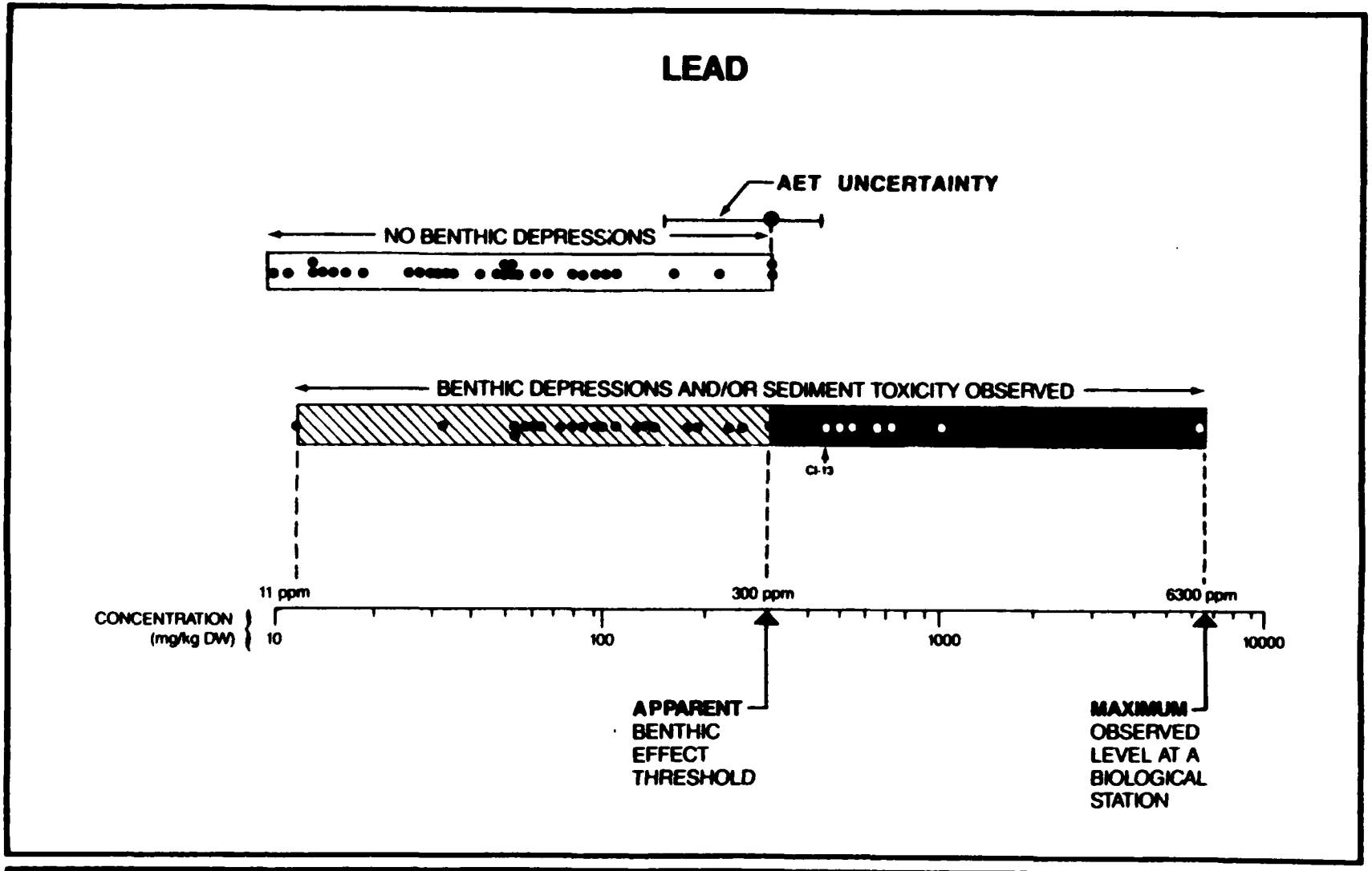

Figure 14. Example confidence limits for benthic AET determined for lead. [Sources of uncertainty include potential misclassification of 3 impacted stations and the concentration range between the lead benthic AET and the next highest concentration at an impacted station (i.e., station CI-13)].

is the total number of impacted stations misclassified). Because of this low probability, and the uncertainty already incorporated in the previous discussion (see "Uncertainty Above the AET Concentration", Section 7.2.2.1), any potential error associated with misclassifying impacted stations is assumed to be negligible in setting the upper limit of AET. This assumption is environmentally protective.

The lower limit of AET is affected by the probability of making Type II errors in the classification of stations. This probability varies for each sample and its calculation is beyond the scope of the present effort. For a given number of samples, the probability of making a Type II error increases as the probability of making a Type I error decreases. For the purpose of analysis, a potential Type II error of 40 percent was assumed (i.e., a statistical power of 60 percent).

The AET will only be affected by a Type II error if the nonimpacted station setting the AET has been misclassified (i.e., the AET would then be equal to the next lower concentration found at a nonimpacted station). Two types of events would cause the AET to be substantially lowered because of misclassification errors: 1) several stations spanning a large range of concentrations were misclassified or 2) only one or two stations were misclassified, but a large concentration difference existed between the station setting the original AET and the station setting the revised AET (Figure 14). The latter event is of concern because of the sensitivity of the AET to an apparently nonimpacted station with anomalously high concentrations of a contaminant. To ensure protective sediment quality values, the lower confidence limit of AET should incorporate this uncertainty.

Assuming a 40 percent probability of misclassifying each of the nonimpacted stations, the total probability of misclassifying three stations at and just below the AET is approximately 5 percent (i.e., $P=0.4^n$, where n is the number of stations misclassified). Hence, for a given data set there is a 95 percent probability that the AET is greater than the concentration found at the nonimpacted station with the fourth highest concentration of each contaminant. If the true probability of making a Type II error is only 20 percent, then misclassification of two stations at and just below the AET would yield a similar 95 percent confidence.

Uncertainty analyses for AET were conducted for concentrations normalized to dry weight of sediment, which was consistently the most accurate set of AET in indicating problem sediments (see Section 7.1.1). The lower limits of AET were initially calculated assuming misclassification of the three nonimpacted stations with the highest concentrations of each contaminant. For all AET values, these lower limits averaged approximately one-half the original AET value, and ranged from 1.2 to 26 times lower than the original AET.

A test of the "accuracy" of these lower limits in correctly predicting impacted sediments was conducted (i.e., see Lower Limit II in Table 19) and compared with the evaluation summarized in Table 12 for the original AET (dry weight). All of the stations with significant oyster larvae and Microtox bioassay results were correctly identified using the lower limits

TABLE 19. EVALUATION OF LOWER AND UPPER LIMITS OF AET WITH BIOLOGICAL DATA

Approach	Sensitivity (Impacted Stations)	Sensitivity (Severely Impacted Stations)	Efficiency
AET - DW Upper Limit[a]			
Amphipod	54 (23/43)[b]	92 (12/13)	100[c] (23/23)
Oyster	94 (15/16)	100 (4/4)	100 (15/15)
Benthic	82 (23/28)	92 (12/13)	100 (23/23)
Microtox	90 (26/29)	---[d]	100 (25/25)
AET - DW Lower Limit I[e]			
Amphipod	70 (30/43)	100 (13/13)	46 (30/65)
Oyster	100 (16/16)	100 (4/4)	33 (16/48)
Benthic	96 (27/28)	100 (13/13)	43 (28/65)
Microtox	93 (27/29)	---	59 (27/46)
AET - DW Lower Limit II[f]			
Amphipod	79 (34/43)	100 (13/13)	40 (34/84)
Oyster	100 (16/16)	100 (4/4)	33 (16/49)
Benthic	96 (27/28)	100 (13/13)	38 (27/71)
Microtox	100 (29/29)	---	40 (29/48)

[a] DW = dry weight normalized; accuracy data for the upper limit of the AET are identical to those for the AET - DW in Table 13 because no data points lie between the AET and the upper limit in the defined data set (see text).

[b] Fraction from which percent was calculated.

[c] By definition; the approach is designed such that all sediments with concentrations exceeding their AET are biologically impacted. This constraint does not apply to the lower limit of AET.

[d] Severe impacts not determined for Microtox data.

[e] Lower limit assuming a 20 percent misclassification error for two nonimpacted stations at and just below the AET. Results in a 95 percent confidence that the AET is greater than the lower limit set by the nonimpacted station with the next highest concentration. Note that for the different indicators, from 33 to 91 percent of all apparently nonimpacted stations in the data set were indicated by the Lower Limit I of AET.

[f] Lower limit assuming a 40 percent misclassification error for three nonimpacted stations at and just below the AET. Results in a 95 percent confidence that the AET is greater than the lower limit set by the nonimpacted station with the next highest concentration. Note that for the different indicators, from 47 to 91 percent of all apparently nonimpacted stations in the data set were indicated by the Lower Limit II of AET.

for AET, and all but one station with significant benthic effects were correctly identified. Although a higher percentage of stations with significant amphipod bioassay responses was identified using lower limits of AET than with the original AET, 9 of 43 impacted stations were missed (6 of the 9 stations had a percent fine-grained material content exceeding 75 percent). More importantly, from 47 to 91 percent of the apparently nonimpacted stations were predicted to exhibit biological impacts using these lower limits of AET for different biological indicators (Table 19). Thus, the efficiency (i.e., discriminating power) of the AET approach is substantially reduced by extending the lower limit of the AET to account for a potential 40 percent misclassification error of nonimpacted stations at a 95 percent confidence level.

This analysis was repeated assuming a potential 20 percent misclassification error of nonimpacted stations (i.e., misclassification of 2 stations to yield a 95 percent confidence). A test of the "accuracy" of these lower limits is also presented in Table 19 (Lower Limit I). Two stations exhibiting significant Microtox bioassay responses and one station exhibiting significant benthic effects were not indicated using these limits. Thirty percent of the stations with significant amphipod bioassay responses were not predicted. Sediments at most of the latter stations had a high percentage of fine-grained material. All severely impacted stations (as defined for each biological indicator in the "Accuracy" section) were correctly predicted using these lower limits.

A majority of the apparently nonimpacted stations were also predicted to be impacted stations using these lower limits of AET (except using the lower limits for the amphipod bioassay AET). These results suggest that apparently nonimpacted and impacted stations are well distinguished only at concentrations close to the originally derived AET. Hence, the small improvement in sensitivity for identifying impacted stations using lower limits of AET must be balanced against a large decrease in efficiency of identifying only impacted stations.

These trends suggest that the lower limit of AET should be set with the assumption that only one station was misclassified (i.e., the station originally setting the AET). Such a lower limit will account for the possibility of anomalous chemical results setting the original AET, and will misidentify a minimum number of apparently nonimpacted stations. The assumption of a single misclassification implies a Type II error of only 5 percent to yield a 95 percent confidence in the lower limit (rather than the 40 or 20 percent assumed in the analyses presented in Table 19). Because of the low Type I error established for the biological indicator tests (i.e., <1 percent for individual statistical comparisons), such a low Type II error may be unrealistic. [Note that if a lower confidence of 80 percent is acceptable, a single misclassification then implies a Type II error of 20 percent].

The lower limit of AET are best suited as guidelines for use of biological screening tests for contaminated sediments. These lower limits should be set protectively by assuming misclassification of at least two nonimpacted stations unless an administrative decision is made to assume a single misclassification.

Lower limits (defined as Lower Limit I) and upper limits of dry-weight normalized AET are presented in Table 20.

7.2.2.3 Weight of Evidence--The number of observations supporting an AET will affect its uncertainty; AET based on a large database are more reliable than those based on a small database. Although the effect of weight of evidence on AET uncertainty is difficult to quantify, it is indirectly incorporated in the approach for estimating confidence limits for AET (discussed in the two preceding sections). The number of stations used to establish an AET would be expected to have a marked effect on confidence limits since small data sets would tend to have less continuous distributions of chemical concentrations than large data sets. That is, small data sets would tend to have larger concentration gaps between stations (and correspondingly wider confidence limits) than larger data sets.

7.2.2.4 Chemical Analysis Error--The analytical precision of chemical analyses in the concentration range of most AET in Table 6 (i.e., several hundred parts per billion to several parts per million) is expected to average approximately ±30 percent for organic compounds and ±5 percent for metals and metalloids (Horwitz et al. 1980; U.S. EPA 1984; Tetra Tech 1985). This uncertainty is typically less than, and independent of, the variability represented by the uncertainty discussed in the previous sections. Hence, the lower and upper limits of AET set by the other sources of error are expected to exceed the analytical error in most chemical results.

Chemical data that are compared with AET (and other sediment quality values) derived in this report should take analytical error into account. In particular, analytical detection limits are recommended to be sufficiently low to ensure confident quantification of contaminants present at concentrations (dry weight) at least half the corresponding AET (see Appendix F).

Detection limits specified by the PSEP protocol for analysis of organic compounds in sediments by gas chromatography/mass spectroscopy range from 1-50 ug/kg (dry weight) (Tetra Tech 1986b). Recommended detection limits for gas chromatography/electron capture analyses are 0.1-5 ug/kg for pesticides and 5-20 ug/kg for PCBs. Comparision of these values with AET in Table 6 reveals that detection limits of 1/2 AET values (e.g., for the lowest AET, usually Microtox) are reasonable. The most serious problems would probably be presented by p,p'-DDT, 2-methylphenol, 2,4-dimethylphenol, N-nitrosodiphenyl amine, and benzyl alcohol. Detection limits of 1/2 lowest AET for chlorinated benzenes (1,2-dichloro- and 1,2,4-trichlorobenzene) could also be difficult to attain, but are technically feasible with existing protocols.

The AET for DDT isomers indicate that mass spectral analysis will not be sufficiently sensitive for the screening of these compounds; detection by electron capture (or equivalent) is recommended with dual column verification and confirmation by mass spectral analyses whenever possible to minimize problems with "false positives".

TABLE 20. LOWER AND UPPER LIMITS OF AET SEDIMENT QUALITY VALUES (DRY WEIGHT)[a]
(ug/kg dry weight for organics; mg/kg dry weight for metals)

Chemical	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Low molecular weight PAH	4200- 6000	3900- 6000	4500-11000	3700- 6000
naphthalene	1600- 4300	1200- 4300	1200- 4300	1200- 4300
acenaphthylene	280- 760	160- >560	330- 3900	190- >560
acenaphthene	500- 2400	230- 2400	290- 2400	190- 2400
fluorene	480- 970	280- 3000	490- 2600	280- 3000
phenanthrene	1500- 2200	1100- 1700	1200- 4200	1100- 1700
anthracene	560- 1300	490- 1300	560- 1500	470- 1300
High molecular weight PAH	13000-19000	12000-17500	17000->51000	8800-13000
fluoranthene	2300- 4000	1900- 3500	2400- 8000	1500- 1800
pyrene	3300- 5500	2600- 4200	2800->7300	1600- 3200
benzo(a)anthracene	1300- 1800	860- 2200	1700- 9400	790- 1500
chrysene	2300- 4600	2300- 4600	2300-10300	1100- 1500
benzofluoranthenes	3200- 4100	2800- 3650	3900- 8400	2800- 3500
benzo(a)pyrene	1400- 3900	1600- 1900	2200- 9700	980- 1900
indeno(1,2,3-c,d)pyrene	580- 760	570- 760	1000->5200	450- 620
dibenzo(a,h)anthracene	U 200- 310	160- 250	260- 1400	160- 250
benzo(g,h,i)perylene	670- 770	610- 730	1800- 7900	380- 710
Total PCBs	1800- 3800	250- 1400	480- 1400	120- 135
Total chlorinated benzenes	310- 1200	240- 660	240- 660	150- 190
1,3-dichlorobenzene	61- >170	40- >170	56- >170	40- >170
1,4-dichlorobenzene	120- 280	64- 170	71- 170	63- 115
1,2-dichlorobenzene	94- >350	27- 72	27- 72	25- 36
1,2,4-trichlorobenzene	34- 250	34- 250	27- 250	U 5- 33
hexachlorobenzene (HCB)	96- 220	96- 720	70- 720	U 10- 95
Total phthalates	3400->5200	1600- 3500	6200->70000	970- 3400
dimethyl phthalate	110- 340	110- 340	110- 340	U 50- 100
diethyl phthalate	47- > 73	47- > 73	73- 310	13- > 48
di-n-butyl phthalate	1500->5100	1000- 1400	2000->5100	840- 1450
butyl benzyl phthalate	125- >470	83- >470	290- 800	U 25- 82
bis(2-ethylhexyl)phthalate	1300->3100	820- 2900	840- 2900	430- 2900
di-n-octyl phthalate	170-> 590	47-> 420	3600->68000	--
Pesticides				
p,p'-DDE	11- 40	--	5- 9.9	--
p,p'-DDD	29- 70	--	1- 11	--
p,p'-DDT	1.4- 5.7	1.3- >6	5.8- 14	--
aldrin	--	--	--	--
chlordane	--	--	--	--
dieldrin	--	--	--	--
heptachlor	--	--	--	--
gamma-HCH (lindane)	--	--	--	--

TABLE 20. (Continued)

	Amphipod AET	Oyster AET	Benthic AET	Microtox AET
Phenols				
phenol	420- 1000	390- 490	420- 1600	260- 1600
2-methylphenol	38- 70	27- 70	43- >72	43- >72
4-methylphenol	600- 2500	420- 880	560- 880	420- 880
2,4-dimethylphenol	>50	U 10- 49	U 10- 49	U 10- 49
pentachlorophenol	>U100	>U100	>U100	>U100
Miscellaneous extractables				
hexachloroethane	--	--	--	--
hexachlorobutadiene	180- 720	140- 280	140- 280	U 25- 125
1-methylphenanthrene	260- 360	270- 520	270- 520	220- 520
2-methylnaphthalene	460- 800	460- 800	460- 800	440- 800
biphenyl	140- 265	110- 265	150- 300	110- 300
dibenzothiophene	180- 245	170- 245	180- 310	110- 310
dibenzofuran	250- 1900	270- 1900	270- 1900	270- 1900
benzyl alcohol	57- 120	42- 120	57- 120	35- 60
benzoic acid	430- >690	390- 680	390- 680	330- 680
N-nitrosodiphenylamine	24- 600	20- 210	61- 120	U 5- 130
Volatile organics				
trichloroethene	--	--	--	--
tetrachloroethene	140- >210	78- 160	78- 160	U 10- >140
ethylbenzene	33- > 50	18- 49	18- 49	U 10- 36
total xylenes	100- >160	53- 150	53- 150	U 20- 105
Metals				
antimony	2.0- 25	3.1- 35	3.1- 3.25	3.1- 35
arsenic	86- 690	90- 1400	49- 85.5	39- 1400
beryllium	5.3- >5.5	0.32->0.45	>0.49	0.28- 0.36
cadmium	5.7- 9.5	4.4- 15	3.4- 6.6	3.4- 15
chromium	82- >130	29- >37	52- 59.5	24- 28
copper	310- 2100	290- 2100	170- 2100	160- 2100
iron	24000-36000	20000-52000	34000-52000	18000-52000
lead	610- 720	500- 720	210- 420	210- 650
manganese	200- 470	200- 550	630->1000	150- 550
mercury	1.7- 2.2	0.49- 1.0	0.52- 0.97	- 0.46
nickel	110- >120	23- 39.5	40- 49.5	21- 29
selenium	U 1-U 1.3	--	U 1- > 63	--
silver	1.6-> 3.7	>0.50->0.56	3.7- 5.3	0.44->0.56
thallium	0.2- 0.45	0.2- 0.45	0.14- 0.46	0.11- 0.45
zinc	490- 900	340- 3200	210- 265	200- 3200
Conventional variables				
total organic carbon	11- 15.5	6-15.5	6-15.5	4-15.5
total volatile solids	18- 34	11-44	12-44	9-44
percent fine-grained	92->98	>86	>96	81-88.5

a Lower limit of AET is as defined for Lower Limit I in Table 19; Upper limit of AET is just less than the next highest concentration above the AET (found at an impacted station).

8.0 RECOMMENDED USES OF SEDIMENT QUALITY VALUES

Sediment quality values derived in this project are appropriate tools for certain aspects of sediment management in Puget Sound, but will be only one component of an overall management approach. The following uses may be appropriate for sediment quality values:

- Application as trigger levels for screening decisions on the need for further chemical and/or biological testing and evaluation of sediments (i.e., dredged material testing or preliminary site investigations)
- Determination of the extent and relative priority of potential problem areas to be managed (e.g., for Superfund remedial investigations, Toxic Action Plans, or NPDES enforcements)
- Identification of potential problem chemicals in problem sediments
- Identification of "acceptable sediments" for dredged materials that may be placed in unconfined, open-water sites (i.e., to preclude the degradation of existing or planned sites)
- Prioritization of laboratory studies for determining cause-effect relationships.

These potential uses are discussed in Sections 8.1 through 8.5. Recommendations related to chemical normalization and use of conventional sediment variables are given in Sections 8.6 and 8.7. A brief summary of all recommendations for use of the sediment quality values generated in this project is given in Section 8.8. Recommendations for future studies are summarized in Section 8.9.

8.1 Screening Technique to Identify Need for Further Testing

Comparisons of the accuracies of the EP and AET approaches (Table 13) indicate that dry-weight AET are the most successful predictors of sediments with biological impacts, based on available data. However, the method of establishing AET allows for the possiblity that impacted stations can be overlooked. For screening level applications, it is preferable to err on the side of underestimating threshold levels to ensure that all potential stations of concern are identified. The lower limits of AET discussed previously (Section 7.2.2.2), were recommended as possible screening guidelines for the need of conducting biological tests on contaminated sediments. The lowest AET for a chemical (i.e., the most sensitive according to a range of biological indicators) is also recommended for use in screening for potentially impacted sediments.

To investigate the performance of this proposed approach, the lowest dry-weight AET (regardless of biological indicator) for each chemical or chemical group were applied to the entire Puget Sound data set. The purpose was to simulate a potential application by sediment quality managers (i.e., use of the most environmentally protective AET for screening). This approach

cannot be used to assess accuracy because stations with different biological effects data have all been grouped together.

Station-by-station listings of chemicals or chemical groups that exceeded the lowest corresponding dry-weight AET are presented in Appendix Table B-5. In total, 124 of the 190 stations in the Puget Sound data set had chemical or chemical group concentrations that exceeded the lowest corresponding AET. This compares to a total of 50 stations predicted by the AET approach to be biologically impacted when stations were partitioned according to available biological effects data. Sixty-three stations were predicted by the EP approach to be impacted.

Besides correctly predicting all but 10 of the 72 biologically impacted stations, the lowest AET predicted impacts at 55 stations for which biological effects were not observed. For example, many Bellingham Bay stations were predicted by the approach to be of concern because of mercury. This is noteworthy because potential mercury sources existed historically in this area (i.e., chloralkali plants). Some stations in Bellingham Bay, Dabob Bay, Sequim Bay, and West Point were also predicted to be of concern for elements that have significant natural sources (e.g., crustal elements such as nickel). These results suggest that elements not previously considered as being of concern in Puget Sound (e.g., chromium) warrant further evaluation. It is recommended that additional matched biological effects and chemical data be collected for sediments having high, but apparently naturally-derived concentrations of crustal elements to better define AET for these elements.

The SLC approach, developed specifically for screening applications, is recommended for further study. The approach, as modified in the limited application, generated sediment quality values consistently below AET and could prove to be environmentally protective as a screening tool.

8.2 Determination and Ranking of Problem Areas

AET were particularly effective at predicting severely impacted sediments, and are designed to identify impacted sediments in general. Determination of the extent and ranking of problem areas is an important use of sediment quality values such as the AET because of their ability to guide efficient allocation of resources. AET are recommended as tools for defining problem sediments. Because AET appear less able to predict amphipod bioassay impacts than impacts for other available biological tests, it is recommended that amphipod bioassays be used in conjunction with dry-weight AET to determine and rank problem areas if resources do not permit a broad suite of biological tests to be conducted.

SLC were intended more for protecting healthy benthic infaunal communities than for effectively distinguishing existing problem areas. As such, SLC may be more sensitive than required in defining problem areas for high priority remedial action. However, SLC are recommended as possible goals for sediment cleanup actions after problem areas have been defined, as are the lower confidence limits of the lowest AET (i.e., most sensitive) determined for a range of biological indicators.

8.3 Identification of Potential Problem Chemicals

Ideally, an approach used to identify potential problem chemicals should be capable of encompassing a wide range of chemicals. The approach should be accurate (i.e., efficient for individual chemicals). The restricted applicability of the EP approach to nonpolar, nonionic organic compounds limits its effectiveness at identifying potential problem chemicals.

The AET approach, which can be applied for any measured chemical, attempts to ensure with high probability that sediments with chemicals exceeding their AET will have associated biological effects. The approach is recommended for identification of problem chemicals because it more accurately identified problem sediments with available biological indicators than other approaches (see Table 13 in Section 7.1.1).

The SLC approach is also recommended as a possible tool for identifying potential problem chemicals. Like the AET approach, it is recommended for application to any measured chemical. It also had a high level of efficiency according to one biological indicator for the chemicals for which it was tested (i.e., sediments with HPAH, naphthalene, or mercury concentrations above SLC often had associated Microtox bioassay impacts).

8.4 Identification of Appropriate Sediments for Open-Water Disposal

The EP approach may be sensitive to potential effects in sediments with low concentrations of selected contaminants, but had poor accuracy in correctly identifying severely impacted sediments. This may result in part because development of sediment quality values for metals and polar organic compounds was not considered appropriate using the EP approach. Hence, EP values for these substances were not available, although exposure to metals and polar organic compounds could potentially result in severe biological impacts. Ideally, an approach used to identify "acceptable sediments" would perfectly predict all impacted sediments, and would easily identify marginally impacted sediments as well (i.e., the approach should be protective without exception). Hence, EP values are recommended for use in identifying appropriate sediments for open-water disposal only when used in conjunction with sediment quality values developed by an alternative approach (e.g., AET or SLC) for metals, polar organic compounds, and ionic nonpolar organic compounds, or with a set of confirming biological tests.

The "potential" effect threshold (discussed in Section 2.7.2 of the AET approach) represents the concentration below which there are no statistically significant biological effects in any sample. This threshold is far more protective than the AET. It is likely too protective in identifying "acceptable" sediments because Puget Sound reference conditions exceed the threshold set for most chemicals, and is not recommended.

AET values, unless used with a safety factor or confirming biological tests, are not well suited for the identification of acceptable sediments for disposal at unconfined open-water sites. The AET approach is designed to predict sediment concentrations above which biological effects are always

expected. Hence, AET are recommended for identifying "acceptable" sediments for disposal if a safety factor is applied that would adjust the sediment quality value to less than the lower confidence limits of the lowest AET determined for each chemical (i.e., the most sensitive AET for a range of biological indicators). A large number of sediments may be misidentified as potentially impacted according to this guideline, but sediments that pass the guideline would likely be without hazard to the environment. This safety factor could be determined arbitrarily or with respect to defined reference conditions. Otherwise, a set of biological tests should be used in conjunction with the original AET values to identify "acceptable" sediments.

SLC values are better suited to identifying sediment concentrations that are protective of sensitive taxa, which presumably would not be adversely affected by exposure to "acceptable sediments." SLC are recommended for this purpose once SLC values have been developed for a wider range of chemicals. By setting a lower concentration cutoff in the SLC approach (e.g., the concentration that is protective of 99 percent of the taxa rather than 95 percent), more protective sediment quality values could also be developed for use in identifying "acceptable sediments."

Alternatively, "acceptable sediments" can be defined as those that already exist in the environment (away from urban centers). This definition suggests use of reference area concentrations to define "acceptable sediments", or continuance of a "non-degradation" policy at disposal sites by not permitting sediments with higher than average concentrations found at the site (i.e., the goal of the Fourmile Rock Interim Criteria). For long-term management, chemical-specific sediment quality values based on biological effects data are recommended over acceptance of these more arbitrary guidelines.

8.5 Prioritization of Laboratory Cause-Effect Studies

Definitive cause-effect relationships can only be determined under controlled laboratory conditions, where chemicals can be added to sediments at known concentrations and biological responses of test organisms can be compared to those of control organisms. Such studies would be very useful for establishing sediment quality values. However, considerable time and effort will be required to account for responses of a wide variety of marine organisms to all potential problem chemicals and combinations of chemicals over wide concentration ranges.

It is recommended that results of applications of sediment quality values be used to guide laboratory cause-effect studies. Chemicals that are frequently identified as problem chemicals should receive high priority in laboratory studies. Assuming that the sediment quality values used are accurate, this prioritization will focus efforts on chemicals that are potentially of greatest concern and will provide information about concentration ranges for their threshold effect levels. Results of laboratory studies will, in turn, provide the most reliable means of testing the accuracy of sediment quality values.

8.6 Appropriate Normalizations of Sediment Quality Values

AET developed from chemical data normalized to sediment dry weight were consistently more accurate in correctly identifying biologically impacted stations than those developed from data normalized to organic carbon content or percent fine-grained sediment. This trend was observed for nonpolar organic compounds as well as other contaminants (Section 7.1.1). Dry-weight normalization also was the most predictive of biological effects in statistical pattern recognition analyses (Appendix D). Hence, dry-weight normalization is recommended as an appropriate normalization technique for sediment quality values developed from field data (e.g., AET and SLC).

Reasons that dry-weight normalization may have outperformed organic carbon normalization are summarized in this section and discussed in more detail in Appendix H (Response to Comments). It is unlikely that the database used for testing of AET influenced the success of organic carbon vs. dry-weight AET. The amphipod bioassay and benthic infaunal stations were compiled from numerous studies and study areas. The oyster larvae and Microtox bioassay samples were taken from the Commencement Bay study only. However, evidence of the better predictive success of dry-weight AET relative to organic carbon AET does not consist solely of oyster larvae and Microtox bioassay AET (although they are consistent with the trends observed for amphipod bioassay and benthic AET).

Dry-weight normalization assumes that mass loading of a contaminant in sediment is a predominant factor influencing toxicity to exposed organisms (although organic carbon interactions may be a secondary factor). Organic carbon normalization theory assumes that interstitial water is the primary source of nonpolar organic contaminants to biota (e.g., Battelle 1986), and that, under equilibrium conditions, the distribution of nonpolar contaminants between sedimentary organic matter and water (K_{OC}) is constant (and predictable). Organic carbon tends to act as a sink for nonpolar contaminants (i.e., organic carbon content and sediment toxicity should be inversely related). Hence, as sediment organic carbon content increases, toxicity "threshold" values expressed per gram of bulk sediment should decrease. If contaminant concentrations are normalized to organic carbon content, then threshold values should be constant for that contaminant in all sediments.

The empirical AET and SLC approaches do not favor one of these mechanistic explanations over the other, but can operate whether one, a combination of the two, or alternative assumptions are appropriate. Further studies are recommended to elucidate the underlying mechanism. For contaminated sediments in the environment, organic carbon normalization could be less predictive than dry-weight normalization if one or more of the following three alternative assumptions are true:

- Sediment/interstitial water systems are not at equilibrium
- All sediment organic matter does not have uniform affinity for hydrophobic pollutants
- Interstitial water is not the predominant route of contaminant uptake.

If sediment-water equilibrium is not attained in the environment, organic carbon content may not correlate well with the bioavailable, toxic portions of nonpolar organic compound loadings in sediment. If different kinds of organic matter differ in their affinity for a given chemical, then normalization to bulk organic carbon content may introduce errors. Finally, release or binding of contaminants through direct alteration of sediment matrices by benthic organisms (e.g., Shaw and Wiggs 1980) could reduce the importance of sediment-water equilibrium (and hence, organic carbon partitioning) as a predominant mechanism controlling contaminant uptake.

8.7 Use of Conventional Variables in Sediment Management

As summarized in Appendix G, conventional variables were evaluated as tools for sediment management in two ways: (1) conventional variables were used to normalize chemical concentrations when generating AET and SLC values, and (2) conventional variables were themselves used as indicators of sediment quality (e.g., a total organic carbon AET was developed, potentially as an indicator of organic enrichment). For both the AET and SLC approaches, use of chemicals normalized to dry weight was consistently more accurate (by measures defined in Section 7.1) than use of chemicals normalized to organic carbon content or percent fine-grained sediment (Tables 13 and 17 in Sections 7.1.1 and 7.1.4, respectively).

Sediment quality values were established using the AET approach for three conventional variables: total organic carbon, total volatile solids, and percent fine-grained material. Because the AET for organic carbon and total volatile solids (Table 6) are at levels that will seldom be exceeded in Puget Sound, these variables may be of limited use for screening samples. For the three stations exceeding these values (1M1-13, 1SP-14, and 3EV-04; Appendix Table B-2), other problem chemicals were also indicated. Thus, the conventional variables did not identify predicted biologically impacted stations that were not already identified by chemical variables. AET for fine-grained particulate material were of limited use because some nonimpacted stations had very high fine-grained sediment content (up to 98 percent).

All conventional variables for which some data were available (e.g., oil and grease, and sulfides) were not evaluated. A general relationship was observed in Commencement Bay sediments between high levels of organic carbon and sulfides. Oil and grease concentrations in Commencement Bay sediments did not correlate well with the distribution of other chemical concentrations. However, high oil and grease concentrations were observed in a waterway that received considerable storm drain runoff (City Waterway; Tetra Tech 1985). This variable may serve as an independent indicator of contamination for specific urban sources. Data for other variables (e.g., chemical oxygen demand) were unavailable.

It is recommended that sediment conventional variables not be used to identify "acceptable sediments" because substantial chemical contamination can be found in sediments that appear "acceptable" according to conventional measurements. These variables can be used to indicate gross contamination

of sediments, and as a cost effective screening tool in a preliminary problem identification.

Overall, conventional variables appeared to be of limited use in the application of sediment quality values. This does not indicate that variables such as organic carbon content are not useful for interpreting geochemical distributions of chemicals (particularly nonpolar organic compounds), but may indicate that conventional variables are not the predominant factors controlling bioavailability and sediment toxicity.

8.8 Summary of Recommendations for Uses of Sediment Quality Values

The recommendations summarized in this section are specific to the potential application of the sediment quality values generated in this project to management of sediments in Puget Sound:

1. For long-term management of contaminated sediments, chemical-specific sediment quality values based on biological effects data are recommended over existing guidelines related to reference area chemical concentrations.

2. Program managers should review a variety of sediment quality values for several approaches when making decisions on appropriate values or their modification for specific applications (e.g., see summary of data in Tables 6-10 for three approaches and existing Puget Sound guidelines)

3. After development of SLC for a wider range of chemicals than determined in this project, SLC are recommended especially for use in screening decisions on the need for further chemical or biological testing of sediments in regulatory programs (Section 8.1).

4. The lower confidence limits established for the lowest AET (i.e., most sensitive) for a chemical based on a range of biological tests are also recommended for use in making screening decisions concerning the need for biological testing of contaminated sediments (Section 8.1).

5. AET normalized to sediment dry weight are recommended as the most accurate sediment quality values for correctly identifying impacted sediments according to available biological indicators (Table 13, and Sections 7.1.1 and 8.2).

6. AET and SLC are both recommended as possible tools for the identification of problem chemicals in biologically impacted sediments. Both of the approaches can be applied to any measured chemical and their apparent high efficiency of identifying problem sediments based on individual chemical values (Section 8.3).

7. Although not generally recommended over other sediment quality values because of low accuracy in identifying severely impacted sediments, selected EP values for chemicals with established chronic water quality criteria (e.g., PCBs and p,p'-DDT) appear to be protective guidelines that may have use in identifying "acceptable" sediments for open-water disposal.

These values must be used in conjunction with additional sediment quality values from other approaches (e.g., AET or SLC) for metals, polar organic compounds, and ionic nonpolar organic compounds, or with a set of confirming biological tests (Sections 7.1.3 and 8.4).

8. AET are recommended for use in identifying "acceptable" sediments for open-water disposal only when a safety factor is applied that would adjust the sediment quality value to less than the lower confidence limits of the most sensitive AET for a range of biological indicators. Otherwise, a set of confirming biological tests should be used in conjunction with the original AET values to determine "acceptable" sediments (Sections 7.2.2.2 and 8.4)

9. SLC are recommended as especially appropriate sediment quality values for use in identifying "acceptable" sediments, but SLC values for a wider range of chemicals than determined in this project will be required (Section 8.4).

10. SLC are recommended as possible remedial action cleanup goals for contaminated sediments. The lower confidence intervals of the most sensitive AET for a range of biological indicators are also recommended for this purpose (Section 8.4).

11. Sediment quality values based on field data (e.g., AET, SLC) should be used to help determine appropriate chemicals for focusing laboratory cause-effect studies (Section 8.5).

12. Dry-weight normalization is recommended as an appropriate method for generating sediment quality values from field data. Normalization to organic carbon content or percent fine-grained material is also appropriate but results in generally lower predictive success in correctly identifying biologically impacted sediments.

13. Chemical detection limits should be low enough to ensure confident quantification of contaminant concentrations (dry weight) at less than one half the corresponding sediment quality value for the chemical, and preferably one tenth the value (Section 7.2.2.4 and Appendix F).

14. Sediment quality values for conventional variables (e.g., sulfides, organic enrichment) were ineffective in predicting biologically impacted sediments. These values should not be used to identify "acceptable" sediments for open-water disposal without confirming evidence, because high concentrations of toxic contaminants can be present in samples that have apparently "normal" values for bulk sediment variables.

8.9 Recommendations for Future Studies

The following recommendations are included as specific suggestions for refining or verifying the sediment quality values generated in this project:

1. Further study of the SLC approach is recommended using a larger biological database and a wider range of chemicals than tested in this project (Sections 6.2.2 and 8.1). The approach should be applied in both its original and modified forms to determine the sensitivity of the underlying assumptions (Section 2.6).

2. AET values should be developed for species-level taxa that are apparently sensitive to toxic contamination in addition to the existing AET for major taxonomic groups (see Section 6.2.2).

3. Additional matched bioeffects and chemical data should be collected for sediments that contain high, but apparently naturally-derived, concentrations of crustal elements (e.g., nickel, chromium) to better define AET for these metals (Section 8.1).

4. The AET and SLC sediment quality values derived in this report should be used to test an independent data set containing a range of chemical and biological indicator data (e.g., results from the Elliott Bay Toxics Action Plan). Such a comparison will test the predictive power of these empirical sediment quality values in identifying problem sediments. In this study, multiple biological indicator data were only available for Commencement Bay samples.

5. Sediment quality values should be developed for other biological indicators (e.g., fish bioaccumulation or histopathology AET) than available for this project because of the potential for chronic effects to occur at lower concentrations than might produce a response in acute bioassays, or in organisms with different sensitivities than benthic infauna.

6. Mechanistic studies should be undertaken to determine why dry-weight normalization appears to yield sediment quality values that more accurately predict biological impacts than sediment quality values normalized to organic carbon (see potential hypotheses in Section 8.6).

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APPENDIX A

SEDIMENT DATA COMPILED IN SEDIMENT QUALITY VALUES DATABASE

APPENDIX A. SEDIMENT DATA

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Each study used for this report has been assigned a group number (i.e., 1-9). This number is in the first column of Tables A-3 through A-8. The study in Table A-1 is group 1 and the study in Table A-2 is group 2. Station numbers have been assigned for this study in addition to the original investigators' station numbers. These station numbers are in column 3 of Tables A-1 and A-2 and in column 2 of Tables A-3 through A-8. The station number prefix corresponds to the geographical location of the station as follows:

AP	Alki Point
B	Blair waterway, Commencement Bay
BH	Bellingham Bay
BL	Blair waterway, Commencement Bay
CI	City waterway, Commencement Bay
CR	Carr Inlet
CS	Case Inlet
DB	Dabob Bay
DR	Duwamish River (includes East and West waterways)
EB	Elliott Bay
EV	Everett Harbor
HY	Hylebos waterway, Commencement Bay
MD	Middle waterway, Commencement Bay
MI	Milwaukee waterway, Commencement Bay
PW	Point Williams
RS	Ruston - Point Defiance Shoreline
SC	Sinclair Inlet
SI	Sitcum waterway, Commencement Bay
SP	St. Paul waterway, Commencement Bay
SM	Samish Inlet
SQ	Sequim Bay
WP	West Point

All organic compounds are expressed as ug/kg (ppb) dry weight and metals are expressed as mg/kg (ppm) dry weight.

Toxicity, benthic, and microtox codes are indicated for all stations. The toxicity code is defined as:

0 = No data available

1 = No significant[a] oyster larvae abnormality or amphipod mortality

2 = Significant[a] oyster larvae abnormality

3 = Significant[a] amphipod mortality

4 = Both significant[a] oyster larvae abnormality and amphipod mortality.

The benthic code is defined as:

0 = No data available

1 = No significant[a] depressions in benthic infaunal abundances

2 = Significant[a] depressions in benthic infaunal abundances of one major taxonomic group

3 = Significant[a] depressions in benthic infaunal abundances of more than one major taxonomic group.

The microtox code is defined as:

0 = No data available

1 = No significant[a] decrease in bacterial luminescence

2 = Significant[a] decrease in bacterial luminescence.

[a] Significance implies statistically significant difference ($P>0.05$) from reference conditions.

Table A-1. COMMENCEMENT BAY - MAIN SEDIMENT QUALITY SURVEY[a]

STATION#	TOX CODE	BENTHIC CODE	MICRO CODE
1 BL-11	1	1	1
1 BL-13	1	1	2
1 BL-21	1	1	1
1 BL-25	3	1	1
1 BL-28	1	1	1
1 BL-31	1	1	2
1 CI-11	4	2	2
1 CI-13	2	3	2
1 CI-16	2	3	2
1 CI-17	1	1	2
1 CI-20	4	1	1
1 CI-22	1	1	1
1 CR-11	1	1	1
1 CR-12	1	1	1
1 CR-13	1	1	1
1 CR-14	1	1	1
1 HY-12	2	1	2
1 HY-14	1	2	2
1 HY-17	2	3	2
1 HY-22	4	3	2
1 HY-23	4	3	2
1 HY-24	1	1	2
1 HY-28	1	1	1
1 HY-32	1	3	1
1 HY-37	1	2	2
1 HY-42	3	1	2
1 HY-43	1	1	2
1 HY-44	1	1	1
1 HY-47	2	2	2
1 HY-50	1	1	2
1 MD-12	1	1	1
1 MI-11	3	1	1
1 MI-13	1	1	2
1 MI-15	3	1	2
1 RS-12	1	1	1
1 RS-13	4	1	1
1 RS-14	1	1	1
1 RS-18	4	3	2
1 RS-19	4	2	2
1 RS-20	1	2	2
1 RS-22	1	0	1
1 RS-24	3	0	1
1 SI-11	1	2	2
1 SI-12	3	2	2
1 SI-15	3	1	1
1 SP-11	1	1	2
1 SP-12	2	1	2
1 SP-14	4	3	2
1 SP-15	4	3	2
1 SP-16	4	2	2

The 50 stations listed on this page have biological effects data and are used for this report. Additional stations and associated chemical data are include on subsequent pages of this Table A-1. Where replicate data have been provided, the mean value is used for calculations.

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	phenol	2,4-di-methyl-phenol
17110019-BL-000-	MSQS	BL-11	S05C -		B10	U10
17110019-BL-000-	MSQS	BL-12	S01C -		B25	U10
17110019-BL-000-	MSQS	BL-13	S05C -		B10	U10
17110019-BL-000-	MSQS	BL-14	S01C -		B25	U10
17110019-BL-000-	MSQS	BL-15	S01C -		15	U10
17110019-BL-000-	MSQS	BL-16	S01C -		220	17
17110019-BL-000-	MSQS	BL-17	S01C -	01	84	U10
17110019-BL-000-	MSQS	BL-17	S01C -	02	200	U10
17110019-BL-000-	MSQS	BL-18	S01C -		220	U10
17110019-BL-000-	MSQS	BL-19	S01C -		130	U10
17110019-BL-000-	MSQS	BL-20	S01C -		230	U10
17110019-BL-000-	MSQS	BL-21	S05C -		240	U10
17110019-BL-000-	MSQS	BL-22	S01C -		140	U10
17110019-BL-000-	MSQS	BL-23	S01C -		550	U10
17110019-BL-000-	MSQS	BL-24	S01C -		82	U10
17110019-BL-000-	MSQS	BL-25	S05C -		63	U10
17110019-BL-000-	MSQS	BL-26	S01C -		420	U10
17110019-BL-000-	MSQS	BL-27	S01C -		110	U10
17110019-BL-000-	MSQS	BL-28	S05C -		62	U10
17110019-BL-000-	MSQS	BL-29	S01C -		190	U10
17110019-BL-000-	MSQS	BL-30	S01C -		240	U10
17110019-BL-000-	MSQS	BL-31	S05C -		420	U10
17110019-BL-000-	MSQS	BL-32	S01C -		160	U10
17110019-HY-000-	MSQS	CB-11	S01C -		200	23
17110019-CB-000-	MSQS	CB-12	S01C -		92	U10
17110019-CB-000-	MSQS	CB-13	S01C -		70	U10
17110019-CB-000-	MSQS	CB-14	S01C -		92	19
17110019-CI-000-	MSQS	CI-11	S02C -		Z1100	U50
17110019-CI-000-	MSQS	CI-12	S01C -		Z270	U10
17110019-CI-000-	MSQS	CI-13	S05C -		Z70	U10
17110019-CI-000-	MSQS	CI-14	S01C -		Z130	U10
17110019-CI-000-	MSQS	CI-15	S01C -		Z240	77
17110019-CW-000-	MSQS	CI-16	S05C -		U10	50
17110019-CI-000-	MSQS	CI-17	S05C -	01	Z190	U10
17110019-CI-000-	MSQS	CI-17	S05C -	02	Z360	U10
17110019-CI-000-	MSQS	CI-18	S01C -		Z160	38
17110019-CI-000-	MSQS	CI-19	S01C -		Z200	U10
17110019-CI-000-	MSQS	CI-20	S05C -		Z1200	29
17110019-CI-000-	MSQS	CI-21	S01C -		Z20	U20
17110019-CI-000-	MSQS	CI-22	S05C -		Z30	U10
17110019-CR-000-	MSQS	CR-11	S01C -		U10	U10
17110019-CR-000-	MSQS	CR-12	S05C -		U10	U10
17110019-CR-000-	MSQS	CR-13	S01C -		44	U10

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	phenol	2,4-di-methyl-phenol
17110019-CR-000-	MSQS	CR-14	S05C	-	62	U10
17110019-HY-000-	MSQS	HY-11	S01C	-	290	U10
17110019-HY-000-	MSQS	HY-12	S01C	-	500	U10
17110019-HY-000-	MSQS	HY-13	S01C	-	130	U10
17110019-HY-000-	MSQS	HY-14	S05C	-	280	U10
17110019-HY-000-	MSQS	HY-15	S01C	-	43	U10
17110019-HY-000-	MSQS	HY-16	S01C	-	2100	U20
17110019-HY-000-	MSQS	HY-17	S01C	-	250	U10
17110019-HY-000-	MSQS	HY-18	S01C	-	120	U20
17110019-HY-000-	MSQS	HY-19	S01C	-	Z190	U20
17110019-HY-000-	MSQS	HY-20	S01C	- 01	Z650	U10
17110019-HY-000-	MSQS	HY-20	S01C	- 02	Z50	U10
17110019-HY-000-	MSQS	HY-21	S01C	-	U10	U10
17110019-HY-000-	MSQS	HY-22	S05C	-	Z530	U10
17110019-HY-000-	MSQS	HY-23	S01C	-	B25	U10
17110019-HY-000-	MSQS	HY-24	S01C	-	B25	U10
17110019-HY-000-	MSQS	HY-25	S01C	-	Z74	U10
17110019-HY-000-	MSQS	HY-26	S01C	-	Z20	U20
17110019-HY-000-	MSQS	HY-27	S01C	-	B10	U10
17110019-HY-000-	MSQS	HY-28	S01C	-	Z110	U10
17110019-HY-000-	MSQS	HY-29	S01C	-	B10	U10
17110019-HY-000-	MSQS	HY-30	S01C	-	140	U10
17110019-HY-000-	MSQS	HY-31	S01C	- 01	68	U10
17110019-HY-000-	MSQS	HY-31	S01C	- 02	61	U10
17110019-HY-000-	MSQS	HY-32	S01C	-	110	U10
17110019-HY-000-	MSQS	HY-33	S01C	-	150	U10
17110019-HY-000-	MSQS	HY-34	S01C	-	90	14
17110019-HY-000-	MSQS	HY-35	S01C	-	110	22
17110019-HY-000-	MSQS	HY-36	S01C	-	490	U10
17110019-HY-000-	MSQS	HY-37	S01C	-	420	U10
17110019-HY-000-	MSQS	HY-38	S01C	-	200	U10
17110019-HY-000-	MSQS	HY-39	S01C	-	B10	U10
17110019-HY-000-	MSQS	HY-40	S01C	-	Z110	U10
17110019-HY-000-	MSQS	HY-41	S01C	-	Z40	U20
17110019-HY-000-	MSQS	HY-42	S01C	-	300	U10
17110019-HY-000-	MSQS	HY-43	S01C	-	350	U10
17110019-HY-000-	MSQS	HY-44	S01C	-	U10	U10
17110019-HY-000-	MSQS	HY-45	S01C	-	B10	U10
17110019-HY-000-	MSQS	HY-46	S01C	-	B10	U10
17110019-HY-000-	MSQS	HY-47	S05C	-	Z120	U20
17110019-HY-000-	MSQS	HY-48	S01C	-	Z57	U10
17110019-HY-000-	MSQS	HY-49	S01C	-	110	U10
17110019-HY-000-	MSQS	HY-50	S05C	-	330	U10

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	phenol	2,4-di-methyl-phenol
17110019-HY-000-	MSQS	HY-51	S01C -		Z150	U10
17110019-MD-000-	MSQS	MD-11	S01C -		Z850	U10
17110019-MD-000-	MSQS	MD-12	S05C -		Z360	U10
17110019-MD-000-	MSQS	MD-13	S01C -		Z200	U10
17110019-MI-000-	MSQS	MI-11	S01C -	02	260	U10
17110019-MI-000-	MSQS	MI-12	S01C -		810	37
17110019-MI-000-	MSQS	MI-13	S01C -		Z150	29
17110019-MI-000-	MSQS	MI-14	S01C -		810	29
17110019-MI-000-	MSQS	MI-15	S01C -		Z20	U10
17110019-RS-000-	MSQS	RS-11	S01C -		260	U10
17110019-RS-000-	MSQS	RS-12	S01C -		51	U10
17110019-RS-000-	MSQS	RS-13	S01C -		230	U10
17110019-RS-000-	MSQS	RS-14	S05C -	01	270	U10
17110019-RS-000-	MSQS	RS-14	S05C -	02	250	U10
17110019-RS-000-	MSQS	RS-15	S02C -		130	U10
17110019-RS-000-	MSQS	RS-16	S01C -		420	210
17110019-RS-000-	MSQS	RS-17	S01C -		110	23
17110019-RS-000-	MSQS	RS-18	S01C -		310	U10
17110019-RS-000-	MSQS	RS-19	S01C -		99	U10
17110019-RS-000-	MSQS	RS-20	S01C -		56	U10
17110019-RS-000-	MSQS	RS-21	S01C -		220	U10
17110019-RS-000-	MSQS	RS-22	S01C -		49	U10
17110019-RS-000-	MSQS	RS-24	S05C -		43	U10
17110019-SI-000-	MSQS	SI-11	S05C -		Z160	U10
17110019-SI-000-	MSQS	SI-12	S01C -		Z190	U10
17110019-SI-000-	MSQS	SI-13	S01C -		Z220	19
17110019-SI-000-	MSQS	SI-14	S01C -		Z16	26
17110019-SI-000-	MSQS	SI-15	S05C -		Z120	U10
17110019-SP-000-	MSQS	SP-11	S05C -		Z130	U10
17110019-SP-000-	MSQS	SP-12	S05C -		Z25	U10
17110019-SP-000-	MSQS	SP-13	S01C -		Z160	71
17110019-SP-000-	MSQS	SP-14	S01C -		Z1700	U40
17110019-SP-000-	MSQS	SP-15	S05C -		Z110	U10
17110019-SP-000-	MSQS	SP-16	S05C -		Z240	U10
17110019-DP-000-	MSQS	WBS	CTL -	01	U10	U10
17110019-DP-000-	MSQS	WBS	CTL -	02	U10	U10

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	2-methyl-phenol	4-methyl-phenol
17110019-BL-000-	MSQS	BL-11	S05C -		L10	48
17110019-BL-000-	MSQS	BL-12	S01C -		14	84
17110019-BL-000-	MSQS	BL-13	S05C -		L10	120
17110019-BL-000-	MSQS	BL-14	S01C -		U10	62
17110019-BL-000-	MSQS	BL-15	S01C -		12	63
17110019-BL-000-	MSQS	BL-16	S01C -		52	320
17110019-BL-000-	MSQS	BL-17	S01C -	01	12	80
17110019-BL-000-	MSQS	BL-17	S01C -	02	62	410
17110019-BL-000-	MSQS	BL-18	S01C -		29	410
17110019-BL-000-	MSQS	BL-19	S01C -		15	110
17110019-BL-000-	MSQS	BL-20	S01C -		U10	110
17110019-BL-000-	MSQS	BL-21	S05C -		U10	420
17110019-BL-000-	MSQS	BL-22	S01C -		11	160
17110019-BL-000-	MSQS	BL-23	S01C -		12	92
17110019-BL-000-	MSQS	BL-24	S01C -		U10	180
17110019-BL-000-	MSQS	BL-25	S05C -		U10	170
17110019-BL-000-	MSQS	BL-26	S01C -		14	120
17110019-BL-000-	MSQS	BL-27	S01C -		26	240
17110019-BL-000-	MSQS	BL-28	S05C -		16	190
17110019-BL-000-	MSQS	BL-29	S01C -		U10	660
17110019-BL-000-	MSQS	BL-30	S01C -		15	240
17110019-BL-000-	MSQS	BL-31	S05C -		L10	230
17110019-BL-000-	MSQS	BL-32	S01C -		22	340
17110019-HY-000-	MSQS	CB-11	S01C -		11	130
17110019-CB-000-	MSQS	CB-12	S01C -		U10	47
17110019-CB-000-	MSQS	CB-13	S01C -		L10	210
17110019-CB-000-	MSQS	CB-14	S01C -		U10	61
17110019-CI-000-	MSQS	CI-11	S02C -		U50	460
17110019-CI-000-	MSQS	CI-12	S01C -		74	550
17110019-CI-000-	MSQS	CI-13	S05C -		36	270
17110019-CI-000-	MSQS	CI-14	S01C -		49	310
17110019-CI-000-	MSQS	CI-15	S01C -		67	940
17110019-CW-000-	MSQS	CI-16	S05C -		46	1200
17110019-CI-000-	MSQS	CI-17	S05C -	01	L10	700
17110019-CI-000-	MSQS	CI-17	S05C -	02	30	500
17110019-CI-000-	MSQS	CI-18	S01C -		40	670
17110019-CI-000-	MSQS	CI-19	S01C -		37	240
17110019-CI-000-	MSQS	CI-20	S05C -		43	230
17110019-CI-000-	MSQS	CI-21	S01C -		35	330
17110019-CI-000-	MSQS	CI-22	S05C -		38	150
17110019-CR-000-	MSQS	CR-11	S01C -		U10	U10
17110019-CR-000-	MSQS	CR-12	S05C -		U10	U10
17110019-CR-000-	MSQS	CR-13	S01C -		U10	26
17110019-CR-000-	MSQS	CR-14	S05C -		U10	32

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	2-methyl-phenol	4-methyl-phenol
17110019-HY-000-	MSQS	HY-11	S01C -		U10	74
17110019-HY-000-	MSQS	HY-12	S01C -		U10	320
17110019-HY-000-	MSQS	HY-13	S01C -		U10	67
17110019-HY-000-	MSQS	HY-14	S05C -		U10	26
17110019-HY-000-	MSQS	HY-15	S01C -		U10	38
17110019-HY-000-	MSQS	HY-16	S01C -		U20	110
17110019-HY-000-	MSQS	HY-17	S01C -		U10	39
17110019-HY-000-	MSQS	HY-18	S01C -		U20	67
17110019-HY-000-	MSQS	HY-19	S01C -		U20	71
17110019-HY-000-	MSQS	HY-20	S01C -	01	95	U10
17110019-HY-000-	MSQS	HY-20	S01C -	02	U10	U10
17110019-HY-000-	MSQS	HY-21	S01C -		U10	U10
17110019-HY-000-	MSQS	HY-22	S05C -		15	88
17110019-HY-000-	MSQS	HY-23	S01C -		U10	21
17110019-HY-000-	MSQS	HY-24	S01C -		U10	110
17110019-HY-000-	MSQS	HY-25	S01C -		U10	70
17110019-HY-000-	MSQS	HY-26	S01C -		U20	160
17110019-HY-000-	MSQS	HY-27	S01C -		U10	110
17110019-HY-000-	MSQS	HY-28	S01C -		U10	180
17110019-HY-000-	MSQS	HY-29	S01C -		U10	U10
17110019-HY-000-	MSQS	HY-30	S01C -		U10	61
17110019-HY-000-	MSQS	HY-31	S01C -	01	U10	U10
17110019-HY-000-	MSQS	HY-31	S01C -	02	U10	U10
17110019-HY-000-	MSQS	HY-32	S01C -		25	190
17110019-HY-000-	MSQS	HY-33	S01C -		U10	75
17110019-HY-000-	MSQS	HY-34	S01C -		16	520
17110019-HY-000-	MSQS	HY-35	S01C -		34	190
17110019-HY-000-	MSQS	HY-36	S01C -		U10	63
17110019-HY-000-	MSQS	HY-37	S01C -		11	50
17110019-HY-000-	MSQS	HY-38	S01C -		U10	71
17110019-HY-000-	MSQS	HY-39	S01C -		21	120
17110019-HY-000-	MSQS	HY-40	S01C -		31	190
17110019-HY-000-	MSQS	HY-41	S01C -		U20	L20
17110019-HY-000-	MSQS	HY-42	S01C -		L10	45
17110019-HY-000-	MSQS	HY-43	S01C -		U10	45
17110019-HY-000-	MSQS	HY-44	S01C -		U10	U10
17110019-HY-000-	MSQS	HY-45	S01C -		U10	55
17110019-HY-000-	MSQS	HY-46	S01C -		U10	90
17110019-HY-000-	MSQS	HY-47	S05C -		14	49
17110019-HY-000-	MSQS	HY-48	S01C -		U10	100
17110019-HY-000-	MSQS	HY-49	S01C -		14	120
17110019-HY-000-	MSQS	HY-50	S05C -		27	290
17110019-HY-000-	MSQS	HY-51	S01C -		15	250
17110019-MD-000-	MSQS	MD-11	S01C -		68	620

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	2-methyl-phenol	4-methyl-phenol
17110019-MD-000-	MSQS	MD-12	S05C -		63	670
17110019-MD-000-	MSQS	MD-13	S01C -		36	450
17110019-MI-000-	MSQS	MI-11	S01C -	01	18	150
17110019-MI-000-	MSQS	MI-11	S01C -	02	15	140
17110019-MI-000-	MSQS	MI-12	S01C -		30	260
17110019-MI-000-	MSQS	MI-13	S01C -		19	140
17110019-MI-000-	MSQS	MI-14	S01C -		23	250
17110019-MI-000-	MSQS	MI-15	S01C -		22	220
17110019-RS-000-	MSQS	RS-11	S01C -		19	380
17110019-RS-000-	MSQS	RS-12	S01C -		13	130
17110019-RS-000-	MSQS	RS-13	S01C -		72	560
17110019-RS-000-	MSQS	RS-14	S05C -	01	U10	500
17110019-RS-000-	MSQS	RS-14	S05C -	02	U10	270
17110019-RS-000-	MSQS	RS-15	S01C -		U10	U10
17110019-RS-000-	MSQS	RS-16	S01C -		46	380
17110019-RS-000-	MSQS	RS-17	S01C -		13	51
17110019-RS-000-	MSQS	RS-18	S01C -		71	190
17110019-RS-000-	MSQS	RS-19	S01C -		U10	L10
17110019-RS-000-	MSQS	RS-20	S01C -		U10	15
17110019-RS-000-	MSQS	RS-21	S01C -		18	79
17110019-RS-000-	MSQS	RS-22	S01C -		U10	U10
17110019-RS-000-	MSQS	RS-24	S05C -		U10	U10
17110019-SI-000-	MSQS	SI-11	S05C -		14	110
17110019-SI-000-	MSQS	SI-12	S01C -		17	180
17110019-SI-000-	MSQS	SI-13	S01C -		19	230
17110019-SI-000-	MSQS	SI-14	S01C -		18	96
17110019-SI-000-	MSQS	SI-15	S05C -		L10	73
17110019-SP-000-	MSQS	SP-11	S05C -		U10	250
17110019-SP-000-	MSQS	SP-12	S05C -		35	390
17110019-SP-000-	MSQS	SP-13	S05C -		100	1900
17110019-SP-000-	MSQS	SP-14	S01C -		U40	96000
17110019-SP-000-	MSQS	SP-15	S05C -		U10	2600
17110019-SP-000-	MSQS	SP-16	S05C -		U10	890
17110019-UP-000-	MSQS	WBS	CTL -	01	U10	U10
17110019-UP-000-	MSQS	WBS	CTL -	02	U10	U10

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2-chloro-phenol	2,4-di-chloro-phenol	4-chloro-3-methyl phenol	2,4,6-tri-chloro-phenol	penta-chloro-phenol	2-nitro-phenol	2,4-di-nitro-phenol	4,6-di-nitro-o-cresol	4-nitro-phenol
17110019-BL-000-	MSQS	BL-11	S05C -		U5	U10	U10	U10	140	U10		U100	U100
17110019-BL-000-	MSQS	BL-12	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-13	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-14	S01C -		U5	U10	U10	U10	58	U10		U100	U100
17110019-BL-000-	MSQS	BL-15	S01C -		U5	U10	U10	U10	44	U10		U100	U100
17110019-BL-000-	MSQS	BL-16	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-17	S01C -	U1	U5	U10	U10	U10	81	U10		U100	U100
17110019-BL-000-	MSQS	BL-17	S01C -	U2	U5	U10	U10	U10	U100	U10		U100	U100
17110019-BL-000-	MSQS	BL-18	S01C -		U5	U10	U10	U10	780	U10		U100	U100
17110019-BL-000-	MSQS	BL-19	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-BL-000-	MSQS	BL-20	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-BL-000-	MSQS	BL-21	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-22	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-BL-000-	MSQS	BL-23	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-24	S01C -		U5	U10	U10	U10	140	U10		U100	U100
17110019-BL-000-	MSQS	BL-25	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-26	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-27	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-BL-000-	MSQS	BL-28	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-BL-000-	MSQS	BL-29	S01C -		U5	U10	U10	U10	92	U10		U100	U100
17110019-BL-000-	MSQS	BL-30	S01C -		U5	U10	U10	U10	860	U10		U100	U100
17110019-BL-000-	MSQS	BL-31	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	MSQS	BL-32	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-MY-000-	MSQS	CB-11	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CB-000-	MSQS	CB-12	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-CB-000-	MSQS	CB-13	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CB-000-	MSQS	CB-14	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CI-000-	MSQS	CI-11	S02C -		U25	U50	U50	U50	U130	U50		U500	U500
17110019-CI-000-	MSQS	CI-12	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-CI-000-	MSQS	CI-13	S05C -		U5	U10	U10	U10	64	U10		U100	U100
17110019-CI-000-	MSQS	CI-14	S01C -		U5	U10	U10	U10	77	U10		U100	U100
17110019-CI-000-	MSQS	CI-15	S01C -		U5	U10	U10	U10	67	U10		U100	U100
17110019-CW-000-	MSQS	CI-16	S05C -		U5	U10	U10	U10	57	U10		U100	U100
17110019-CI-000-	MSQS	CI-17	S05C -	U1	U5	U10	U10	U10	45	U10		U100	U100
17110019-CI-000-	MSQS	CI-17	S05C -	U2	U5	U10	U10	U10	U25	U10		U100	U100
17110019-CI-000-	MSQS	CI-18	S01C -		U5	U10	U10	U10	57	U10		U100	U100
17110019-CI-000-	MSQS	CI-19	S01C -		U5	U10	U10	U10	56	U10		U100	U100
17110019-CI-000-	MSQS	CI-20	S05C -		U5	U10	U10	U10	48	U10		U100	U100
17110019-CI-000-	MSQS	CI-21	S01C -		U10	U20	U20	U20	U80	U20		U200	U200
17110019-CI-000-	MSQS	CI-22	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CR-000-	MSQS	CR-11	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CR-000-	MSQS	CR-12	S05C -		U5	U10	U10	U10	U50	U10		U100	U100

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2-chloro-phenol	2,4-di-chloro-phenol	4-chloro-3-methyl phenol	2,4,6-tri-chloro-phenol	penta-chloro-phenol	2-nitro-phenol	2,4-di-nitro-phenol	4,6-di-nitro-o-cresol	4-nitro-phenol
17110019-CR-000-	MSQS	CR-13	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-CR-000-	MSQS	CR-14	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-11	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-12	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-13	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-14	S05C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-15	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-16	S01C -		U10	U20	U10	U20	U50	U20		U100	U200
17110019-HY-000-	MSQS	HY-17	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-18	S01C -		U10	U20	U10	U20	U50	U20		U100	U200
17110019-HY-000-	MSQS	HY-19	S01C -		U10	U20	U10	U20	U50	U20		U100	U200
17110019-HY-000-	MSQS	HY-20	S01C -	01	U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-20	S01C -	02	U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-21	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-22	S05C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-23	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-24	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-25	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-26	S01C -		U10	U20	U10	U20	U50	U20		U100	U200
17110019-HY-000-	MSQS	HY-27	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-28	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-29	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-30	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-31	S01C -	01	U5	U10	U10	160	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-31	S01C -	02	U5	U10	U10	140	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-32	S01C -		U5	U10	U10	U10	71	U10		U100	U100
17110019-HY-000-	MSQS	HY-33	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-34	S01C -		U5	U10	U10	U10	120	U10		U100	U100
17110019-HY-000-	MSQS	HY-35	S01C -		U5	U10	U10	U10	110	U10		U100	U100
17110019-HY-000-	MSQS	HY-36	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-37	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-38	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-39	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-40	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-41	S01C -		U10	U20	U20	U20	U100	U20		U200	U200
17110019-HY-000-	MSQS	HY-42	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-43	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-44	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-45	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-46	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-HY-000-	MSQS	HY-47	S05C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-HY-000-	MSQS	HY-48	S01C -		U5	U10	U10	U10	U50	U10		U100	U100

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2-chloro-phenol	2,4-di-chloro-phenol	4-chloro-3-methyl phenol	2,4,6-tri-chloro-phenol	penta-chloro-phenol	2-nitro-phenol	2,4-di-nitro-phenol	4,6-di-nitro-o-cresol	4-nitro-phenol
17110019-HY-000-	MSQS	HY-49	S01C -		U5	U10	U10	U10	150	U10		U100	U100
17110019-HY-000-	MSQS	HY-50	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-HY-000-	MSQS	HY-51	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-MD-000-	MSQS	MD-11	S01C -		U5	U10	U10	U10	620	U10		U100	U100
17110019-MD-000-	MSQS	MD-12	S05C -		U5	U10	U10	25	77	U10		U100	U100
17110019-MD-000-	MSQS	MD-13	S01C -		U5	U10	U10	U10	49	U10		U100	U100
17110019-MI-000-	MSQS	MI-11	S01C -	01	U5	U10	U10	U10	U50	U10		U100	U100
17110019-MI-000-	MSQS	MI-11	S01C -	02	U5	U10	U10	U10	U50	U10		U100	U100
17110019-MI-000-	MSQS	MI-12	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-MI-000-	MSQS	MI-13	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-MI-000-	MSQS	MI-14	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-MI-000-	MSQS	MI-15	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-11	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-RS-000-	MSQS	RS-12	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-RS-000-	MSQS	RS-13	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-14	S05C -	01	U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-14	S05C -	02	U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-15	S02C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-RS-000-	MSQS	RS-16	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-17	S01C -		U5	U10	U10	U10	34	U10		U100	U100
17110019-RS-000-	MSQS	RS-18	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-19	S01C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-RS-000-	MSQS	RS-20	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-RS-000-	MSQS	RS-21	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-RS-000-	MSQS	RS-22	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-RS-000-	MSQS	RS-24	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-SI-000-	MSQS	SI-11	S05C -		U5	U10	U10	U10	U75	U10		U100	U100
17110019-SI-000-	MSQS	SI-12	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-SI-000-	MSQS	SI-13	S01C -		U5	U10	U10	U10	L25	U10		U100	U100
17110019-SI-000-	MSQS	SI-14	S01C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-SI-000-	MSQS	SI-15	S05C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-SP-000-	MSQS	SP-11	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-SP-000-	MSQS	SP-12	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-SP-000-	MSQS	SP-13	S01C -		U5	U10	U10	U10	U100	U10		U100	U100
17110019-SP-000-	MSQS	SP-14	S01C -		U20	U40	U40	U40	U100	U40		U400	U400
17110019-SP-000-	MSQS	SP-15	S05C -		U5	U10	U10	U10	U50	U10		U100	U100
17110019-SP-000-	MSQS	SP-16	S05C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-DP-000-	MSQS	WBS	CTL -	01	U5	U10	U10	U10	U25	U10		U100	U100
17110019-DP-000-	MSQS	WBS	CTL -	02	U5	U10	U10	U10	U50	U10		U100	U100

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2,4,5-trichlorophenol
17110019-BL-000-	MSQS	BL-11	SU5C -		U10
17110019-BL-000-	MSQS	BL-12	SU1C -		U10
17110019-BL-000-	MSQS	BL-13	SU5C -		U10
17110019-BL-000-	MSQS	BL-14	SU1C -		U10
17110019-BL-000-	MSQS	BL-15	SU1C -		U10
17110019-BL-000-	MSQS	BL-16	SU1C -		U10
17110019-BL-000-	MSQS	BL-17	SU1C -	01	U10
17110019-BL-000-	MSQS	BL-17	SU1C -	02	U10
17110019-BL-000-	MSQS	BL-18	SU1C -		U10
17110019-BL-000-	MSQS	BL-19	SU1C -		U10
17110019-BL-000-	MSQS	BL-20	SU1C -		U10
17110019-BL-000-	MSQS	BL-21	SU5C -		U10
17110019-BL-000-	MSQS	BL-22	SU1C -		U10
17110019-BL-000-	MSQS	BL-23	SU1C -		U10
17110019-BL-000-	MSQS	BL-24	SU1C -		U10
17110019-BL-000-	MSQS	BL-25	SU5C -		U10
17110019-BL-000-	MSQS	BL-26	SU1C -		U10
17110019-BL-000-	MSQS	BL-27	SU1C -		U10
17110019-BL-000-	MSQS	BL-28	SU5C -		U10
17110019-BL-000-	MSQS	BL-29	SU1C -		U10
17110019-BL-000-	MSQS	BL-30	SU1C -		U10
17110019-BL-000-	MSQS	BL-31	SU5C -		U10
17110019-BL-000-	MSQS	BL-32	SU1C -		U10
17110019-HY-000-	MSQS	CB-11	SU1C -		U10
17110019-CB-000-	MSQS	CB-12	SU1C -		U10
17110019-CB-000-	MSQS	CB-13	SU1C -		U10
17110019-CB-000-	MSQS	CB-14	SU1C -		U10
17110019-CI-000-	MSQS	CI-11	SU2C -		U50
17110019-CI-000-	MSQS	CI-12	SU1C -		U10
17110019-CI-000-	MSQS	CI-13	SU5C -		U10
17110019-CI-000-	MSQS	CI-14	SU1C -		U10
17110019-CI-000-	MSQS	CI-15	SU1C -		U10
17110019-CW-000-	MSQS	CI-16	SU5C -		U10
17110019-CI-000-	MSQS	CI-17	SU5C -	01	U10
17110019-CI-000-	MSQS	CI-17	SU5C -	02	U10
17110019-CI-000-	MSQS	CI-18	SU1C -		U10
17110019-CI-000-	MSQS	CI-19	SU1C -		U10
17110019-CI-000-	MSQS	CI-20	SU5C -		U10
17110019-CI-000-	MSQS	CI-21	SU1C -		U20
17110019-CI-000-	MSQS	CI-22	SU5C -		U10
17110019-CR-000-	MSQS	CR-11	SU1C -		U10
17110019-CR-000-	MSQS	CR-12	SU5C -		U10

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2,4,5-tri-chloro-phenol
17110019-CR-000-	MSQS	CR-13	S01C -		U10
17110019-CR-000-	MSQS	CR-14	S05C -		U10
17110019-HY-000-	MSQS	HY-11	S01C -		U10
17110019-HY-000-	MSQS	HY-12	S01C -		U10
17110019-HY-000-	MSQS	HY-13	S01C -		U10
17110019-HY-000-	MSQS	HY-14	S05C -		U10
17110019-HY-000-	MSQS	HY-15	S01C -		U10
17110019-HY-000-	MSQS	HY-16	S01C -		U10
17110019-HY-000-	MSQS	HY-17	S01C -		U10
17110019-HY-000-	MSQS	HY-18	S01C -		U20
17110019-HY-000-	MSQS	HY-19	S01C -		U20
17110019-HY-000-	MSQS	HY-20	S01C -	01	U10
17110019-HY-000-	MSQS	HY-20	S01C -	02	U10
17110019-HY-000-	MSQS	HY-21	S01C -		U10
17110019-HY-000-	MSQS	HY-22	S05C -		U10
17110019-HY-000-	MSQS	HY-23	S01C -		U10
17110019-HY-000-	MSQS	HY-24	S01C -		U10
17110019-HY-000-	MSQS	HY-25	S01C -		U10
17110019-HY-000-	MSQS	HY-26	S01C -		U20
17110019-HY-000-	MSQS	HY-27	S01C -		U10
17110019-HY-000-	MSQS	HY-28	S01C -		U10
17110019-HY-000-	MSQS	HY-29	S01C -		U10
17110019-HY-000-	MSQS	HY-30	S01C -		U10
17110019-HY-000-	MSQS	HY-31	S01C -	01	U10
17110019-HY-000-	MSQS	HY-31	S01C -	02	U10
17110019-HY-000-	MSQS	HY-32	S01C -		U10
17110019-HY-000-	MSQS	HY-33	S01C -		U10
17110019-HY-000-	MSQS	HY-34	S01C -		U10
17110019-HY-000-	MSQS	HY-35	S01C -		U10
17110019-HY-000-	MSQS	HY-36	S01C -		U10
17110019-HY-000-	MSQS	HY-37	S01C -		U10
17110019-HY-000-	MSQS	HY-38	S01C -		U10
17110019-HY-000-	MSQS	HY-39	S01C -		U10
17110019-HY-000-	MSQS	HY-40	S01C -		U10
17110019-HY-000-	MSQS	HY-41	S01C -		U20
17110019-HY-000-	MSQS	HY-42	S01C -		U10
17110019-HY-000-	MSQS	HY-43	S01C -		U10
17110019-HY-000-	MSQS	HY-44	S01C -		U10
17110019-HY-000-	MSQS	HY-45	S01C -		U10
17110019-HY-000-	MSQS	HY-46	S01C -		U10
17110019-HY-000-	MSQS	HY-47	S05C -		U10
17110019-HY-000-	MSQS	HY-48	S01C -		U10

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2,4,5-tri-chloro-phenol
17110019-HY-000-	MSQS	HY-49	S01C -		U10
17110019-HY-000-	MSQS	HY-50	S05C -		U10
17110019-HY-000-	MSQS	HY-51	S01C -		U10
17110019-MD-000-	MSQS	MD-11	S01C -		150
17110019-MD-000-	MSQS	MD-12	S05C -		29
17110019-MD-000-	MSQS	MD-13	S01C -		U10
17110019-MI-000-	MSQS	MI-11	S01C -	01	U10
17110019-MI-000-	MSQS	MI-11	S01C -	02	U10
17110019-MI-000-	MSQS	MI-12	S01C -		U10
17110019-MI-000-	MSQS	MI-13	S01C -		U10
17110019-MI-000-	MSQS	MI-14	S01C -		U10
17110019-MI-000-	MSQS	MI-15	S01C -		U10
17110019-RS-000-	MSQS	RS-11	S01C -		U10
17110019-RS-000-	MSQS	RS-12	S01C -		U10
17110019-RS-000-	MSQS	RS-13	S01C -		U10
17110019-RS-000-	MSQS	RS-14	S05C -	01	U10
17110019-RS-000-	MSQS	RS-14	S05C -	02	U10
17110019-RS-000-	MSQS	RS-15	S01C -		U10
17110019-RS-000-	MSQS	RS-16	S01C -		U10
17110019-RS-000-	MSQS	RS-17	S01C -		U10
17110019-RS-000-	MSQS	RS-18	S01C -		U10
17110019-RS-000-	MSQS	RS-19	S01C -		U10
17110019-RS-000-	MSQS	RS-20	S01C -		U10
17110019-RS-000-	MSQS	RS-21	S01C -		U10
17110019-RS-000-	MSQS	RS-22	S01C -		U10
17110019-RS-000-	MSQS	RS-24	S05C -		U10
17110019-SI-000-	MSQS	SI-11	S05C -		U10
17110019-SI-000-	MSQS	SI-12	S01C -		U10
17110019-SI-000-	MSQS	SI-13	S01C -		U10
17110019-SI-000-	MSQS	SI-14	S01C -		U10
17110019-SI-000-	MSQS	SI-15	S05C -		U10
17110019-SP-000-	MSQS	SP-11	S05C -		U10
17110019-SP-000-	MSQS	SP-12	S05C -		U10
17110019-SP-000-	MSQS	SP-13	S05C -		U10
17110019-SP-000-	MSQS	SP-14	S01C -		U40
17110019-SP-000-	MSQS	SP-15	S05C -		U10
17110019-SP-000-	MSQS	SP-16	S05C -		U10
17110019-DP-000-	MSQS	WBS	CTL -	01	U10
17110019-DP-000-	MSQS	WBS	CTL -	02	U10

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
LOW MOLECULAR WEIGHT AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	2-methyl naphthalene	naphthalene	acenaphthylene	acenaphthene	fluorene	phenanthrene	anthracene	anthracene/phenanthrene
17110019-BL-000-	MSQS	BL-11	S05C	-	65	300	22	U5	19	98	44	
17110019-BL-000-	MSQS	BL-12	S01C	-	130	310	57	39	52	240	120	
17110019-BL-000-	MSQS	BL-13	S05C	-	110	280	57	39	48	220	110	
17110019-BL-000-	MSQS	BL-14	S01C	-	140	230	98	270	220	1200	780	
17110019-BL-000-	MSQS	BL-15	S01C	-	71	240	33	25	35	140	69	
17110019-BL-000-	MSQS	BL-16	S01C	-	380	590	43	50	73	340	110	
17110019-BL-000-	MSQS	BL-17	S01C	-	01 120	400	51	56	62	220	91	
17110019-BL-000-	MSQS	BL-17	S01C	-	02 270	390	51	44	62	250	98	
17110019-BL-000-	MSQS	BL-18	S01C	-	280	330	33	38	62	230	91	
17110019-BL-000-	MSQS	BL-19	S01C	-	100	260	36	26	34	160	68	
17110019-BL-000-	MSQS	BL-20	S01C	-	120	360	32	38	45	200	86	
17110019-BL-000-	MSQS	BL-21	S05C	-	280	360	37	38	47	230	82	
17110019-BL-000-	MSQS	BL-22	S01C	-	150	750	46	88	84	300	160	
17110019-BL-000-	MSQS	BL-23	S01C	-	170	850	49	120	120	420	220	
17110019-BL-000-	MSQS	BL-24	S01C	-	240	530	44	65	76	310	140	
17110019-BL-000-	MSQS	BL-25	S05C	-	180	480	65	54	69	270	150	
17110019-BL-000-	MSQS	BL-26	S01C	-	240	1100	92	140	120	540	220	
17110019-BL-000-	MSQS	BL-27	S01C	-	160	110	11	38	43	180	62	
17110019-BL-000-	MSQS	BL-28	S05C	-	140	380	38	54	68	290	170	
17110019-BL-000-	MSQS	BL-29	S01C	-	320	870	68	190	190	770	230	
17110019-BL-000-	MSQS	BL-30	S01C	-	130	410	33	58	48	210	77	
17110019-BL-000-	MSQS	BL-31	S05C	-	78	150	34	31	110	570	220	
17110019-BL-000-	MSQS	BL-32	S01C	-	270	750	44	92	110	470	220	
17110019-HY-000-	MSQS	CB-11	S01C	-	130	330	43	30	53	260	91	
17110019-CB-000-	MSQS	CB-12	S01C	-	93	68	U5	7.1	14	85	14	
17110019-CB-000-	MSQS	CB-13	S01C	-	160	85	21	9.8	16	82	20	
17110019-CB-000-	MSQS	CB-14	S01C	-	120	83	25	10	16	88	15	
17110019-CI-000-	MSQS	CI-11	S02C	-	590	1100	180	460	U25	1800	460	
17110019-CI-000-	MSQS	CI-12	S01C	-	740	5500	250	220	290	1900	660	
17110019-CI-000-	MSQS	CI-13	S05C	-	330	1100	170	110	160	830	310	
17110019-CI-000-	MSQS	CI-14	S01C	-	290	1700	110	74	110	540	190	
17110019-CI-000-	MSQS	CI-15	S01C	-	700	2100	250	360	490	2500	830	
17110019-CW-000-	MSQS	CI-16	S05C	-	460	1300	190	130	200	790	330	
17110019-CI-000-	MSQS	CI-17	S05C	-	01 600	1200	230	170	280	1100	530	
17110019-CI-000-	MSQS	CI-17	S05C	-	02 530	1900	330	180	300	1200	450	
17110019-CI-000-	MSQS	CI-18	S01C	-	480	950	180	100	190	760	400	
17110019-CI-000-	MSQS	CI-19	S01C	-	320	830	140	90	110	510	230	
17110019-CI-000-	MSQS	CI-20	S05C	-	360	980	190	130	160	670	330	
17110019-CI-000-	MSQS	CI-21	S01C	-	890	2400	650	380	600	2700	1600	
17110019-CI-000-	MSQS	CI-22	S05C	-	460	1200	330	190	280	1500	960	
17110019-CR-000-	MSQS	CR-11	S01C	-	U5	7.4	U5	U5	U5	14	6.7	
17110019-CR-000-	MSQS	CR-12	S05C	-	U5	13	U5	U5	U5	12	8.6	
17110019-CR-000-	MSQS	CR-13	S01C	-	U5	U5	U5	U5	U5	16	.5	

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
LOW MOLECULAR WEIGHT AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	2-methyl naphthalene	naphthalene	acenaphthylene	acenaphthene	fluorene	phenanthrene	anthracene	anthracene/phenanthrene
17110019-CR-000-	MSQS	CR-14	S05C	-	U5	7.5	U5	U5	U5	16	22	
17110019-HY-000-	MSQS	HY-11	S01C	-	50	79	45	79	82	440	160	
17110019-HY-000-	MSQS	HY-12	S01C	-	58	160	42	39	55	420	190	
17110019-HY-000-	MSQS	HY-13	S01C	-	82	190	49	49	85	510	460	
17110019-HY-000-	MSQS	HY-14	S05C	-	55	130	35	51	120	700	390	
17110019-HY-000-	MSQS	HY-15	S01C	-	68	160	53	34	53	490	260	
17110019-HY-000-	MSQS	HY-16	S01C	-	100	190	110	200	280	1600	1300	
17110019-HY-000-	MSQS	HY-17	S01C	-	69	240	61	86	120	720	440	
17110019-HY-000-	MSQS	HY-18	S01C	-	120	300	67	110	110	970	700	
17110019-HY-000-	MSQS	HY-19	S01C	-	130	250	87	120	150	680	680	
17110019-HY-000-	MSQS	HY-20	S01C	- 01	220	610	87	61	89	580	Z290	
17110019-HY-000-	MSQS	HY-20	S01C	- 02	200	580	130	71	87	C	C	550
17110019-HY-000-	MSQS	HY-21	S01C	-	270	610	81	97	110	750	Z360	
17110019-HY-000-	MSQS	HY-22	S05C	-	390	1600	100	450	480	1200	Z580	
17110019-HY-000-	MSQS	HY-23	S01C	-	180	380	79	88	160	2300	Z930	
17110019-HY-000-	MSQS	HY-24	S01C	-	130	360	50	61	94	Z620	Z230	
17110019-HY-000-	MSQS	HY-25	S01C	-	150	2600	42	40	65	Z360	Z170	
17110019-HY-000-	MSQS	HY-26	S01C	-	380	480	57	43	63	Z450	Z330	
17110019-HY-000-	MSQS	HY-27	S01C	-	91	280	56	44	58	400	160	
17110019-HY-000-	MSQS	HY-28	S01C	-	120	480	61	79	100	570	240	
17110019-HY-000-	MSQS	HY-29	S01C	-	91	300	48	39	57	310	190	
17110019-HY-000-	MSQS	HY-30	S01C	-	74	240	34	34	45	240	110	
17110019-HY-000-	MSQS	HY-31	S01C	- 01	80	340	68	36	48	290	120	
17110019-HY-000-	MSQS	HY-31	S01C	- 02	77	300	55	32	59	300	270	
17110019-HY-000-	MSQS	HY-32	S01C	-	150	510	77	85	85	420	220	
17110019-HY-000-	MSQS	HY-33	S01C	-	210	1100	93	85	98	550	260	
17110019-HY-000-	MSQS	HY-34	S01C	-	150	740	130	130	140	570	280	
17110019-HY-000-	MSQS	HY-35	S01C	-	280	740	94	92	100	460	260	
17110019-HY-000-	MSQS	HY-36	S01C	-	380	840	120	190	200	750	430	
17110019-HY-000-	MSQS	HY-37	S01C	-	170	920	93	76	100	460	220	
17110019-HY-000-	MSQS	HY-38	S01C	-	260	740	110	110	150	620	310	
17110019-HY-000-	MSQS	HY-39	S01C	-	390	1200	100	67	75	Z320	Z170	
17110019-HY-000-	MSQS	HY-40	S01C	-	330	1100	88	60	92	Z390	Z180	
17110019-HY-000-	MSQS	HY-41	S01C	-	250	750	62	58	85	Z430	Z150	
17110019-HY-000-	MSQS	HY-42	S01C	-	160	530	87	83	160	720	380	
17110019-HY-000-	MSQS	HY-43	S01C	-	130	490	90	90	110	530	220	
17110019-HY-000-	MSQS	HY-44	S01C	-	42	23	7.8	U5	8.6	42	26	
17110019-HY-000-	MSQS	HY-45	S01C	-	290	850	95	73	95	Z230	Z130	
17110019-HY-000-	MSQS	HY-46	S01C	-	340	980	94	100	220	Z470	Z200	
17110019-HY-000-	MSQS	HY-47	S05C	-	160	670	80	51	86	Z420	Z150	
17110019-HY-000-	MSQS	HY-48	S01C	-	270	760	76	110	88	Z310	Z130	
17110019-HY-000-	MSQS	HY-49	S01C	-	100	200	38	22	26	120	56	
17110019-HY-000-	MSQS	HY-50	S05C	-	190	400	27	54	31	190	83	

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
LOW MOLECULAR WEIGHT AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	2-methyl naphthalene	naphthalene	acenaphthylene	acenaphthene	fluorene	phenanthrene	anthracene	anthracene/phenanthrene
17110019-HY-000-	MSQS	HY-51	S01C	-	170	250	40	21	36	170	62	
17110019-MD-000-	MSQS	MD-11	S01C	-	910	2900	530	350	410	2100	440	
17110019-MD-000-	MSQS	MD-12	S05C	-	670	2100	560	500	540	1100	380	
17110019-MD-000-	MSQS	MD-13	S01C	-	320	1200	600	190	230	830	380	
17110019-MI-000-	MSQS	MI-11	S01C	-	01	360	Z910	150	160	190	Z870	440
17110019-MI-000-	MSQS	MI-11	S01C	-	02	320	Z890	170	150	18	Z890	500
17110019-MI-000-	MSQS	MI-12	S01C	-		450	1300	170	150	180	740	390
17110019-MI-000-	MSQS	MI-13	S01C	-		270	Z680	110	120	150	Z570	310
17110019-MI-000-	MSQS	MI-14	S01C	-		310	770	110	110	170	670	350
17110019-MI-000-	MSQS	MI-15	S01C	-		220	Z550	56	60	91	Z340	110
17110019-RS-000-	MSQS	RS-11	S01C	-		320	620	120	110	180	820	500
17110019-RS-000-	MSQS	RS-12	S01C	-		190	330	76	160	240	940	410
17110019-RS-000-	MSQS	RS-13	S01C	-		440	1200	140	390	490	1100	330
17110019-RS-000-	MSQS	RS-14	S05C	-	01	350	55	120	180	220	1000	740
17110019-RS-000-	MSQS	RS-14	S05C	-	02	180	540	97	140	160	740	380
17110019-RS-000-	MSQS	RS-15	S02C	-		12	36	6.4	11	16	89	43
17110019-RS-000-	MSQS	RS-16	S01C	-		830	1900	210	900	790	1900	710
17110019-RS-000-	MSQS	RS-17	S01C	-		250	450	94	140	220	640	330
17110019-RS-000-	MSQS	RS-18	S01C	-		1200	1900	290	2500	3100	11000	1400
17110019-RS-000-	MSQS	RS-19	S01C	-		61	150	22	U5	140	570	400
17110019-RS-000-	MSQS	RS-20	S01C	-		21	83	26	14	22	210	56
17110019-RS-000-	MSQS	RS-21	S01C	-		1100	1200	120	790	1100	1800	1200
17110019-RS-000-	MSQS	RS-22	S01C	-		U5	U5	U5	U5	U5	11	8.7
17110019-RS-000-	MSQS	RS-24	S05C	-		33	63	16	U5	14	67	43
17110019-SI-000-	MSQS	SI-11	S05C	-		270	Z910	120	240	250	Z480	220
17110019-SI-000-	MSQS	SI-12	S01C	-		180	Z740	65	120	120	Z480	210
17110019-SI-000-	MSQS	SI-13	S01C	-		230	530	49	68	88	350	140
17110019-SI-00-	MSQS	SI-14	S01C	-		720	1400	70	640	610	1800	460
17110019-SI-000-	MSQS	SI-15	S05C	-		380	Z860	56	87	130	Z460	160
17110019-SP-000-	MSQS	SP-11	S05C	-		130	Z560	150	73	95	Z330	120
17110019-SP-000-	MSQS	SP-12	S05C	-		200	Z720	110	120	160	Z540	140
17110019-SP-000-	MSQS	SP-13	S01C	-		390	2700	290	290	370	950	450
17110019-SP-000-	MSQS	SP-14	S01C	-		810	4400	410	270	240	Z660	Z85
17110019-SP-000-	MSQS	SP-15	S05C	-		70	Z270	75	36	42	Z160	Z36
17110019-SP-000-	MSQS	SP-16	S05C	-		110	Z290	45	27	32	Z150	Z39
17110019-DP-000-	MSQS	WBS	CTL	-		U5	U5	U5	U5	U5	U5	U5
17110019-DP-000-	MSQS	WBS	CTL	-		U5	190	U5	U5	U5	Z6	Z4

Number of observations

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					pyrene	benz[a]anthracene	chrysene	benzo[b]fluoranthene	benzo[k]fluoranthene	benzo[a]pyrene	indeno(1,2,3-cd)pyrene
[illegible]	MSQS	[illegible]	S01C		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.5	05
[illegible]	MSQS	MY-11	S01		[illegible]	570	[illegible]	[illegible]	[illegible]	470	260
[illegible]	MSQS	MY-12	S01		[illegible]	1300	[illegible]	[illegible]	[illegible]	1200	580
[illegible]	MSQS	MY-13	S01		[illegible]	2200	[illegible]	[illegible]	[illegible]	1700	740
[illegible]	MSQS	MY-14	S01		[illegible]	9300	1600	2800	C	1300	600
[illegible]	MSQS	MY-15	S01		[illegible]	3400	1100	2800	C	5300	1200
[illegible]	MSQS	MY-16	S01C		54[illegible]	4800	2200	6100	C	1800	1700
[illegible]	MSQS	MY-17	S01C		[illegible]	4300	1200	2700	C	2400	69
[illegible]	MSQS	MY-18	S01C		[illegible]	3300	2300	3900	C	4200	940
[illegible]	MSQS	MY-19	S01C		58[illegible]	5800	3500	5500	C	2100	1500
[illegible]	MSQS	MY-20	S01C		[illegible]	1700	1300	2300	C	2600	920
[illegible]	MSQS	MY-20	S01C		[illegible]	2000	C	C	C	2900	760
[illegible]	MSQS	MY-21	S01C		[illegible]	2100	1300	2300	C	1400	720
[illegible]	MSQS	MY-22	S05C		[illegible]	2600	2300	2700	C	6100	2700
[illegible]	MSQS	MY-23	S01C		[illegible]	1900	1000	2300	C	2000	150
[illegible]	MSQS	MY-24	S01C		[illegible]	1500	670	2300	C	1300	690
[illegible]	MSQS	MY-25	S01C		[illegible]	1400	880	1500	C	530	350
[illegible]	MSQS	MY-26	S01C		[illegible]	3500	1300	2600	C	1700	630
[illegible]	MSQS	MY-27	S01		[illegible]	790	370	980	C	330	230
[illegible]	MSQS	MY-28	S01C		[illegible]	1200	770	1100	C	670	240
[illegible]	MSQS	MY-29	S01C		[illegible]	800	360	950	C	440	270
[illegible]	MSQS	MY-30	S01C		[illegible]	480	370	900	C	390	160
[illegible]	MSQS	MY-31	S01C		[illegible]	460	320	700	C	270	120
[illegible]	MSQS	MY-31	S01C		[illegible]	500	300	540	C	210	110
[illegible]	MSQS	MY-32	S01C		[illegible]	1000	400	940	C	510	200
[illegible]	MSQS	MY-33	S01C		[illegible]	1300	560	1100	C	2800	390
[illegible]	MSQS	MY-34	S01C		[illegible]	1300	700	1100	C	510	350
[illegible]	MSQS	MY-35	S01C		[illegible]	900	480	1200	C	520	420
[illegible]	MSQS	MY-36	S01C		[illegible]	1400	[illegible]	1600	C	1000	410
[illegible]	MSQS	MY-37	S01C		[illegible]	880	500	940	C	580	260
[illegible]	MSQS	MY-38	S01C		[illegible]	1100	400	950	C	550	290
[illegible]	MSQS	MY-39	S01C		24[illegible]	2710	260	2570	C	390	210
[illegible]	MSQS	MY-40	S01C		[illegible]	2720	380	2760	C	580	210
[illegible]	MSQS	MY-41	S01C		[illegible]	2610	350	2650	C	510	210
[illegible]	MSQS	MY-42	S01C		[illegible]	140	830	1800	C	890	300
[illegible]	MSQS	MY-43	S01C		84[illegible]	710	560	650	C	580	380
[illegible]	MSQS	MY-44	S01C		72	65	26	62	C	42	20
[illegible]	MSQS	MY-45	S01C		26[illegible]	2590	330	2410	C	310	130
[illegible]	MSQS	MY-46	S01C		[illegible]	2910	520	2770	C	480	220
[illegible]	MSQS	MY-47	S05C		26[illegible]	2640	310	2560	C	370	170
[illegible]	MSQS	MY-48	S01C		24[illegible]	2640	310	2480	C	360	190
[illegible]	MSQS	MY-49	S01C		34[illegible]	200	90	160	C	78	68
[illegible]	MSQS	MY-50	S05C		25[illegible]	290	110	170	C	130	71

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	fluor-anthene	pyrene	benzo(a) anthra-cene	chrysene	benzo(b) fluor-anthene	benzo(k) fluor-anthene	benzo(a) pyrene	indeno-(1,2,3-cd) pyrene
17110019-HY-000-	MSQS	HY-51	S01C	-	210	190	85	160	C	C	110	30
17110019-MD-000-	MSQS	MD-11	S01C	-	2800	2900	1200	1500	C	C	1600	710
17110019-MD-000-	MSQS	MD-12	S05C	-	1500	1600	710	920	C	C	1600	100
17110019-MD-000-	MSQS	MD-13	S01C	-	1300	1600	530	530	C	C	770	360
17110019-MI-000-	MSQS	MI-11	S01C	-	01	1500	1600	620	820	C	C	980	480
17110019-MI-000-	MSQS	MI-11	S01C	-	02	1500	1500	560	880	C	C	920	420
17110019-MI-000-	MSQS	MI-12	S01C	-		1300	1200	450	610	C	C	630	320
17110019-MI-000-	MSQS	MI-13	S01C	-		980	2970	330	460	C	C	480	230
17110019-MI-000-	MSQS	MI-14	S01C	-		1200	1000	420	710	C	C	560	200
17110019-MI-000-	MSQS	MI-15	S01C	-		550	2480	100	350	C	C	180	95
17110019-RS-000-	MSQS	RS-11	S01C	-		1000	1300	650	870	C	C	1000	350
17110019-RS-000-	MSQS	RS-12	S01C	-		1000	1300	480	650	C	C	1000	460
17110019-RS-000-	MSQS	RS-13	S01C	-		1300	1200	1100	1400	C	C	980	600
17110019-RS-000-	MSQS	RS-14	S05C	-	01	1800	1700	710	1400	C	C	880	320
17110019-RS-000-	MSQS	RS-14	S05C	-	02	1600	1600	620	880	C	C	790	320
17110019-RS-000-	MSQS	RS-15	S02C	-		79	100	41	54	C	C	43	19
17110019-RS-000-	MSQS	RS-16	S01C	-		1300	1900	500	750	C	C	540	250
17110019-RS-000-	MSQS	RS-17	S01C	-		640	620	590	1000	C	C	880	17
17110019-RS-000-	MSQS	RS-18	S01C	-		8100	5600	3200	4700	C	C	4000	770
17110019-RS-000-	MSQS	RS-19	S01C	-		850	680	350	400	C	C	270	90
17110019-RS-000-	MSQS	RS-20	S01C	-		180	210	76	92	C	C	110	58
17110019-RS-000-	MSQS	RS-21	S01C	-		3600	2100	1800	2300	C	C	1400	480
17110019-RS-000-	MSQS	RS-22	S01C	-		11	12	U5	7.0	C	C	5.8	U5
17110019-RS-000-	MSQS	RS-24	S05C	-		160	110	97	95	C	C	100	40
17110019-SI-000-	MSQS	SI-11	S05C	-		780	2680	860	1200	C	C	1400	570
17110019-SI-000-	MSQS	SI-12	S01C	-		450	2920	400	630	C	C	730	180
17110019-SI-000-	MSQS	SI-13	S01C	-		840	670	250	400	C	C	600	210
17110019-SI-000-	MSQS	SI-14	S01C	-		1100	930	710	710	C	C	570	270
17110019-SI-000-	MSQS	SI-15	S05C	-		530	2600	300	260	C	C	410	190
17110019-SP-000-	MSQS	SP-11	S05C	-		520	2490	110	170	C	C	84	U5
17110019-SP-000-	MSQS	SP-12	S05C	-		550	2680	140	220	C	C	160	61
17110019-SP-000-	MSQS	SP-13	S01C	-		1700	1400	550	660	C	C	370	170
17110019-SP-000-	MSQS	SP-14	S01C	-		2300	2290	93	259	C	C	100	67
17110019-SP-000-	MSQS	SP-15	S05C	-		150	2330	32	256	C	C	21	U5
17110019-SP-000-	MSQS	SP-16	S05C	-		140	2110	41	269	C	C	45	23
17110019-UP-000-	MSQS	WBS	CTL	-	01	U5	U5	U5	U5	U5	U5	U5	U5
17110019-UP-000-	MSQS	WBS	CTL	-	02	U5	U5	U5	U5	U5	U5	U5	U5

Number of observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	dibenzo-(a,h)anthracene	benzo-(ghi) perylene	total benzo-fluoranthenes	benzo(a) anthracene/ chrysene
17110019-BL-000-	MSQS	BL-11	S05C	-	22	78	260	
17110019-BL-000-	MSQS	BL-12	S01C	-	34	150	1200	
17110019-BL-000-	MSQS	BL-13	S05C	-	30	120	540	
17110019-BL-000-	MSQS	BL-14	S01C	-	120	240	1100	
17110019-BL-000-	MSQS	BL-15	S01C	-	23	81	330	
17110019-BL-000-	MSQS	BL-16	S01C	-	41	100	410	
17110019-BL-000-	MSQS	BL-17	S01C	- 01	36	100	400	
17110019-BL-000-	MSQS	BL-17	S01C	- 02	24	110	420	
17110019-BL-000-	MSQS	BL-18	S01C	-	53	130	480	
17110019-BL-000-	MSQS	BL-19	S01C	-	16	77	510	
17110019-BL-000-	MSQS	BL-20	S01C	-	21	89	360	
17110019-BL-000-	MSQS	BL-21	S05C	-	23	90	420	
17110019-BL-000-	MSQS	BL-22	S01C	-	33	150	630	
17110019-BL-000-	MSQS	BL-23	S01C	-	62	240	1000	
17110019-BL-000-	MSQS	BL-24	S01C	-	65	150	580	
17110019-BL-000-	MSQS	BL-25	S05C	-	42	130	520	
17110019-BL-000-	MSQS	BL-26	S01C	-	50	170	560	
17110019-BL-000-	MSQS	BL-27	S01C	-	15	38	140	
17110019-BL-000-	MSQS	BL-28	S05C	-	36	130	1300	
17110019-BL-000-	MSQS	BL-29	S01C	-	110	210	560	
17110019-BL-000-	MSQS	BL-30	S01C	-	26	50	110	
17110019-BL-000-	MSQS	BL-31	S05C	-	43	89	150	
17110019-BL-000-	MSQS	BL-32	S01C	-	90	190	800	
17110019-HY-000-	MSQS	CB-11	S01C	-	21	91	330	
17110019-CB-000-	MSQS	CB-12	S01C	-	U5	14	51	
17110019-CB-000-	MSQS	CB-13	S01C	-	0.4	12	33	
17110019-CB-000-	MSQS	CB-14	S01C	-	U5	15	31	
17110019-CI-000-	MSQS	CI-11	S02C	-	U25	780	3200	
17110019-CI-000-	MSQS	CI-12	S01C	-	260	740	2500	
17110019-CI-000-	MSQS	CI-13	S05C	-	160	390	2100	
17110019-CI-000-	MSQS	CI-14	S01C	-	69	200	1100	
17110019-CI-000-	MSQS	CI-15	S01C	-	160	420	2500	
17110019-CW-000-	MSQS	CI-16	S05C	-	50	230	640	
17110019-CI-000-	MSQS	CI-17	S05C	- 01	180	480	2600	
17110019-CI-000-	MSQS	CI-17	S05C	- 02	95	400	750	
17110019-CI-000-	MSQS	CI-18	S01C	-	110	290	1500	
17110019-CI-000-	MSQS	CI-19	S01C	-	110	290	1500	
17110019-CI-000-	MSQS	CI-20	S05C	-	67	260	690	
17110019-CI-000-	MSQS	CI-21	S01C	-	270	640	4400	
17110019-CI-000-	MSQS	CI-22	S01C	-	25	240	2600	
17110019-CR-000-	MSQS	CR-11	S01C	-	5	U5	18	
17110019-CR-000-	MSQS	CR-12	S01C	-	5	U5	17	

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	dibenzo-(a,h)an-thracene	benzo-(ghi) perylene	total benzo-fluor-anthenes	benzo(a) anthracene/ chrysene
17110019-CH-000-	MSQS	CH-13	S01C	-	U5	U5	U5	
17110019-CH-000-	MSQS	CH-14	S05C	-	U5	U5	15	
17110019-HY-000-	MSQS	HY-11	S01C	-	82	100	1200	
17110019-HY-000-	MSQS	HY-12	S01C	-	260	740	2100	
17110019-HY-000-	MSQS	HY-13	S01C	-	280	670	3800	
17110019-HY-000-	MSQS	HY-14	S05C	-	230	720	3600	
17110019-HY-000-	MSQS	HY-15	S01C	-	470	1100	5500	
17110019-HY-000-	MSQS	HY-16	S01C	-	580	1900	8800	
17110019-HY-000-	MSQS	HY-17	S01C	-	58	75	3700	
17110019-HY-000-	MSQS	HY-18	S01C	-	280	1000	4800	
17110019-HY-000-	MSQS	HY-19	S01C	-	480	1100	5500	
17110019-HY-000-	MSQS	HY-20	S01C	-	340	740	5800	
17110019-HY-000-	MSQS	HY-20	S01C	-	240	610	5800	3300
17110019-HY-000-	MSQS	HY-21	S01C	-	270	610	6100	
17110019-HY-000-	MSQS	HY-22	S05C	-	1500	U5	8500	
17110019-HY-000-	MSQS	HY-23	S01C	-	440	1100	2400	
17110019-HY-000-	MSQS	HY-24	S01C	-	170	610	2400	
17110019-HY-000-	MSQS	HY-25	S01C	-	110	440	1500	
17110019-HY-000-	MSQS	HY-26	S01C	-	160	690	6300	
17110019-HY-000-	MSQS	HY-27	S01C	-	79	280	1200	
17110019-HY-000-	MSQS	HY-28	S01C	-	100	340	1800	
17110019-HY-000-	MSQS	HY-29	S01C	-	84	210	730	
17110019-HY-000-	MSQS	HY-30	S01C	-	45	200	570	
17110019-HY-000-	MSQS	HY-31	S01C	-	41	170	540	
17110019-HY-000-	MSQS	HY-31	S01C	-	23	140	550	
17110019-HY-000-	MSQS	HY-32	S01C	-	75	290	3200	
17110019-HY-000-	MSQS	HY-33	S01C	-	140	650	2200	
17110019-HY-000-	MSQS	HY-34	S01C	-	71	290	1100	
17110019-HY-000-	MSQS	HY-35	S01C	-	68	370	1100	
17110019-HY-000-	MSQS	HY-36	S01C	-	150	350	1600	
17110019-HY-000-	MSQS	HY-37	S01C	-	71	340	900	
17110019-HY-000-	MSQS	HY-37	S01C	-	71	290	1000	
17110019-HY-000-	MSQS	HY-38	S01C	-	76	21	1400	
17110019-HY-000-	MSQS	HY-43	S01C	-	55	210	920	
17110019-HY-000-	MSQS	HY-43	S01C	-	53	140	810	
17110019-HY-000-	MSQS	HY-42	S01C	-	130	320	1200	
17110019-HY-000-	MSQS	HY-43	S01C	-	72	420	670	
17110019-HY-000-	MSQS	HY-44	S01C	-	5	14	150	
17110019-HY-000-	MSQS	HY-45	S01C	-	55	140	1100	
17110019-HY-000-	MSQS	HY-46	S01C	-	45	200	1500	
17110019-HY-000-	MSQS	HY-47	S05C	-	45	160	670	
17110019-HY-000-	MSQS	HY-48	S01C	-	54	140	1200	

MAIN SEDIMENT QUALITY SURVEY ORGANIC [illegible] values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	3]benzo-(a,h)an-thracene	benzo-(ghi)perylene	total benzo-fluor-anthenes	benzo(a) anthracene/ chrysene
17110019-MY-000-	MSQS	MY-49	S01	-	.5	54	200	
17110019-MY-000-	MSQS	MY-50	S05C	-	.4	63	820	
17110019-MY-000-	MSQS	MY-51	S01	-	.5	49	190	
17110019-MD-000-	MSQS	MD-11	S01	-	.4C	74C	1800	
17110019-MD-000-	MSQS	MD-12	S05C	-	.1	670	1400	
17110019-MD-000-	MSQS	MD-13	S01	-	.1	340	940	
17110019-MI-000-	MSQS	MI-11	S01C	-	190	360	2400	
17110019-MI-000-	MSQS	MI-11	S01C	- .2	.3C	320	2400	
17110019-MI-000-	MSQS	MI-12	S01C	-	6.	240	940	
17110019-MI-000-	MSQS	MI-13	S01C	-	48	160	1300	
17110019-MI-000-	MSQS	MI-14	S01C	-	48	180	830	
17110019-MI-000-	MSQS	MI-15	S01C	-	29	100	910	
17110019-MS-000-	MSQS	MS-11	S01C	-	85	320	940	
17110019-MS-000-	MSQS	MS-12	S01C	-	170	370	1700	
17110019-MS-000-	MSQS	MS-13	S01C	-	230	460	3000	
17110019-MS-000-	MSQS	MS-14	S05C	- .1	140	250	1200	
17110019-MS-000-	MSQS	MS-14	S05C	- .2	79	260	940	
17110019-MS-000-	MSQS	MS-15	S02C	-	.5	17	64	
17110019-MS-000-	MSQS	MS-16	S01	-	42	230	730	
17110019-MS-000-	MSQS	MS-17	S01C	-	21	23	1000	
17110019-MS-000-	MSQS	MS-18	S01	-	320	.5	4200	
17110019-MS-000-	MSQS	MS-19	S01	-	2.	76	400	
17110019-MS-000-	MSQS	MS-20	S01	-	4.5	57	190	
17110019-MS-000-	MSQS	MS-21	S01	-	2.0	480	1900	
17110019-MS-000-	MSQS	MS-22	S01	-	.5	.5	21	
17110019-MS-000-	MSQS	MS-24	S05	-	.4	37	250	
17110019-SI-000-	MSQS	SI-11	S05C	-	.5	570	1500	
17110019-SI-000-	MSQS	SI-12	S01	-	.5	280	810	
17110019-SI-000-	MSQS	SI-13	S01	-	4.	170	610	
17110019-SI-000-	MSQS	SI-14	S01	-	4.	220	830	
17110019-SI-000-	MSQS	SI-15	S05	-	.5	180	490	
17110019-SP-000-	MSQS	SP-11	S05	-	.5	.5	360	
17110019-SP-000-	MSQS	SP-12	S05C	-	.5	55	610	
17110019-SP-000-	MSQS	SP-13	S01	-	.5	160	580	
17110019-SP-000-	MSQS	SP-14	S01	-	.5	67	140	
17110019-SP-000-	MSQS	SP-15	S05	-	.5	18	130	
17110019-SP-000-	MSQS	SP-16	S05	-	.5	25	170	
17110019-DP-000-	MSQS	WBS	[illegible]	- .1	.5	.5		
17110019-DP-000-	MSQS	WBS	[illegible]	- .2	.5	.5		

Number of observations

[illegible] SEDIMENT QUALITY SURVEY [illegible] values in ppb dry weight
CHLORINATED AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	1,3-di-chloro-benzene	1,4-di-chloro-benzene	1,2-di-chloro-benzene	1,2,4-tri-chloro-benzene	2-chloro-naph-thalene	hexa-chloro-benzene
[illegible]0019-CR-U00-	MSQS	CR-13	SD1C	-	U5	U5	U5	U5	U5	U10
[illegible]0019-CR-U00-	MSQS	CR-14	SD5C	-	U5	U5	U5	U5	U5	U10
[illegible]0019-MY-U0U-	MSQS	MY-11	SD1C	-	U5	U5	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-12	SD1C	-	U5	19	L5	U5	U5	22
[illegible]0019-MY-U0U-	MSQS	MY-13	SD1C	-	28	U5	U5	U5	U5	31
[illegible]0019-MY-U00-	MSQS	MY-14	SD5C	-	U5	21	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-15	SD1C	-	28	U5	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-16	SD1C	-	U5	U5	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-17	SD1C	-	U5	22	U5	U5	U5	U10
[illegible]0019-MY-U0U-	MSQS	MY-18	SD1C	-	U5	18	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-19	SD1C	-	U5	U5	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-20	SD1C	-1	U5	87	U5	U5	U5	61
[illegible]0019-MY-U00-	MSQS	MY-20	SD1C	-2	U5	68	U5	U5	U5	63
[illegible]0019-MY-U00-	MSQS	MY-21	SD1C	-	U5	94	U5	U5	U5	78
[illegible]0019-MY-U00-	MSQS	MY-22	SD5C	-	85	180	73	260	U5	730
[illegible]0019-MY-U00-	MSQS	MY-23	SD1C	-	U5	53	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-24	SD1C	-	19	39	U5	27	U5	67
[illegible]0019-MY-U00-	MSQS	MY-25	SD1C	-	22	67	19	26	U5	35
[illegible]0019-MY-U00-	MSQS	MY-26	SD1C	-	U20	U20	U20	U5	U5	33
[illegible]0019-MY-U00-	MSQS	MY-27	SD1C	-	33	35	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-28	SD1C	-	U5	42	U5	U5	U5	70
[illegible]0019-MY-U00-	MSQS	MY-29	SD1C	-	36	U5	U5	U5	U5	U10
[illegible]0019-MY-U0U-	MSQS	MY-30	SD1C	-	150	U5	U5	U5	U5	U10
[illegible]0019-MY-U00-	MSQS	MY-31	SD1C	-1	110	25	U5	U5	U5	25
[illegible]0019-MY-U00-	MSQS	MY-31	SD1C	-2	210	30	U5	U5	U5	23
[illegible]0019-MY-U0U-	MSQS	MY-32	SD1C	-	U5	40	U5	31	U5	54
[illegible]0019-MY-U00-	MSQS	MY-33	SD1C	-	22	98	U5	U5	U5	56
[illegible]0019-MY-U00-	MSQS	MY-34	SD1C	-	U5	26	U5	14	U5	24
[illegible]0019-MY-000-	MSQS	MY-35	SD1C	-	46	64	U5	38	U5	84
[illegible]0019-MY-000-	MSQS	MY-36	SD1C	-	80	180	U5	54	U5	220
[illegible]0019-MY-U00-	MSQS	MY-37	SD1C	-	8.2	56	8.8	34	U5	96
[illegible]0019-MY-U0U-	MSQS	MY-38	SD1C	-	110	U5	U5	38	U5	140
[illegible]0019-MY-000-	MSQS	MY-39	SD1C	-	65	150	U5	120	U5	77
[illegible]0019-MY-000-	MSQS	MY-40	SD1C	-	44	150	U5	90	U5	130
[illegible]0019-MY-000-	MSQS	MY-41	SD1C	-	U5	81	14	100	U5	230
[illegible]0019-MY-U0U-	MSQS	MY-42	SD1C	-	23	64	14	64	U5	230
[illegible]0019-MY-U0U-	MSQS	MY-43	SD1C	-	13	71	9.2	51	U5	130
[illegible]019-MY-000-	MSQS	MY-44	SD1C	-	5	U5	U5	U5	U5	U10
[illegible]0019-MY-000-	MSQS	MY-45	SD1C	-	45	80	U5	110	U5	120
[illegible]19-MY-U0U-	MSQS	MY-46	SD1C	-	17	200	46	260	U5	370
[illegible]19-MY-000-	MSQS	MY-47	SD1C	-	14	120	22	51	U5	100
[illegible]19-MY-000-	MSQS	MY-48	SD1C	-	5	200	U5	39	5	69

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
CHLORINATED AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep.	1,3-di-chloro-benzene	1,4-di-chloro-benzene	1,2-di-chloro-benzene	1,2,4-tri-chloro-benzene	2-chloro-naph-thalene	hexa-chloro-benzene
17110019-MY-000-	MSQS	MY-49	S01C -		1[illegible]	10	U5	U5	U5	U10
17110019-MY-000-	MSQS	MY-50	S05C -		[illegible]	U10	U10	U5	U5	U10
17110019-MY-000-	MSQS	MY-51	S01C -		2[illegible]	U5	U5	U5	U5	17
17110019-MD-000-	MSQS	MD-11	S01C -		U5	1[illegible]	97	16	U5	U10
17110019-MD-000-	MSQS	MD-12	S05C -		U5	63	35	7.3	U5	U10
17110019-MD-000-	MSQS	MD-13	S01C -		U5	4[illegible]	14	U5	U5	U10
17110019-MI-000-	MSQS	MI-11	S01C -	[illegible]	U5	22	U5	U5	U5	U10
17110019-MI-000-	MSQS	MI-11	S01C -	[illegible]	U5	19	U5	U5	U5	U10
17110019-MI-000-	MSQS	MI-12	S01C -		4[illegible]	33	U5	U5	U5	U10
17110019-MI-000-	MSQS	MI-13	S01C -		12	17	U5	U5	U5	U10
17110019-MI-000-	MSQS	MI-14	S01C -		U5	1[illegible]	U5	U5	U5	U10
17110019-MI-000-	MSQS	MI-15	S01C -		36	17	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-11	S01C -		U5	60	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-12	S01C -		40	25	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-13	S01C -		U5	110	16	U5	U5	U10
17110019-RS-000-	MSQS	RS-14	S05C -	01	U5	26	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-14	S05C -	02	U5	29	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-15	S02C -		U5	U5	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-16	S01C -		U5	40	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-17	S01C -		U5	38	9.4	U5	U5	U10
17110019-RS-000-	MSQS	RS-18	S01C -		U5	250	18	U5	U5	U10
17110019-RS-000-	MSQS	RS-19	S01C -		U5	10	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-20	S01C -		12	U5	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-21	S01C -		U5	73	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-22	S01C -		U5	U5	U5	U5	U5	U10
17110019-RS-000-	MSQS	RS-24	S05C -		U5	U5	U5	U5	U5	U10
17110019-SI-000-	MSQS	SI-11	S05C -		U5	24	16	U5	U5	U10
17110019-SI-000-	MSQS	SI-12	S01C -		U5	24	U5	U5	U5	U10
17110019-SI-000-	MSQS	SI-13	S01C -		U5	23	U5	U5	U5	U10
17110019-SI-000-	MSQS	SI-14	S01C -		19	30	U5	U5	U5	U10
17110019-SI-000-	MSQS	SI-15	S05C -		U5	17	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-11	S05C -		8.6	11	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-12	S05C -		12	13	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-13	S01C -		U5	U5	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-14	S01C -		U5	U5	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-15	S05C -		U5	10	U5	U5	U5	U10
17110019-SP-000-	MSQS	SP-16	S05C -		15	12	U5	U5	U5	U10
17110019-UP-000-	MSQS	WBS	CTL -	01	U5	U5	U5	U5	U5	U10
17110019-UP-000-	MSQS	WBS	CTL -	02	U5	U5	U5	U5	U5	U10

Number of observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
CHLORINATED ALIPHATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	hexa-chloro-ethane	hexa-chloro-buta-diene	hexa-chloro-cyclo-penta-diene
17110019-BL-000-	MSQS	BL-11	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-12	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-13	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-14	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-15	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-16	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-17	S01C	- 01	U50	U25	
17110019-BL-000-	MSQS	BL-17	S01C	- 02	U50	U50	
17110019-BL-000-	MSQS	BL-18	S01C	-	U50	U50	
17110019-BL-000-	MSQS	BL-19	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-20	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-21	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-22	S01C	-	U100	U25	
17110019-BL-000-	MSQS	BL-23	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-24	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-25	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-26	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-27	S01C	-	U50	U50	
17110019-BL-000-	MSQS	BL-28	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-29	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-30	S01C	-	U50	U25	
17110019-BL-000-	MSQS	BL-31	S05C	-	U50	U25	
17110019-BL-000-	MSQS	BL-32	S01C	-	U50	U25	
17110019-MY-000-	MSQS	CB-11	S01C	-	U50	64	
17110019-CB-000-	MSQS	CB-12	S01C	-	U50	U25	
17110019-CB-000-	MSQS	CB-13	S01C	-	U50	U25	
17110019-CB-000-	MSQS	CB-14	S01C	-	U50	U25	
17110019-CI-000-	MSQS	CI-11	S02C	-	U250	U130	
17110019-CI-000-	MSQS	CI-12	S01C	-	U100	U25	
17110019-CI-000-	MSQS	CI-13	S05C	-	U50	U25	
17110019-CI-000-	MSQS	CI-14	S01C	-	U50	U25	
17110019-CI-000-	MSQS	CI-15	S01C	-	U50	U25	
17110019-CW-000-	MSQS	CI-16	S05C	-	U50	U25	
17110019-CI-000-	MSQS	CI-17	S05C	- 01	U50	U25	
17110019-CI-000-	MSQS	CI-17	S05C	- 02	U50	U25	
17110019-CI-000-	MSQS	CI-18	S01C	-	U50	U25	
17110019-CI-000-	MSQS	CI-19	S01C	-	U50	U25	
17110019-CI-000-	MSQS	CI-20	S05C	-	U50	U25	
17110019-CI-000-	MSQS	CI-21	S01C	-	U100	U50	
17110019-CI-000-	MSQS	CI-22	S05C	-	U50	U25	
17110019-CR-000-	MSQS	CR-11	S01C	-	U50	U25	

MAIN SEDIMENT QUALITY MONITORING [illegible] ppb dry weight
CHLORINATED ALIPHATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	[illegible]-trichloro-ethane	hexa-chloro-buta-diene	hexa-chloro-cyclo-penta-diene
17110019-CR-000-	MSQS	CR-12	SQSC	-	50	U25	
17110019-CR-000-	MSQS	CR-13	SQ1C	-	U50	U25	
17110019-CR-000-	MSQS	CR-14	SQSC	-	U50	U25	
17110019-MY-000-	MSQS	MY-11	SQ1C	-	U50	U25	
17110019-MY-000-	MSQS	MY-12	SQ1C	-	U50	U25	
17110019-MY-000-	MSQS	MY-13	SQ1C	-	U50	U25	
17110019-MY-000-	MSQS	MY-14	SQSC	-	U50	E15	
17110019-MY-000-	MSQS	MY-15	SQ1C	-	U50	U25	
17110019-MY-000-	MSQS	MY-16	SQ1C	-	U50	U25	
17110019-MY-000-	MSQS	MY-17	SQ1C	-	50	31	
17110019-MY-000-	MSQS	MY-18	SQ1C	-	5[illegible]	U25	
17110019-MY-000-	MSQS	MY-19	SQ1C	-	5[illegible]	U25	
17110019-MY-000-	MSQS	MY-20	SQ1C	-	[illegible]	140	
17110019-MY-000-	MSQS	MY-20	SQ1C	-	5[illegible]	160	
17110019-MY-000-	MSQS	MY-21	SQ1C	-	5[illegible]	170	
17110019-MY-000-	MSQS	MY-22	SQSC	-	[illegible]	730	
17110019-MY-000-	MSQS	MY-23	SQ1C	-	5[illegible]	170	
17110019-MY-000-	MSQS	MY-24	SQ1C	-	[illegible]	140	
17110019-MY-000-	MSQS	MY-25	SQ1C	-	[illegible]	130	
17110019-MY-000-	MSQS	MY-26	SQ1C	-	[illegible]	U25	
17110019-MY-000-	MSQS	MY-27	SQ1C	-	[illegible]	U25	
17110019-MY-000-	MSQS	MY-28	SQ1C	-	[illegible]	120	
17110019-MY-000-	MSQS	MY-29	SQ1C	-	[illegible]	U25	
17110019-MY-000-	MSQS	MY-30	SQ1C	-	[illegible]	U25	
17110019-MY-000-	MSQS	MY-31	SQ1C	-	[illegible]	50	
17110019-MY-000-	MSQS	MY-31	SQ1C	-	[illegible]	48	
17110019-MY-000-	MSQS	MY-32	SQ1C	-	[illegible]	98	
17110019-MY-000-	MSQS	MY-33	SQ1C	-	[illegible]	130	
17110019-MY-000-	MSQS	MY-34	SQ1C	-	[illegible]	34	
17110019-MY-000-	MSQS	MY-35	SQ1C	-	[illegible]	190	
17110019-MY-000-	MSQS	MY-36	SQ1C	-	[illegible]	360	
17110019-MY-000-	MSQS	MY-37	SQ1C	-	[illegible]	130	
17110019-MY-000-	MSQS	MY-38	SQ1C	-	[illegible]	210	
17110019-MY-000-	MSQS	MY-39	SQ1C	-	[illegible]	300	
17110019-MY-000-	MSQS	MY-4	SQ1C	-	[illegible]	350	
17110019-MY-000-	MSQS	MY-40	SQ1C	-	[illegible]	680	
17110019-MY-000-	MSQS	MY-40	SQ1C	-	[illegible]	270	
17110019-MY-000-	MSQS	MY-41	SQ1C	-	[illegible]	140	
17110019-MY-000-	MSQS	MY-42	SQ1C	-	[illegible]	25	
17110019-MY-000-	MSQS	MY-43	SQ1C	-	[illegible]	44	
17110019-MY-000-	MSQS	MY-44	SQ1C	-	[illegible]	44	

[illegible] SEDIMENT QUALITY SURVEY [illegible] ... values in ppb dry weight
[illegible] STATION AND SAMPLE NUMBER ASSIGNMENT

Area Name	Survey	Station	Sample	Rep	hexa-chloro-ethane	hexa chloro-buta-diene	hexa-chloro-cyclo-penta-diene
[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	

... ORGANIC CHEMICALS - Values in ppb dry weight

...	Survey	Station	Sample	Rep	dimethyl phtha-late	diethyl phtha-late	di-n-butyl phtha late	butyl benzyl phtha-late	bis(2-ethyl-hexyl)-phtha-late	di-n-octyl phtha-late
...-BL-000-	MSQS	BL-11	S05C -		U50	U10	Z140	63	460	U25
...-BL-000-	MSQS	BL-12	S01C -		L50	43	Z1200	93	1000	U25
17110019-BL-000-	MSQS	BL-13	S05C -		L50	U10	Z210	83	760	U25
...-BL-000-	MSQS	BL-14	S01C -		U50	53	Z1100	64	780	27
...-BL-000-	MSQS	BL-15	S01C -		U50	U10	Z420	U25	120	U25
...-BL-000-	MSQS	BL-16	S01C -		U50	U10	Z230	U25	B25	U25
17110019-BL-000-	MSQS	BL-17	S01C -	01	L50	U10	B25	Z45	B25	U25
17110019-BL-000-	MSQS	BL-17	S01C -	02	U50	U10	Z370	U25	U25	U25
17110019-BL-000-	MSQS	BL-18	S01C -		U50	U10	Z1400	U25	U25	U25
17110019-BL-000-	MSQS	BL-19	S01C -		U50	U10	Z1200	U25	B25	U25
17110019-BL-000-	MSQS	BL-20	S01C -		U50	U10	Z5	U25	U25	U25
17110019-BL-000-	MSQS	BL-21	S05C -		U50	U10	Z530	U25	U25	U25
17110019-BL-000-	MSQS	BL-22	S01C -		U50	U10	Z760	U25	B25	U25
17110019-BL-000-	MSQS	BL-23	S01C -		U50	U10	Z1600	U25	U25	U25
17110019-BL-000-	MSQS	BL-24	S01C -		U50	U10	Z1000	U25	U25	U25
17110019-BL-000-	MSQS	BL-25	S05C -		L50	U10	B25	Z25	B25	U25
17110019-BL-000-	MSQS	BL-26	S01C -		U50	U10	Z180	U25	B25	U25
17110019-BL-000-	MSQS	BL-27	S01C -		U50	U10	Z340	U25	U25	U25
17110019-BL-000-	MSQS	BL-28	S05C -		L50	U10	B25	U25	B25	U25
17110019-BL-000-	MSQS	BL-29	S01C -		97	U10	B25	L25	B25	L25
17110019-BL-000-	MSQS	BL-30	S01C -		U50	U10	B25	L25	B25	U25
17110019-BL-000-	MSQS	BL-31	S05C -		U50	U10	Z420	U25	B25	U25
17110019-BL-000-	MSQS	BL-32	S01C -		U50	U10	Z85	U25	B25	U25
17110019-MY-000-	MSQS	CB-11	S01C -		U50	U10	Z9800	U25	B25	U25
17110019-CB-000-	MSQS	CB-12	S01C -		U100	L20	Z3700	U50	B25	250
17110019-CB-000-	MSQS	CB-13	S01C -		U50	U10	Z150	U25	B25	L25
17110019-CB-000-	MSQS	CB-14	S01C -		U50	U10	Z280	U25	B25	U25
17110019-CI-000-	MSQS	CI-11	S02C -		U250	U50	U50	U130	U130	U130
17110019-CI-000-	MSQS	CI-12	S01C -		84	U10	Z510	660	6600	290
17110019-CI-000-	MSQS	CI-13	S05C -		58	U10	Z50	210	3100	130
17110019-CI-000-	MSQS	CI-14	S01C -		66	23	Z15	130	1500	49
17110019-CI-000-	MSQS	CI-15	S01C -		L50	31	Z70	150	1800	U25
17110019-CW-000-	MSQS	CI-16	S05C -		U50	U10	Z1600	U25	860	U25
17110019-CI-000-	MSQS	CI-17	S05C -	01	78	38	Z270	L25	550	U25
17110019-CI-000-	MSQS	CI-17	S05C -	02	U50	U10	Z1000	U25	700	U25
17110019-CI-000-	MSQS	CI-18	S01C -		L50	26	B25	33	790	U25
17110019-CI-000-	MSQS	CI-19	S01C -		L50	U10	B25	56	930	U25
17110019-CI-000-	MSQS	CI-20	S05C -		U50	U10	Z130	U25	U25	U25
17110019-CI-000-	MSQS	CI-21	S01C -		L100	44	Z140	L50	710	U50
17110019-CI-000-	MSQS	CI-22	S05C -		U50	U10	Z20	L25	430	U25
17110019-CR-000-	MSQS	CR-11	S01C -		U50	U10	Z760	U25	B25	U25
17110019-CR-000-	MSQS	CR-12	S05C -		U50	13	B25	U25	B25	U25

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHTHALATES

Drainage	Survey	Station	Sample	Rep	dimethyl phtha-late	diethyl phtha-late	di-n-butyl phtha late	butyl benzyl phtha-late	bis(2-ethyl-hexyl)-phtha-late	di-n-octyl phtha-late
17110019-CR-000-	MSQS	CR-13	S01C -		U50	10	B25	U25	B25	U25
17110019-CR-000-	MSQS	CR-14	S05C -		U50	18	Z30	U25	B25	U25
17110019-HY-000-	MSQS	HY-11	S01C -		L50	U10	B10	U25	B25	39
17110019-HY-000-	MSQS	HY-12	S01C -		U50	U10	Z5100	U25	B25	U25
17110019-HY-000-	MSQS	HY-13	S01C -		220	U10	B10	67	Z360	44
17110019-HY-000-	MSQS	HY-14	S05C -		U50	U10	Z270	U25	B25	U25
17110019-HY-000-	MSQS	HY-15	S01C -		74	U10	B10	U25	B25	U25
17110019-HY-000-	MSQS	HY-16	S01C -		180	U10	B10	U25	B25	U25
17110019-HY-000-	MSQS	HY-17	S01C -		U50	U10	B25	U25	B25	U25
17110019-HY-000-	MSQS	HY-18	S01C -		550	U10	Z260	U25	U25	U25
17110019-HY-000-	MSQS	HY-19	S01C -		200	U10	Z260	100	1500	U25
17110019-HY-000-	MSQS	HY-20	S01C -	01	890	37	Z12	U25	920	50
17110019-HY-000-	MSQS	HY-20	S01C -	02	680	74	Z130	U25	U25	U25
17110019-HY-000-	MSQS	HY-21	S01C -		1100	42	Z100	U25	460	U25
17110019-HY-000-	MSQS	HY-22	S05C -		U50	U10	Z560	U25	3000	U25
17110019-HY-000-	MSQS	HY-23	S01C -		350	U10	Z92	110	710	U25
17110019-HY-000-	MSQS	HY-24	S01C -		120	47	Z100	470	810	47
17110019-HY-000-	MSQS	HY-25	S01C -		U50	U10	Z930	U25	530	U25
17110019-HY-000-	MSQS	HY-26	S01C -		50	65	350	33	U25	U25
17110019-HY-000-	MSQS	HY-27	S01C -		L50	U10	B10	300	820	U25
17110019-HY-000-	MSQS	HY-28	S01C -		U50	U10	U10	U25	B25	U25
17110019-HY-000-	MSQS	HY-29	S01C -		73	U10	B10	580	B25	U25
17110019-HY-000-	MSQS	HY-30	S01C -		71	U10	B10	U25	U25	U50
17110019-HY-000-	MSQS	HY-31	S01C -	01	L50	27	B25	U25	B25	U25
17110019-HY-000-	MSQS	HY-31	S01C -	02	L100	U20	Z260	U50	2200	U50
17110019-HY-000-	MSQS	HY-32	S01C -		50	48	B25	58	B25	U25
17110019-HY-000-	MSQS	HY-33	S01C -		U50	U10	Z450	U25	B25	U25
17110019-HY-000-	MSQS	HY-34	S01C -		L50	26	B10	350	B25	U25
17110019-HY-000-	MSQS	HY-35	S01C -		52	22	B10	890	210	U25
17110019-HY-000-	MSQS	HY-36	S01C -		1000	U10	B10	U25	B25	U25
17110019-HY-000-	MSQS	HY-37	S01C -		U50	U10	B25	U25	B25	U25
17110019-HY-000-	MSQS	HY-38	S01C -		64	33	B10	U25	B25	U25
17110019-HY-000-	MSQS	HY-39	S01C -		L50	U10	Z15	130	320	U25
17110019-HY-000-	MSQS	HY-40	S01C -		270	50	Z180	100	480	U25
17110019-HY-000-	MSQS	HY-41	S01C -		51	30	Z140	620	1500	U25
17110019-HY-000-	MSQS	HY-42	S01C -		[illegible]	[illegible]	B25	U25	240	U25
17110019-HY-000-	MSQS	HY-43	S01C -		[illegible]	U10	B25	U25	240	U25
17110019-HY-000-	MSQS	HY-44	S01C -		[illegible]	U10	B25	U25	U25	U25
17110019-HY-000-	MSQS	HY-45	S01C -		[illegible]	10	U10	U25	U25	U25
17110019-HY-000-	MSQS	HY-46	S01C -		[illegible]	44	Z50	U25	44	U25
17110019-HY-000-	MSQS	HY-47	S01C -		[illegible]	[illegible]	Z1500	U25	U25	U25
17110019-HY-000-	MSQS	HY-48	S01C -		[illegible]	[illegible]	Z50	U25	U25	U25

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PHTHALATES

Drainage	Survey	Station	Sample	Rep	dimethyl phtha-late	diethyl phtha-late	di-n-butyl phtha late	butyl benzyl phtha-late	bis(2-ethyl-hexyl)-phtha-late	di-n-octyl phtha-late
17110019-NY-000-	MSQS	NY-49	SO1C -		66	U10	2460	U25	B25	U25
17110019-NY-000-	MSQS	NY-50	SO5C -		U50	U10	21000	U25	B25	U25
17110019-NY-000-	MSQS	NY-51	SO1C -		68	U10	B10	U25	B25	U25
17110019-MD-000-	MSQS	MD-11	SO1C -		U50	U10	2170	U25	1200	U25
17110019-MD-000-	MSQS	MD-12	SO5C -		U50	U10	21400	U25	1900	U25
17110019-MD-000-	MSQS	MD-13	SO1C -		U50	U10	2350	U25	300	U25
17110019-MI-000-	MSQS	MI-11	SO1C -	01	U50	U10	B25	U25	B25	U25
17110019-MI-000-	MSQS	MI-11	SO1C -	02	82	U10	B25	L25	B25	U25
17110019-MI-000-	MSQS	MI-12	SO1C -		59	U10	B10	U25	B25	U25
17110019-MI-000-	MSQS	MI-13	SO1C -		110	U10	B25	U25	B25	U25
17110019-MI-000-	MSQS	MI-14	SO1C -		110	U10	B10	U25	B25	U25
17110019-MI-000-	MSQS	MI-15	SO1C -		U50	U10	B25	U25	B25	U25
17110019-RS-000-	MSQS	RS-11	SO1C -		U50	U10	2850	U25	B25	U25
17110019-RS-000-	MSQS	RS-12	SO1C -		71	U10	2230	L25	B25	L25
17110019-RS-000-	MSQS	RS-13	SO1C -		U50	U10	2560	U25	B25	U25
17110019-RS-000-	MSQS	RS-14	SO5C -	01	L50	U10	2470	U25	B25	U25
17110019-RS-000-	MSQS	RS-14	SO5C -	02	U50	U10	21200	U25	B25	U25
17110019-RS-000-	MSQS	RS-15	SO2C -		U50	U10	21300	U25	B25	U25
17110019-RS-000-	MSQS	RS-16	SO1C -		U50	U10	26700	U25	B25	230
17110019-RS-000-	MSQS	RS-17	SO1C -		L50	U10	230	U25	B25	L25
17110019-RS-000-	MSQS	RS-18	SO1C -		U50	U10	B25	U25	U25	U25
17110019-RS-000-	MSQS	RS-19	SO1C -		U50	U10	21600	U25	B25	U25
17110019-RS-000-	MSQS	RS-20	SO1C -		U50	U10	2740	U25	B25	U25
17110019-RS-000-	MSQS	RS-21	SO1C -		U50	U10	21400	U25	B25	U25
17110019-RS-000-	MSQS	RS-22	SO1C -		L50	U10	2120	U25	B25	U25
17110019-RS-000-	MSQS	RS-24	SO5C -		U50	U10	2940	U25	B25	U25
17110019-SI-000-	MSQS	SI-11	SO5C -		U50	U10	B25	U25	U25	U25
17110019-SI-000-	MSQS	SI-12	SO1C -		U50	U10	B25	U25	B25	U25
17110019-SI-000-	MSQS	SI-13	SO1C -		U50	U10	B10	U25	B25	U25
17110019-SI-000-	MSQS	SI-14	SO1C -		88	U10	U10	U25	B25	U25
17110019-SI-000-	MSQS	SI-15	SO5C -		U50	U10	B25	U25	B25	U25
17110019-SP-000-	MSQS	SP-11	SO5C -		L50	U10	B25	U25	B25	U25
17110019-SP-000-	MSQS	SP-12	SO5C -		L50	U10	B25	U25	B25	U25
17110019-SP-000-	MSQS	SP-13	SO1C -		U50	U10	B10	U25	B25	U25
17110019-SP-000-	MSQS	SP-14	SO1C -		U50	U10	U10	U25	B25	U25
17110019-SP-000-	MSQS	SP-15	SO5C -		U50	U10	B25	L25	B25	25
17110019-SP-000-	MSQS	SP-16	SO5C -		L50	U10	B25	U25	B25	U25
17110019-DP-000-	MSQS	WBS	CTL -	01	210	U10	2160	U25	B25	U25
17110019-DP-000-	MSQS	WBS	CTL -	02	240	U10	B10	U25	B25	U25

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
MISCELLANEOUS OXYGENATED COMPOUNDS

Drainage	Survey	Station	Sample	Rep	benzyl alcohol	benzoic acid	dibenzo-furan
17110019-BL-000-	MSQS	BL-11	S05C -		22	U25	33
17110019-BL-000-	MSQS	BL-12	S01C -		34	260	75
17110019-BL-000-	MSQS	BL-13	S05C -		16	390	76
17110019-BL-000-	MSQS	BL-14	S01C -		29	U25	210
17110019-BL-000-	MSQS	BL-15	S01C -		L10	U25	52
17110019-BL-000-	MSQS	BL-16	S01C -		36	8000	100
17110019-BL-000-	MSQS	BL-17	S01C -	01	16	U25	71
17110019-BL-000-	MSQS	BL-17	S01C -	02	58	450	89
17110019-BL-000-	MSQS	BL-18	S01C -		27	360	76
17110019-BL-000-	MSQS	BL-19	S01C -		L10	250	58
17110019-BL-000-	MSQS	BL-20	S01C -		14	180	77
17110019-BL-000-	MSQS	BL-21	S05C -		57	250	72
17110019-BL-000-	MSQS	BL-22	S01C -		U10	89	120
17110019-BL-000-	MSQS	BL-23	S01C -		U10	U25	170
17110019-BL-000-	MSQS	BL-24	S01C -		17	250	100
17110019-BL-000-	MSQS	BL-25	S05C -		42	330	96
17110019-BL-000-	MSQS	BL-26	S01C -		16	1500	180
17110019-BL-000-	MSQS	BL-27	S01C -		23	390	46
17110019-BL-000-	MSQS	BL-28	S05C -		20	650	87
17110019-BL-000-	MSQS	BL-29	S01C -		23	230	240
17110019-BL-000-	MSQS	BL-30	S01C -		38	230	70
17110019-BL-000-	MSQS	BL-31	S05C -		11	68	110
17110019-BL-000-	MSQS	BL-32	S01C -		27	200	130
17110019-HY-000-	MSQS	CB-11	S01C -		30	40	60
17110019-CB-000-	MSQS	CB-12	S01C -		42	L25	15
17110019-CB-000-	MSQS	CB-13	S01C -		61	U25	18
17110019-CB-000-	MSQS	CB-14	S01C -		80	95	24
17110019-CI-000-	MSQS	CI-11	S02C -		140	U130	370
17110019-CI-000-	MSQS	CI-12	S01C -		110	790	260
17110019-CI-000-	MSQS	CI-13	S05C -		25	690	180
17110019-CI-000-	MSQS	CI-14	S01C -		54	U25	130
17110019-CI-000-	MSQS	CI-15	S01C -		51	310	450
17110019-CW-000-	MSQS	CI-16	S05C -		U10	U25	210
17110019-CI-000-	MSQS	CI-17	S05C -	01	33	330	190
17110019-CI-000-	MSQS	CI-17	S05C -	02	12	U25	250
17110019-CI-000-	MSQS	CI-18	S01C -		29	330	120
17110019-CI-000-	MSQS	CI-19	S01C -		44	460	130
17110019-CI-000-	MSQS	CI-20	S05C -		18	U25	160
17110019-CI-000-	MSQS	CI-21	S01C -		31	350	310
17110019-CI-000-	MSQS	CI-22	S05C -		29	U25	170
17110019-CR-000-	MSQS	CR-11	S01C -		U10	U25	U5
17110019-CR-000-	MSQS	CR-12	S05C -		U10	430	U5
17110019-CR-000-	MSQS	CR-13	S01C -		U10	210	U5
17110019-CR-000-	MSQS	CR-14	S05C -		U10	200	U5

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
MISCELLANEOUS OXYGENATED COMPOUNDS

Drainage	Survey	Station	Sample	Rep	benzyl alcohol	benzoic acid	dibenzo-furan
17110019-HY-000-	MSQS	HY-11	S01C -		45	U25	66
17110019-HY-000-	MSQS	HY-12	S01C -		14	U25	66
17110019-HY-000-	MSQS	HY-13	S01C -		25	54	82
17110019-HY-000-	MSQS	HY-14	S05C -		U10	U25	79
17110019-HY-000-	MSQS	HY-15	S01C -		13	150	60
17110019-HY-000-	MSQS	HY-16	S01C -		U10	U25	170
17110019-HY-000-	MSQS	HY-17	S01C -		U10	U25	120
17110019-HY-000-	MSQS	HY-18	S01C -		24	U25	97
17110019-HY-000-	MSQS	HY-19	S01C -		U10	U25	130
17110019-HY-000-	MSQS	HY-20	S01C -	01	95	U25	110
17110019-HY-000-	MSQS	HY-20	S01C -	02	66	U25	68
17110019-HY-000-	MSQS	HY-21	S01C -		500	250	130
17110019-HY-000-	MSQS	HY-22	S05C -		U10	U25	480
17110019-HY-000-	MSQS	HY-23	S01C -		41	470	120
17110019-HY-000-	MSQS	HY-24	S01C -		33	U25	100
17110019-HY-000-	MSQS	HY-25	S01C -		U10	U25	77
17110019-HY-000-	MSQS	HY-26	S01C -		U10	670	72
17110019-HY-000-	MSQS	HY-27	S01C -		63	230	74
17110019-HY-000-	MSQS	HY-28	S01C -		U10	U25	120
17110019-HY-000-	MSQS	HY-29	S01C -		48	170	66
17110019-HY-000-	MSQS	HY-30	S01C -		21	U25	50
17110019-HY-000-	MSQS	HY-31	S01C -	01	U10	U25	55
17110019-HY-000-	MSQS	HY-31	S01C -	02	U10	U25	57
17110019-HY-000-	MSQS	HY-32	S01C -		29	U25	94
17110019-HY-000-	MSQS	HY-33	S01C -		56	U25	130
17110019-HY-000-	MSQS	HY-34	S01C -		18	220	120
17110019-HY-000-	MSQS	HY-35	S01C -		38	U25	150
17110019-HY-000-	MSQS	HY-36	S01C -		35	550	300
17110019-HY-000-	MSQS	HY-37	S01C -		14	U25	120
17110019-HY-000-	MSQS	HY-38	S01C -		50	290	160
17110019-HY-000-	MSQS	HY-39	S01C -		U10	250	110
17110019-HY-000-	MSQS	HY-40	S01C -		100	U25	140
17110019-HY-000-	MSQS	HY-41	S01C -		340	U50	110
17110019-HY-000-	MSQS	HY-42	S01C -		U10	U25	170
17110019-HY-000-	MSQS	HY-43	S01C -		U10	U25	160
17110019-HY-000-	MSQS	HY-44	S01C -		U10	U25	8.0
17110019-HY-000-	MSQS	HY-45	S01C -		33	U25	110
17110019-HY-000-	MSQS	HY-46	S01C -		U10	U25	150
17110019-HY-000-	MSQS	HY-47	S05C -		U10	U25	110
17110019-HY-000-	MSQS	HY-48	S01C -		61	U25	130
17110019-HY-000-	MSQS	HY-49	S01C -		74	140	50
17110019-HY-000-	MSQS	HY-50	S05C -		73	U25	54
17110019-HY-000-	MSQS	HY-51	S01C -		79	150	49
17110019-MD-000-	MSQS	MD-11	S01C -		47	U25	440

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
MISCELLANEOUS OXYGENATED COMPOUNDS

Drainage	Survey	Station	Sample	Rep	benzyl alcohol	benzoic acid	dibenzo-furan
17110019-MD-000-	MSQS	MD-12	S05C -		29	U25	540
17110019-MD-000-	MSQS	MD-13	S01C -		23	U25	190
17110019-MI-000-	MSQS	MI-11	S01C -	01	17	U25	280
17110019-MI-000-	MSQS	MI-11	S01C -	02	32	U25	260
17110019-MI-000-	MSQS	MI-12	S01C -		43	310	320
17110019-MI-000-	MSQS	MI-13	S01C -		23	U25	250
17110019-MI-000-	MSQS	MI-14	S01C -		48	230	250
17110019-MI-000-	MSQS	MI-15	S01C -		31	U25	130
17110019-RS-000-	MSQS	RS-11	S01C -		15	110	150
17110019-RS-000-	MSQS	RS-12	S01C -		35	U25	150
17110019-RS-000-	MSQS	RS-13	S01C -		21	U25	400
17110019-RS-000-	MSQS	RS-14	S05C -	01	U10	U25	210
17110019-RS-000-	MSQS	RS-14	S05C -	02	U10	U25	150
17110019-RS-000-	MSQS	RS-15	S01C -		U10	L25	12
17110019-RS-000-	MSQS	RS-16	S01C -		U10	250	920
17110019-RS-000-	MSQS	RS-17	S01C -		10	200	190
17110019-RS-000-	MSQS	RS-18	S01C -		24	U25	2000
17110019-RS-000-	MSQS	RS-19	S01C -		U10	U25	110
17110019-RS-000-	MSQS	RS-20	S01C -		U10	U25	14
17110019-RS-000-	MSQS	RS-21	S01C -		U10	260	820
17110019-RS-000-	MSQS	RS-22	S01C -		U10	U25	U5
17110019-RS-000-	MSQS	RS-24	S05C -		U10	U25	17
17110019-SI-000-	MSQS	SI-11	S05C -		25	U25	310
17110019-SI-000-	MSQS	SI-12	S01C -		15	U25	190
17110019-SI-000-	MSQS	SI-13	S01C -		26	170	110
17110019-SI-000-	MSQS	SI-14	S01C -		40	140	610
17110019-SI-000-	MSQS	SI-15	S05C -		13	U25	130
17110019-SP-000-	MSQS	SP-11	S05C -		U10	U25	170
17110019-SP-000-	MSQS	SP-12	S05C -		61	U25	200
17110019-SP-000-	MSQS	SP-13	S05C -		180	630	420
17110019-SP-000-	MSQS	SP-14	S01C -		U10	U100	280
17110019-SP-000-	MSQS	SP-15	S05C -		U10	U25	40
17110019-SP-000-	MSQS	SP-16	S05C -		130	U25	38
17110019-DP-000-	MSQS	WBS	CTL -	01	U10	U25	U5
17110019-DP-000-	MSQS	WBS	CTL -	02	U10	U25	U5

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
ORGANONITROGEN COMPOUNDS

Drainage	Survey	Station	Sample	Rep	nitro-benzene	N-nitroso-dipropyl-amine	2,6-di-nitro-toluene	2,4-di-nitro-toluene	N-nitroso-diphenyl-amine	1,2-di-phenyl-hydra-zine	benzi-dine	3,3'-di-chloro-benzi-dine	N-nitroso-dimethyl amine
17110019-BL-000-	MSQS	BL-11	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-12	S01C -		U5	U10	U10	U5	U5	1200		U100	
17110019-BL-000-	MSQS	BL-13	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-14	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-15	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-16	S01C -		U5	U10	U10	U5	59	U5		U100	
17110019-BL-000-	MSQS	BL-17	S01C -	01	U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-17	S01C -	02	U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-18	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-19	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-20	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-21	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-22	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-23	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-24	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-25	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-26	S01C -		U5	U10	U10	U5	90	280		U100	
17110019-BL-000-	MSQS	BL-27	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-28	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-29	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-30	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-31	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	MSQS	BL-32	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MY-000-	MSQS	CB-11	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CB-000-	MSQS	CB-12	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CB-000-	MSQS	CB-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CB-000-	MSQS	CB-14	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-11	S02C -		U25	U50	U50	U25	U25	U25		U500	
17110019-CI-000-	MSQS	CI-12	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-13	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-14	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-15	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CW-000-	MSQS	CI-16	S05C -		U5	U10	U10	U5	220	U5		U100	
17110019-CI-000-	MSQS	CI-17	S05C -	01	U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-17	S05C -	02	U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-18	S01C -		U5	U10	U10	U5	120	U5		U100	
17110019-CI-000-	MSQS	CI-19	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-20	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CI-000-	MSQS	CI-21	S01C -		U10	U20	U20	U10	U10	U10		U200	
17110019-CI-000-	MSQS	CI-22	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CR-000-	MSQS	CR-11	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CR-000-	MSQS	CR-12	S05C -		U5	U10	U10	U5	U5	U5		U100	

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
ORGANONITROGEN COMPOUNDS

Drainage	Survey	Station	Sample	Rep	nitro-benzene	N-nitroso-dipropyl-amine	2,6-di-nitro-toluene	2,4-di-nitro-toluene	N-nitroso-diphenyl-amine	1,2-di-phenyl-hydra-zine	benzi-dine	3,3'-di-chloro-benzi-dine	N-nitroso-dimethyl amine
17110019-CR-000-	MSQS	CR-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-CR-000-	MSQS	CR-14	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-11	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-12	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-14	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-15	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-16	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-17	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-18	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-19	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-20	S01C -	01	U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-20	S01C -	02	U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-21	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-22	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-23	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-24	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-25	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-26	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-27	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-28	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-29	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-30	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-31	S01C -	01	U5	U10	U10	U5	77	U5		U100	
17110019-HY-000-	MSQS	HY-31	S01C -	02	U5	U10	U10	U5	50	U5		U100	
17110019-HY-000-	MSQS	HY-32	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-33	S01C -		U5	U10	U10	U5	96	U5		U100	
17110019-HY-000-	MSQS	HY-34	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-35	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-36	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-37	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-38	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-39	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-40	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-41	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-42	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-43	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-44	S01C -		U5	U10	U10	U5	28	34		U100	
17110019-HY-000-	MSQS	HY-45	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-46	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-47	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-48	S01C -		U5	U10	U10	U5	U5	U5		U100	

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
ORGANONITROGEN COMPOUNDS

Drainage	Survey	Station	Sample	Rep	nitro-benzene	N-nitroso-diprcpyl-amine	2,6-di-nitro-toluene	2,4-di-nitro-toluene	N-nitroso-diphenyl-amine	1,2-di-phenyl-hydra-zine	benzi-dine	3,3'-di-chloro-benzi-dine	N-nitroso-dimethyl amine
17110019-HY-000-	MSQS	HY-49	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-50	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-HY-000-	MSQS	HY-51	SU1C -		U5	U10	40	U5	U5	U5		U100	
17110019-MD-000-	MSQS	MD-11	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MD-000-	MSQS	MD-12	SU5C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MD-000-	MSQS	MD-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-11	S01C -	01	U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-11	S01C -	02	U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-12	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-14	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-MI-000-	MSQS	MI-15	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-11	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-12	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-14	S05C -	01	U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-14	S05C -	02	U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-15	S02C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-16	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-17	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-18	S01C -		U5	U10	U10	U5	610	U5		U100	
17110019-RS-000-	MSQS	RS-19	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-20	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-21	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-22	S01C -		5	U10	U10	U5	U5	U5		U100	
17110019-RS-000-	MSQS	RS-24	S05C -		U5	U10	U10	U5	40	U5		U100	
17110019-SI-000-	MSQS	SI-11	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SI-000-	MSQS	SI-12	SU1C -		U5	U10	U10	U5	130	U5		U100	
17110019-SI-000-	MSQS	SI-13	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SI-000-	MSQS	SI-14	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SI-000-	MSQS	SI-15	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-11	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-12	SU5C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-13	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-14	SU1C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-15	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-SP-000-	MSQS	SP-16	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-DP-000-	MSQS	WBS	CTL -	01	U5	U10	U10	U5	33	U5		U100	
17110019-DP-000-	MSQS	WBS	CTL -	02	U5	U10	U10	U5	43	U5		U100	

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PESTICIDES I

Drainage	Survey	Station	Sample	Rep	4,4'-DDE	4,4'-DDD	4,4'-DDT	aldrin	dieldrin	a-HCH	b-HCH	d-HCH	g-HCH
17110019-BL-000-	MSQS	BL-11	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-12	S01C -		U40	U40	U40	U40	U40	U40	U40	U40	U40
17110019-BL-000-	MSQS	BL-13	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-14	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-BL-000-	MSQS	BL-15	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-BL-000-	MSQS	BL-16	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-17	S01C -	01	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-17	S01C -	02	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-18	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-19	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-BL-000-	MSQS	BL-20	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-BL-000-	MSQS	BL-21	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-22	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-23	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-24	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-25	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-26	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-27	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-28	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-29	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-30	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-31	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	MSQS	BL-32	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	CB-11	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CB-000-	MSQS	CB-12	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CB-000-	MSQS	CB-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CB-000-	MSQS	CB-14	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-11	S02C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-12	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-13	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-14	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-15	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CW-000-	MSQS	CI-16	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-17	S05C -	01	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-17	S05C -	02	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-18	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-19	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CI-000-	MSQS	CI-20	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-21	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-CI-000-	MSQS	CI-22	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CR-000-	MSQS	CR-11	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CR-000-	MSQS	CR-12	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CR-000-	MSQS	CR-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-CR-000-	MSQS	CR-14	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-11	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PESTICIDES I

Drainage	Survey	Station	Sample	Rep	4,4'-DDE	4,4'-DDD	4,4'-DDT	aldrin	dieldrin	a-HCH	b-HCH	d-HCH	g-HCH
17110019-HY-000-	MSQS	HY-12	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-14	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-15	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-16	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-17	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-18	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-19	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-20	S01C -	01	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-20	S01C -	02	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-21	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-22	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-23	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-24	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-25	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-26	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-27	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-28	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-29	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-30	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-31	S01C -	01	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-31	S01C -	02	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-32	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-33	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-34	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-35	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-36	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-37	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-38	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-39	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-40	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-41	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-42	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-43	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-44	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-45	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-46	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-47	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-HY-000-	MSQS	HY-48	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-49	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-50	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-HY-000-	MSQS	HY-51	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MD-000-	MSQS	MD-11	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-MD-000-	MSQS	MD-12	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-MD-000-	MSQS	MD-13	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PESTICIDES 1

Drainage	Survey	Station	Sample	Rep	4,4'-DDE	4,4'-DDD	4,4'-DDT	aldrin	dieldrin	a-HCH	b-HCH	d-HCH	g-HCH
17110019-MI-000-	MSQS	MI-11	S01C -	01	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MI-000-	MSQS	MI-11	S01C -	02	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MI-000-	MSQS	MI-12	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MI-000-	MSQS	MI-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MI-000-	MSQS	MI-14	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-MI-000-	MSQS	MI-15	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-11	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-12	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-14	S05C -	01	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-14	S05C -	02	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-15	S02C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-16	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-17	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-18	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-RS-000-	MSQS	RS-19	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-RS-000-	MSQS	RS-20	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-21	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-22	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-RS-000-	MSQS	RS-24	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SI-000-	MSQS	SI-11	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-SI-000-	MSQS	SI-12	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-SI-000-	MSQS	SI-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SI-000-	MSQS	SI-14	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SI-000-	MSQS	SI-15	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-SP-000-	MSQS	SP-11	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SP-000-	MSQS	SP-12	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SP-000-	MSQS	SP-13	S01C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SP-000-	MSQS	SP-14	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-SP-000-	MSQS	SP-15	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-SP-000-	MSQS	SP-16	S05C -		U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-DP-000-	MSQS	WBS	CTL -	01	U25	U25	U25	U25	U25	U25	U25	U25	U25
17110019-DP-000-	MSQS	WBS	CTL -	02	U25	U25	U25	U25	U25	U25	U25	U25	U25

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PCBS

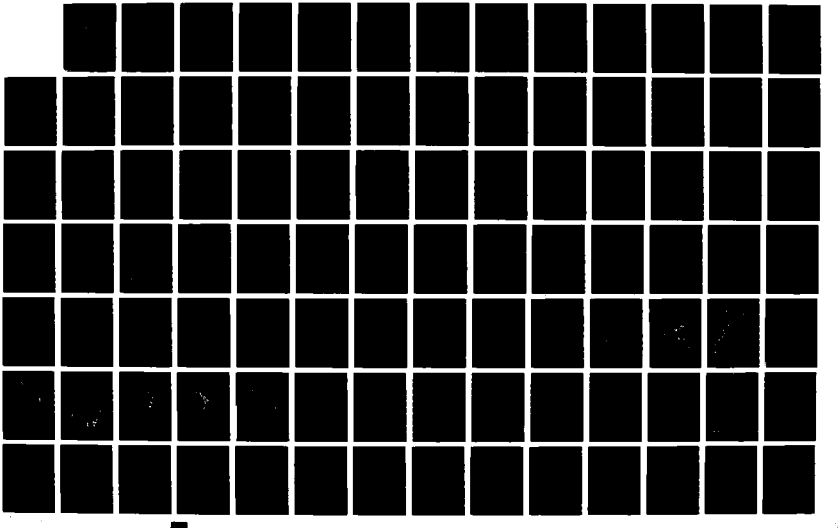
Drainage	Survey	Station	Sample	Rep	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCBs
17110019-BL-000-	MSQS	BL-11	SU5C	-				U10	U10	C	C	17
17110019-BL-000-	MSQS	BL-12	S01C	-				U10	U10	C	C	68
17110019-BL-000-	MSQS	BL-13	S05C	-				U10	U10	C	C	22
17110019-BL-000-	MSQS	BL-14	S01C	-				U100	U100	C	C	U110
17110019-BL-000-	MSQS	BL-15	S01C	-				U10	U10	C	C	15
17110019-BL-000-	MSQS	BL-16	S01C	-				U100	U100	C	C	U110
17110019-BL-000-	MSQS	BL-17	S01C	-	01			U10	U10	C	C	22
17110019-BL-000-	MSQS	BL-17	S01C	-	02			U100	U100	C	C	200
17110019-BL-000-	MSQS	BL-18	S01C	-				U10	U10	C	C	13
17110019-BL-000-	MSQS	BL-19	S01C	-				U10	U10	C	C	9.4
17110019-BL-000-	MSQS	BL-20	S01C	-				U10	U10	C	C	13
17110019-BL-000-	MSQS	BL-21	S05C	-				U10	U10	C	C	6.7
17110019-BL-000-	MSQS	BL-22	S01C	-				U10	U10	C	C	11
17110019-BL-000-	MSQS	BL-23	S01C	-				U10	U10	C	C	17
17110019-BL-000-	MSQS	BL-24	S01C	-				U10	U10	C	C	18
17110019-BL-000-	MSQS	BL-25	S05C	-				U10	U10	C	C	38
17110019-BL-000-	MSQS	BL-26	S01C	-				U100	U100	C	C	U100
17110019-BL-000-	MSQS	BL-27	S01C	-				U7	U7	C	C	6.8
17110019-BL-000-	MSQS	BL-28	S05C	-				U80	U80	C	C	84
17110019-BL-000-	MSQS	BL-29	S01C	-				U80	U80	C	C	140
17110019-BL-000-	MSQS	BL-30	S01C	-				U10	U10	C	C	30
17110019-BL-000-	MSQS	BL-31	S05C	-				U10	U10	C	C	3
17110019-BL-000-	MSQS	BL-32	S01C	-				U10	U10	C	C	14
17110019-HY-000-	MSQS	CB-11	S01C	-				U100	U100	C	C	U100
17110019-CB-000-	MSQS	CB-12	S01C	-				U10	U10	C	C	U8
17110019-CB-000-	MSQS	CB-13	S01C	-				U10	U10	C	C	U8
17110019-CB-000-	MSQS	CB-14	S01C	-				U10	U10	C	C	U8
17110019-CI-000-	MSQS	CI-11	S02C	-				U1200	U1200	C	C	15
17110019-CI-000-	MSQS	CI-12	S01C	-				U130	U130	C	C	79
17110019-CI-000-	MSQS	CI-13	S05C	-				U130	U130	C	C	140
17110019-CI-000-	MSQS	CI-14	S01C	-				U130	U130	C	C	57
17110019-CI-000-	MSQS	CI-15	S01C	-				U130	U130	C	C	51
17110019-CW-000-	MSQS	CI-16	S05C	-				U15	U15	C	C	36
17110019-CI-000-	MSQS	CI-17	S05C	-	01			U15	U15	C	C	50
17110019-CI-000-	MSQS	CI-17	S05C	-	02			U130	U130	C	C	100
17110019-CI-000-	MSQS	CI-18	S01C	-				U130	U130	C	C	95
17110019-CI-000-	MSQS	CI-19	S01C	-				U130	U130	C	C	49
17110019-CI-000-	MSQS	CI-20	S05C	-				U10	U10	C	C	19
17110019-CI-000-	MSQS	CI-21	S01C	-				U100	U100	C	C	U90
17110019-CI-000-	MSQS	CI-22	S05C	-				U80	U80	C	C	32
17110019-CR-000-	MSQS	CR-11	S01C	-				U7	U7	C	C	U7
17110019-CR-000-	MSQS	CR-12	S05C	-				U7	U7	C	C	U7
17110019-CR-000-	MSQS	CR-13	S01C	-				U7	U7	C	C	U7
17110019-CR-000-	MSQS	CR-14	S05C	-				U7	U7	C	C	U7
17110019-HY-000-	MSQS	HY-11	SU1C	-				U130	U130	C	C	U130

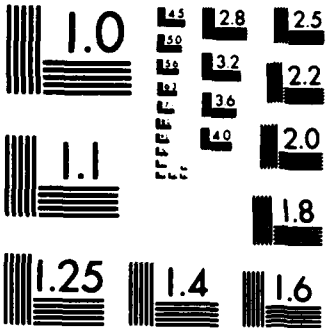
MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PCBS

Drainage	Survey	Station	Sample	Rep	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCBs
[illegible]	MSQS	MY-12	S01C	-				U80	U80	C	C	110
[illegible]	MSQS	MY-13	S01C	-				U130	U130	C	C	77
[illegible]	MSQS	MY-14	S05C	-				U50	U50	C	C	85
[illegible]	MSQS	MY-15	S01C	-				U100	U100	C	C	130
[illegible]	MSQS	MY-16	S01C	-				U150	U150	C	C	330
[illegible]	MSQS	MY-17	S01C	-				U130	U130	C	C	170
[illegible]	MSQS	MY-18	S01C	-				U150	U150	C	C	150
[illegible]	MSQS	MY-19	S01C	-				U150	U150	C	C	210
[illegible]	MSQS	MY-20	S01C	-	01			U130	U130	C	C	210
[illegible]	MSQS	MY-20	S01C	-	02			U130	U130	C	C	320
[illegible]	MSQS	MY-21	S01C	-				U130	U130	C	C	330
[illegible]	MSQS	MY-22	S05C	-				U1500	U1500	C	C	2000
[illegible]	MSQS	MY-23	S01C	-				U150	U150	C	C	1500
[illegible]	MSQS	MY-24	S01C	-				U130	U130	C	C	250
[illegible]	MSQS	MY-25	S01C	-				U130	U130	C	C	190
[illegible]	MSQS	MY-26	S01C	-				U100	U100	C	C	170
[illegible]	MSQS	MY-27	S01C	-				U130	U130	C	C	860
[illegible]	MSQS	MY-28	S01C	-				U900	U900	C	C	120
[illegible]	MSQS	MY-29	S01C	-				U100	U100	C	C	220
[illegible]	MSQS	MY-30	S01C	-				U130	U130	C	C	240
[illegible]	MSQS	MY-31	S01C	-	01			U100	U100	C	C	110
[illegible]	MSQS	MY-31	S01C	-	02			U100	U50	C	C	110
[illegible]	MSQS	MY-32	S01C	-				U100	U100	C	C	130
[illegible]	MSQS	MY-33	S01C	-				U100	U100	C	C	U90
[illegible]	MSQS	MY-34	S01C	-				U100	U100	C	C	200
[illegible]	MSQS	MY-35	S01C					U1000	U1000	C	C	140
[illegible]	MSQS	MY-36	S01C	-				U100	U100	C	C	110
[illegible]	MSQS	MY-37	S01C	-				U1000	U50	C	C	420
[illegible]	MSQS	MY-38	S01C	-				U130	U130	C	C	210
[illegible]	MSQS	MY-39	S01C	-				U900	U900	C	C	
[illegible]	MSQS	MY-40	S01C	-				U1000	U1000	C	C	190
[illegible]	MSQS	MY-41	S01C	-				U100	U100	C	C	U95
[illegible]	MSQS	MY-42	S01C	-				U10000	U1000	C	C	1100
[illegible]	MSQS	MY-43	S01C	-				U1000	U1000	C	C	U100
[illegible]	MSQS	MY-44	S01C	-				U80	U80	C	C	U65
[illegible]	MSQS	MY-45	S01C	-				U900	U900	C	C	130
[illegible]	MSQS	MY-46	S01C	-				U1000	U1000	C	C	280
[illegible]	MSQS	MY-47	S01C	-				U1000	U1000	C	C	
[illegible]	MSQS	MY-48	S01C	-				U80	U80	C	C	U85
[illegible]	MSQS	MY-49	S01C	-				U100	U100	C	C	20
[illegible]	MSQS	MY-50	S01C	-				U10	U10	C	C	33
[illegible]	MSQS	MY-51	S01C	-				U100	U100	C	C	U95
[illegible]	MSQS	MY-52	S01C	-				U15	U15	C	C	29
[illegible]	MSQS	MY-53	S01C	-				U10	U10	C	C	130
[illegible]	MSQS	MY-54	S01C	-				U10	U10	C	C	38

AD-A184 867 DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND 3/6
VOLUME 1(U) TETRA TECH INC BELLEVUE WA SEP 86
TC3090-02-VOL-1 DACW67-85-D-0029

UNCLASSIFIED F/G 24/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
PCBS

Drainage	Survey	Station	Sample	Rep	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCBs
17110019-MI-000-	MSQS	MI-11	S01C -	01				U10	U10	C	C	14
17110019-MI-000-	MSQS	MI-11	S01C -	02				U100	U100	C	C	56
17110019-MI-000-	MSQS	MI-12	S01C -					U100	U100	C	C	87
17110019-MI-000-	MSQS	MI-13	S01C -					U10	U10	C	C	13
17110019-MI-000-	MSQS	MI-14	S01C -					U100	U100	C	C	63
17110019-MI-000-	MSQS	MI-15	S01C -					U10	U10	C	C	16
17110019-RS-000-	MSQS	RS-11	S01C -					U7	U7	C	C	U7
17110019-RS-000-	MSQS	RS-12	S01C -					U80	U80	C	C	16
17110019-RS-000-	MSQS	RS-13	S01C -					U10	U10	C	C	14
17110019-RS-000-	MSQS	RS-14	S05C -	01				U150	U150	C	C	18
17110019-RS-000-	MSQS	RS-14	S05C -	02				U15	U15	C	C	15
17110019-RS-000-	MSQS	RS-15	S02C -					U7	U7	C	C	U7
17110019-RS-000-	MSQS	RS-16	S01C -					U200	U200	C	C	580
17110019-RS-000-	MSQS	RS-17	S01C -					U100	U100	C	C	510
17110019-RS-000-	MSQS	RS-18	S01C -					U15	U15	C	C	26
17110019-RS-000-	MSQS	RS-19	S01C -					U7	U7	C	C	14
17110019-RS-000-	MSQS	RS-20	S01C -					U7	U7	C	C	4
17110019-RS-000-	MSQS	RS-21	S01C -					U150	U150	C	C	580
17110019-RS-000-	MSQS	RS-22	S01C -					U7	U7	C	C	U6
17110019-RS-000-	MSQS	RS-24	S05C -					U7	U7	C	C	17
17110019-SI-000-	MSQS	SI-11	S05C -					U10	U10	C	C	20
17110019-SI-000-	MSQS	SI-12	S01C -					U10	U10	C	C	18
17110019-SI-000-	MSQS	SI-13	S01C -					U10	U10	C	C	35
17110019-SI-000-	MSQS	SI-14	S01C -					U100	U100	C	C	140
17110019-SI-000-	MSQS	SI-15	S05C -					U10	U10	C	C	16
17110019-SP-000-	MSQS	SP-11	S05C -					U100	U100	C	C	U90
17110019-SP-000-	MSQS	SP-12	S05C -					U100	U100	C	C	U100
17110019-SP-000-	MSQS	SP-13	S01C -					U130	U130	C	C	79
17110019-SP-000-	MSQS	SP-14	S01C -					U180	U180	C	C	U180
17110019-SP-000-	MSQS	SP-15	S05C -					U100	U100	C	C	U90
17110019-SP-000-	MSQS	SP-16	S05C -					U80	U80	C	C	U90
17110019-DP-000-	MSQS	WBS	CTL -	01				U6	U6	C	C	U6
17110019-DP-000-	MSQS	WBS	CTL -	02				U7	U7	C	C	U7

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE HALOGENATED ALKENES

Drainage	Survey	Station	Sample	Rep	vinyl chloride	1,1-di-chloro-ethene	1,2-trans-dichloro ethylene	cis-1,3-di-chloro-propene	trans-1,3-di-chloro-propene	tri-chloro-ethene	tetra-chloro-ethene
17110019-BL-000-	MSQS	BL-11	S05C -								
17110019-BL-000-	MSQS	BL-12	S01C -								
17110019-BL-000-	MSQS	BL-13	S05C -								
17110019-BL-000-	MSQS	BL-14	S01C -								
17110019-BL-000-	MSQS	BL-15	S01C -								
17110019-BL-000-	MSQS	BL-16	S01C -								
17110019-BL-000-	MSQS	BL-17	S01C -	01							
17110019-BL-000-	MSQS	BL-17	S01C -	02							
17110019-BL-000-	MSQS	BL-18	S01C -								
17110019-BL-000-	MSQS	BL-19	S01C -								
17110019-BL-000-	MSQS	BL-20	S01C -								
17110019-BL-000-	MSQS	BL-21	S05C -		U10	U10	U10	U10	U10	U10	U10
17110019-BL-000-	MSQS	BL-22	S01C -		U10	U10	U10	U10	U10	U10	U10
17110019-BL-000-	MSQS	BL-23	S01C -								
17110019-BL-000-	MSQS	BL-24	S01C -								
17110019-BL-000-	MSQS	BL-25	S05C -								
17110019-BL-000-	MSQS	BL-26	S01C -								
17110019-BL-000-	MSQS	BL-27	S01C -								
17110019-BL-000-	MSQS	BL-28	S05C -								
17110019-BL-000-	MSQS	BL-29	S01C -								
17110019-BL-000-	MSQS	BL-30	S01C -								
17110019-BL-000-	MSQS	BL-31	S05C -								
17110019-BL-000-	MSQS	BL-32	S01C -								
17110019-MY-000-	MSQS	CB-11	S01C -								
17110019-CB-000-	MSQS	CB-12	S01C -								
17110019-CB-000-	MSQS	CB-13	S01C -								
17110019-CB-000-	MSQS	CB-14	S01C -								
17110019-CI-000-	MSQS	CI-11	S02C -		U10	U10	U10	U10	U10	U10	U10
17110019-CI-000-	MSQS	CI-12	S01C -								
17110019-CI-000-	MSQS	CI-13	S05C -								
17110019-CI-000-	MSQS	CI-14	S01C -								
17110019-CI-000-	MSQS	CI-15	S01C -								
17110019-CW-000-	MSQS	CI-16	S05C -		U10	U10	U10	U10	U10	U10	U10
17110019-CI-000-	MSQS	CI-17	S05C -	01	U10	U10	U10	U10	U10	U10	U10
17110019-CI-000-	MSQS	CI-17	S05C -	02	U10	U10	U10	U10	U10	U10	U10
17110019-CI-000-	MSQS	CI-18	S01C -								
17110019-CI-000-	MSQS	CI-19	S01C -								
17110019-CI-000-	MSQS	CI-20	S05C -								
17110019-CI-000-	MSQS	CI-21	S01C -								
17110019-CI-000-	MSQS	CI-22	S05C -								
17110019-CR-000-	MSQS	CR-11	S01C -								
17110019-CR-000-	MSQS	CR-12	S05C -								
17110019-CR-000-	MSQS	CR-13	S01C -								

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE HALOGENATED ALKENES

Drainage	Survey	Station	Sample	Rep	vinyl chloride	1,1-di-chloro-ethene	1,2-trans-dichloro ethylene	cis-1,3-di-chloro-propene	trans-1,3-di-chloro-propene	tri-chloro-ethene	tetra-chloro-ethene
17110019-CR-000-	MSQS	CR-14	SU5C -								
17110019-HY-000-	MSQS	HY-11	S01C -								
17110019-HY-000-	MSQS	HY-12	S01C -								
17110019-HY-000-	MSQS	HY-13	SU1C -								
17110019-HY-000-	MSQS	HY-14	S05C -								
17110019-HY-000-	MSQS	HY-15	S01C -								
17110019-HY-000-	MSQS	HY-16	S01C -								
17110019-HY-000-	MSQS	HY-17	S01C -		U10	U10	U10	U10	U10	U10	210
17110019-HY-000-	MSQS	HY-18	S01C -								
17110019-HY-000-	MSQS	HY-19	S01C -								
17110019-HY-000-	MSQS	HY-20	SU1C -	01							
17110019-HY-000-	MSQS	HY-20	SU1C -	02							
17110019-HY-000-	MSQS	HY-21	S01C -		U10	U10	U10	U10	U10	U10	160
17110019-HY-000-	MSQS	HY-22	S05C -		U10	U10	U10	U10	U10	U10	67
17110019-HY-000-	MSQS	HY-23	S01C -		U10	U10	U10	U10	U10	U10	170
17110019-HY-000-	MSQS	HY-24	S01C -								
17110019-HY-000-	MSQS	HY-25	S01C -		U10	U10	U10	U10	U10	U10	140
17110019-HY-000-	MSQS	HY-26	S01C -								
17110019-HY-000-	MSQS	HY-27	S01C -								
17110019-HY-000-	MSQS	HY-28	S01C -		U10	U10	U10	U10	U10	U10	140
17110019-HY-000-	MSQS	HY-29	S01C -								
17110019-HY-000-	MSQS	HY-30	S01C -								
17110019-HY-000-	MSQS	HY-31	S01C -	01							
17110019-HY-000-	MSQS	HY-31	SU1C -	02							
17110019-HY-000-	MSQS	HY-32	S01C -								
17110019-HY-000-	MSQS	HY-33	S01C -								
17110019-HY-000-	MSQS	HY-34	SU1C -								
17110019-HY-000-	MSQS	HY-35	SU1C -								
17110019-HY-000-	MSQS	HY-36	S01C -								
17110019-HY-000-	MSQS	HY-37	SU1C -								
17110019-HY-000-	MSQS	HY-38	S01C -								
17110019-HY-000-	MSQS	HY-39	SU1C -								
17110019-HY-000-	MSQS	HY-40	S01C -								
17110019-HY-000-	MSQS	HY-41	S01C -		U10	U10	U10	U10	U10	U10	47
17110019-HY-000-	MSQS	HY-42	S01C -		U10	U10	U10	U10	U10	U10	78
17110019-HY-000-	MSQS	HY-43	S01C -		U10	U10	U10	U10	U10	U10	140
17110019-HY-000-	MSQS	HY-44	S01C -		U10	U10	U10	U10	U10	U10	57
17110019-HY-000-	MSQS	HY-45	S01C -		U10	U10	U10	U10	U10	U10	68
17110019-HY-000-	MSQS	HY-46	S01C -								
17110019-HY-000-	MSQS	HY-47	S05C -								
17110019-HY-000-	MSQS	HY-48	S01C -								
17110019-HY-000-	MSQS	HY-49	SU1C -								
17110019-HY-000-	MSQS	HY-50	S05C -								

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE HALOGENATED ALKENES

Drainage	Survey	Station	Sample	Rep	vinyl chloride	1,1-di-chloro-ethene	1,2-trans-dichloro ethylene	cis-1,3-di-chloro-propene	trans-1,3-di-chloro-propene	tri-chloro-ethene	tetra-chloro-ethene
17110019-HY-000-	MSQS	HY-51	S01C -								
17110019-MD-000-	MSQS	MD-11	S01C -								
17110019-MD-000-	MSQS	MD-12	S05C -								
17110019-MD-000-	MSQS	MD-13	S01C -								
17110019-MI-000-	MSQS	MI-11	S01C -	01							
17110019-MI-000-	MSQS	MI-11	S01C -	02							
17110019-MI-000-	MSQS	MI-12	S01C -								
17110019-MI-000-	MSQS	MI-13	S01C -								
17110019 MI-000-	MSQS	MI-14	S01C -								
17110019-MI-000-	MSQS	MI-15	S01C -								
17110019-RS-000-	MSQS	RS-11	S01C -								
17110019-RS-000-	MSQS	RS-12	S01C -								
17110019-RS-000-	MSQS	RS-13	S01C -								
17110019-RS-000-	MSQS	RS-14	S05C -	01							
17110019-RS-000-	MSQS	RS-14	S05C -	02							
17110019-RS-000-	MSQS	RS-15	S02C -								
17110019-RS-000-	MSQS	RS-16	S01C -								
17110019-RS-000-	MSQS	RS-17	S01C -								
17110019-RS-000-	MSQS	RS-18	S01C -								
17110019-RS-000-	MSQS	RS-19	S01C -								
17110019-RS-000-	MSQS	RS-20	S01C -								
17110019-RS-000-	MSQS	RS-21	S01C -								
17110019-RS-000-	MSQS	RS-22	S01C -								
17110019-RS-000-	MSQS	RS-24	S05C -								
17110019-SI-000-	MSQS	SI-11	S05C -		U10	U10	U10	U10	U10	U10	U10
17110019-SI-000-	MSQS	SI-12	S01C -								
17110019-SI-000-	MSQS	SI-13	S01C -								
17110019-SI-000-	MSQS	SI-14	S01C -								
17110019-SI-000-	MSQS	SI-15	S05C -								
17110019-SP-000-	MSQS	SP-11	S05C -								
17110019-SP-000-	MSQS	SP-12	S05C -		U10	U10	U10	U10	U10	U10	U10
17110019-SP-000-	MSQS	SP-13	S01C -								
17110019-SP-000-	MSQS	SP-14	S01C -		U10	U10	U10	U10	U10	U10	U10
17110019-SP-000-	MSQS	SP-15	S05C -		U10	U10	U10	U10	U10	U10	U10
17110019-SP-000-	MSQS	SP-16	S05C -								
17110019-DP-000-	MSQS	WBS	CTL -	01							
17110019-DP-000-	MSQS	WBS	CTL -	02							

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	benzene	toluene	ethyl-benzene
17110019-BL-000-	MSQS	BL-11	S05C	-			
17110019-BL-000-	MSQS	BL-12	S01C	-			
17110019-BL-000-	MSQS	BL-13	S05C	-			
17110019-BL-000-	MSQS	BL-14	S01C	-			
17110019-BL-000-	MSQS	BL-15	S01C	-			
17110019-BL-000-	MSQS	BL-16	S01C	-			
17110019-BL-000-	MSQS	BL-17	S01C	- 01			
17110019-BL-000-	MSQS	BL-17	S01C	- 02			
17110019-BL-000-	MSQS	BL-18	S01C	-			
17110019-BL-000-	MSQS	BL-19	S01C	-			
17110019-BL-000-	MSQS	BL-20	S01C	-			
17110019-BL-000-	MSQS	BL-21	S05C	-	U10	U10	U10
17110019-BL-000-	MSQS	BL-22	S01C	-	U10	U10	U10
17110019-BL-000-	MSQS	BL-23	S01C	-			
17110019-BL-000-	MSQS	BL-24	S01C	-			
17110019-BL-000-	MSQS	BL-25	S05C	-			
17110019-BL-000-	MSQS	BL-26	S01C	-			
17110019-BL-000-	MSQS	BL-27	S01C	-			
17110019-BL-000-	MSQS	BL-28	S05C	-			
17110019-BL-000-	MSQS	BL-29	S01C	-			
17110019-BL-000-	MSQS	BL-30	S01C	-			
17110019-BL-000-	MSQS	BL-31	S05C	-			
17110019-BL-000-	MSQS	BL-32	S01C	-			
17110019-HY-000-	MSQS	CB-11	S01C	-			
17110019-CB-000-	MSQS	CB-12	S01C	-			
17110019-CB-000-	MSQS	CB-13	S01C	-			
17110019-CB-000-	MSQS	CB-14	S01C	-			
17110019-CI-000-	MSQS	CI-11	S02C	-	U10	U10	U10
17110019-CI-000-	MSQS	CI-12	S01C	-			
17110019-CI-000-	MSQS	CI-13	S05C	-			
17110019-CI-000-	MSQS	CI-14	S01C	-			
17110019-CI-000-	MSQS	CI-15	S01C	-			
17110019-CW-000-	MSQS	CI-16	S05C	-	U10	U10	U10
17110019-CI-000-	MSQS	CI-17	S05C	- 01	U10	U10	U10
17110019-CI-000-	MSQS	CI-17	S05C	- 02	U10	U10	U10
17110019-CI-000-	MSQS	CI-18	S01C	-			
17110019-CI-000-	MSQS	CI-19	S01C	-			
17110019-CI-000-	MSQS	CI-20	S05C	-			
17110019-CI-000-	MSQS	CI-21	S01C	-			
17110019-CI-000-	MSQS	CI-22	S05C	-			
17110019-CR-000-	MSQS	CR-11	S01C	-			
17110019-CR-000-	MSQS	CR-12	S05C	-			
17110019-CR-000-	MSQS	CR-13	S01C	-			
17110019-CR-000-	MSQS	CR-14	S05C	-			

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	benzene	toluene	ethyl-benzene
17110019-HY-000-	MSQS	HY-11	S01C	-			
17110019-HY-000-	MSQS	HY-12	S01C	-			
17110019-HY-000-	MSQS	HY-13	S01C	-			
17110019-HY-000-	MSQS	HY-14	S05C	-			
17110019-HY-000-	MSQS	HY-15	S01C	-			
17110019-HY-000-	MSQS	HY-16	S01C	-			
17110019-HY-000-	MSQS	HY-17	S01C	-	U10	U10	50
17110019-HY-000-	MSQS	HY-18	S01C	-			
17110019-HY-000-	MSQS	HY-19	S01C	-			
17110019-HY-000-	MSQS	HY-20	S01C	-	U1		
17110019-HY-000-	MSQS	HY-20	S01C	-	U2		
17110019-HY-000-	MSQS	HY-21	S01C	-	U10	U10	U10
17110019-HY-000-	MSQS	HY-22	S05C	-	U10	U10	17
17110019-HY-000-	MSQS	HY-23	S01C	-	U10	U10	31
17110019-HY-000-	MSQS	HY-24	S01C	-			
17110019-HY-000-	MSQS	HY-25	S01C	-	U10	U10	30
17110019-HY-000-	MSQS	HY-26	S01C	-			
17110019-HY-000-	MSQS	HY-27	S01C	-			
17110019-HY-000-	MSQS	HY-28	S01C	-	U10	U10	33
17110019-HY-000-	MSQS	HY-29	S01C	-			
17110019-HY-000-	MSQS	HY-30	S01C	-			
17110019-HY-000-	MSQS	HY-31	S01C	-	U1		
17110019-HY-000-	MSQS	HY-31	S01C	-	U2		
17110019-HY-000-	MSQS	HY-32	S01C	-			
17110019-HY-000-	MSQS	HY-33	S01C	-			
17110019-HY-000-	MSQS	HY-34	S01C	-			
17110019-HY-000-	MSQS	HY-35	S01C	-			
17110019-HY-000-	MSQS	HY-36	S01C	-			
17110019-HY-000-	MSQS	HY-37	S01C	-			
17110019-HY-000-	MSQS	HY-38	S01C	-			
17110019-HY-000-	MSQS	HY-39	S01C	-			
17110019-HY-000-	MSQS	HY-40	S01C	-			
17110019-HY-000-	MSQS	HY-41	S01C	-	U10	U10	L10
17110019-HY-000-	MSQS	HY-42	S01C	-	U10	U10	18
17110019-HY-000-	MSQS	HY-43	S01C	-	U10	U10	37
17110019-HY-000-	MSQS	HY-44	S01C	-	U10	U10	10
17110019-HY-000-	MSQS	HY-45	S01C	-	U10	U10	13
17110019-HY-000-	MSQS	HY-46	S01C	-			
17110019-HY-000-	MSQS	HY-47	S05C	-			
17110019-HY-000-	MSQS	HY-48	S01C	-			
17110019-HY-000-	MSQS	HY-49	S01C	-			
17110019-HY-000-	MSQS	HY-50	S05C	-			
17110019-HY-000-	MSQS	HY-51	S01C	-			
17110019-MD-000-	MSQS	MD-11	S01C	-			

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	benzene	toluene	ethyl-benzene
17110019-MD-000-	MSQS	MD-12	SU5C -				
17110019-MD-000-	MSQS	MD-13	SU1C -				
17110019-MI-000-	MSQS	MI-11	SU1C -	01			
17110019-MI-000-	MSQS	MI-11	SU1C -	02			
17110019-MI-000-	MSQS	MI-12	SU1C -				
17110019-MI-000-	MSQS	MI-13	SU1C -				
17110019-MI-000-	MSQS	MI-14	SU1C -				
17110019-MI-000-	MSQS	MI-15	SU1C -				
17110019-RS-000-	MSQS	RS-11	SU1C -				
17110019-RS-000-	MSQS	RS-12	SU1C -				
17110019-RS-000-	MSQS	RS-13	SU1C -				
17110019-RS-000-	MSQS	RS-14	SU5C -	01			
17110019-RS-000-	MSQS	RS-14	SU5C -	02			
17110019-RS-000-	MSQS	RS-15	SU2C -				
17110019-RS-000-	MSQS	RS-16	SU1C -				
17110019-RS-000-	MSQS	RS-17	SU1C -				
17110019-RS-000-	MSQS	RS-18	SU1C -				
17110019-RS-000-	MSQS	RS-19	SU1C -				
17110019-RS-000-	MSQS	RS-20	SU1C -				
17110019-RS-000-	MSQS	RS-21	SU1C -				
17110019-RS-000-	MSQS	RS-22	SU1C -				
17110019-RS-000-	MSQS	RS-24	SU5C -				
17110019-SI-000-	MSQS	SI-11	SU5C -		U10	U10	U10
17110019-SI-000-	MSQS	SI-12	SU1C -				
17110019-SI-000-	MSQS	SI-13	SU1C -				
17110019-SI-000-	MSQS	SI-14	SU1C -				
17110019-SI-000-	MSQS	SI-15	SU5C -				
17110019-SP-000-	MSQS	SP-11	SU5C -				
17110019-SP-000-	MSQS	SP-12	SU5C -		U10	U10	U10
17110019-SP-000-	MSQS	SP-13	SU1C -				
17110019-SP-000-	MSQS	SP-14	SU1C -		U10	U10	U10
17110019-SP-000-	MSQS	SP-15	SU5C -		U10	U10	U10
17110019-SP-000-	MSQS	SP-16	SU5C -				
17110019-DP-000-	MSQS	WBS	CTL -	01			
17110019-DP-000-	MSQS	WBS	CTL -	02			

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	styrene	total xylenes	o-xylene
17110019-BL-000-	MSQS	BL-11	SO5C -				
17110019-BL-000-	MSQS	BL-12	SO1C -				
17110019-BL-000-	MSQS	BL-13	SO5C -				
17110019-BL-000-	MSQS	BL-14	SO1C -				
17110019-BL-000-	MSQS	BL-15	SO1C -				
17110019-BL-000-	MSQS	BL-16	SO1C -				
17110019-BL-000-	MSQS	BL-17	SO1C -	01			
17110019-BL-000-	MSQS	BL-17	SO1C -	02			
17110019-BL-000-	MSQS	BL-18	SO1C -				
17110019-BL-000-	MSQS	BL-19	SO1C -				
17110019-BL-000-	MSQS	BL-20	SO1C -				
17110019-BL-000-	MSQS	BL-21	SO5C -		U20	U20	C
17110019-BL-000-	MSQS	BL-22	SO1C -		U20	U20	C
17110019-BL-000-	MSQS	BL-23	SO1C -				
17110019-BL-000-	MSQS	BL-24	SO1C -				
17110019-BL-000-	MSQS	BL-25	SO5C -				
17110019-BL-000-	MSQS	BL-26	SO1C -				
17110019-BL-000-	MSQS	BL-27	SO1C -				
17110019-BL-000-	MSQS	BL-28	SO5C -				
17110019-BL-000-	MSQS	BL-29	SO1C -				
17110019-BL-000-	MSQS	BL-30	SO1C -				
17110019-BL-000-	MSQS	BL-31	SO5C -				
17110019-BL-000-	MSQS	BL-32	SO1C -				
17110019-HY-000-	MSQS	CB-11	SO1C -				
17110019-CB-000-	MSQS	CB-12	SO1C -				
17110019-CB-000-	MSQS	CB-13	SO1C -				
17110019-CB-000-	MSQS	CB-14	SO1C -				
17110019-CI-000-	MSQS	CI-11	SO2C -		U20	U20	C
17110019-CI-000-	MSQS	CI-12	SO1C -				
17110019-CI-000-	MSQS	CI-13	SO5C -				
17110019-CI-000-	MSQS	CI-14	SO1C -				
17110019-CI-000-	MSQS	CI-15	SO1C -				
17110019-CW-000-	MSQS	CI-16	SO5C -		U20	U20	C
17110019-CI-000-	MSQS	CI-17	SO5C -	01	U20	U20	C
17110019-CI-000-	MSQS	CI-17	SO5C -	02		U20	
17110019-CI-000-	MSQS	CI-18	SO1C -				
17110019-CI-000-	MSQS	CI-19	SO1C -				
17110019-CI-000-	MSQS	CI-20	SO5C -				
17110019-CI-000-	MSQS	CI-21	SO1C -				
17110019-CI-000-	MSQS	CI-22	SO5C -				
17110019-CR-000-	MSQS	CR-11	SO1C -				
17110019-CR-000-	MSQS	CR-12	SO5C -				
17110019-CR-000-	MSQS	CR-13	SO1C -				
17110019-CR-000-	MSQS	CR-14	SO5C -				

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	styrene	total xylenes	o-xylene
17110019-HY-000-	MSQS	HY-11	S01C -				
17110019-HY-000-	MSQS	HY-12	S01C -				
17110019-HY-000-	MSQS	HY-13	S01C -				
17110019-HY-000-	MSQS	HY-14	S05C -				
17110019-HY-000-	MSQS	HY-15	S01C -				
17110019-HY-000-	MSQS	HY-16	S01C -				
17110019-HY-000-	MSQS	HY-17	S01C -		U20	160	C
17110019-HY-000-	MSQS	HY-18	S01C -				
17110019-HY-000-	MSQS	HY-19	S01C -				
17110019-HY-000-	MSQS	HY-20	S01C -	01			
17110019-HY-000-	MSQS	HY-20	S01C -	02			
17110019-HY-000-	MSQS	HY-21	S01C -		U20	U20	C
17110019-HY-000-	MSQS	HY-22	S05C -		U20	70	C
17110019-HY-000-	MSQS	HY-23	S01C -		U20	110	C
17110019-HY-000-	MSQS	HY-24	S01C -				
17110019-HY-000-	MSQS	HY-25	S01C -		U20	98	C
17110019-HY-000-	MSQS	HY-26	S01C -				
17110019-HY-000-	MSQS	HY-27	S01C -				
17110019-HY-000-	MSQS	HY-28	S01C -		U20	100	C
17110019-HY-000-	MSQS	HY-29	S01C -				
17110019-HY-000-	MSQS	HY-30	S01C -				
17110019-HY-000-	MSQS	HY-31	S01C -	01			
17110019-HY-000-	MSQS	HY-31	S01C -	02			
17110019-HY-000-	MSQS	HY-32	S01C -				
17110019-HY-000-	MSQS	HY-33	S01C -				
17110019-HY-000-	MSQS	HY-34	S01C -				
17110019-HY-000-	MSQS	HY-35	S01C -				
17110019-HY-000-	MSQS	HY-36	S01C -				
17110019-HY-000-	MSQS	HY-37	S01C -				
17110019-HY-000-	MSQS	HY-38	S01C -				
17110019-HY-000-	MSQS	HY-39	S01C -				
17110019-HY-000-	MSQS	HY-40	S01C -				
17110019-HY-000-	MSQS	HY-41	S01C -		U20	L20	C
17110019-HY-000-	MSQS	HY-42	S01C -		U20	53	C
17110019-HY-000-	MSQS	HY-43	S01C -		U20	120	C
17110019-HY-000-	MSQS	HY-44	S01C -		U20	30	C
17110019-HY-000-	MSQS	HY-45	S01C -		U20	49	C
17110019-HY-000-	MSQS	HY-46	S01C -				
17110019-HY-000-	MSQS	HY-47	S05C -				
17110019-HY-000-	MSQS	HY-48	S01C -				
17110019-HY-000-	MSQS	HY-49	S01C -				
17110019-HY-000-	MSQS	HY-50	S05C -				
17110019-HY-000-	MSQS	HY-51	S01C -				
17110019-MD-000-	MSQS	MD-11	S01C -				

MAIN SEDIMENT QUALITY SURVEY ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	styrene	total xylenes	o-xylene
17110019-MD-000-	MSQS	MD-12	SO5C -				
17110019-MD-000-	MSQS	MD-13	SO1C -				
17110019-MI-000-	MSQS	MI-11	SO1C -	01			
17110019-MI-000-	MSQS	MI-11	SO1C -	02			
17110019-MI-000-	MSQS	MI-12	SO1C -				
17110019-MI-000-	MSQS	MI-13	SO1C -				
17110019-MI-000-	MSQS	MI-14	SO1C -				
17110019-MI-000-	MSQS	MI-15	SO1C -				
17110019-RS-000-	MSQS	RS-11	SO1C -				
17110019-RS-000-	MSQS	RS-12	SO1C -				
17110019-RS-000-	MSQS	RS-13	SO1C -				
17110019-RS-000-	MSQS	RS-14	SO5C -	01			
17110019-RS-000-	MSQS	RS-14	SO5C -	02			
17110019-RS-000-	MSQS	RS-15	SO1C -				
17110019-RS-000-	MSQS	RS-16	SO1C -				
17110019-RS-000-	MSQS	RS-17	SO1C -				
17110019-RS-000-	MSQS	RS-18	SO1C -				
17110019-RS-000-	MSQS	RS-19	SO1C -				
17110019-RS-000-	MSQS	RS-20	SO1C -				
17110019-RS-000-	MSQS	RS-21	SO1C -				
17110019-RS-000-	MSQS	RS-22	SO1C -				
17110019-RS-000-	MSQS	RS-24	SO5C -				
17110019-SI-000-	MSQS	SI-11	SO5C -		U20	U20	C
17110019-SI-000-	MSQS	SI-12	SO1C -				
17110019-SI-000-	MSQS	SI-13	SO1C -				
17110019-SI-000-	MSQS	SI-14	SO1C -				
17110019-SI-000-	MSQS	SI-15	SO5C -				
17110019-SP-000-	MSQS	SP-11	SO5C -				
17110019-SP-000-	MSQS	SP-12	SO5C -		U20	U20	C
17110019-SP-000-	MSQS	SP-13	SO5C -				
17110019-SP-000-	MSQS	SP-14	SO1C -		U20	U20	C
17110019-SP-000-	MSQS	SP-15	SO5C -		U20	U20	C
17110019-SP-000-	MSQS	SP-16	SO5C -				
17110019-DP-000-	MSQS	WBS	CTL -	01			
17110019-DP-000-	MSQS	WBS	CTL -	02			

Number of Observations: 123

MAIN SEDIMENT TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample	Rep	1-methyl-2-(1-methyl-ethyl) benzene	2-methoxy phenol	pentachloro-cyclopentane	1-methyl naphthalene	1,1' biphenyl	2,6-dimethyl naphthalene
17110019-BL-000-	MSQS	BL-11	S05C -		E81	E20	U		E9.0	
17110019-BL-000-	MSQS	BL-12	S01C -							
17110019-BL-000-	MSQS	BL-13	S05C -		E87	E35	U		E22	
17110019-BL-000-	MSQS	BL-14	S01C -		E31	U	U		E33	
17110019-BL-000-	MSQS	BL-15	S01C -		E140	E28	U		E11	
17110019-BL-000-	MSQS	BL-16	S01C -		E25	E29	U		U	
17110019-BL-000-	MSQS	BL-17	S01C -	01	E56	E18	U		E16	
17110019-BL-000-	MSQS	BL-17	S01C -	02						
17110019-BL-000-	MSQS	BL-18	S01C -		E12	E12	U		E12	
17110019-BL-000-	MSQS	BL-19	S01C -		E47	E17	U		E15	
17110019-BL-000-	MSQS	BL-20	S01C -		E130	E23	U		E18	
17110019-BL-000-	MSQS	BL-21	S05C -		E1.7	E18	U		E12	
17110019-BL-000-	MSQS	BL-22	S01C -		E990	E29	U		E32	
17110019-BL-000-	MSQS	BL-23	S01C -		E110	E39	U		E55	
17110019-BL-000-	MSQS	BL-24	S01C -		E30	E43	U		E34	
17110019-BL-000-	MSQS	BL-25	S05C -		E42	E18	U		E13	
17110019-BL-000-	MSQS	BL-26	S01C -		E52	E47	E1.8		E34	
17110019-BL-000-	MSQS	BL-27	S01C -		E1.3	E8.9	U		E8.9	
17110019-BL-000-	MSQS	BL-28	S05C -		E5.5	E14	U		E11	
17110019-BL-000-	MSQS	BL-29	S01C -		E28	E11	U		E30	
17110019-BL-000-	MSQS	BL-30	S01C -		E53	E39	U		E11	
17110019-BL-000-	MSQS	BL-31	S05C -		E230	E49	E1.1		E11	
17110019-BL-000-	MSQS	BL-32	S01C -		E120	E160	U		E44	
17110019-HY-000-	MSQS	CB-11	S01C -		E150	E100	E11		E21	
17110019-CB-000-	MSQS	CB-12	S01C -		E95	E42	U		E15	
17110019-CB-000-	MSQS	CB-13	S01C -		E39	E53	U		E170	
17110019-CB-000-	MSQS	CB-14	S01C -		E160	U	U		E19	
17110019-CI-000-	MSQS	CI-11	S02C -		E330	U	U		E110	
17110019-CI-000-	MSQS	CI-12	S01C -		U	U	U		E200	
17110019-CI-000-	MSQS	CI-13	S05C -		E86	E120	U		E76	
17110019-CI-000-	MSQS	CI-14	S01C -		E46	E150	U		E46	
17110019-CI-000-	MSQS	CI-15	S01C -		E86	U	U		E110	
17110019-CW-000-	MSQS	CI-16	S05C -		E170	U	U		E140	
17110019-CI-000-	MSQS	CI-17	S05C -	01	E180	E160	U		E150	
17110019-CI-000-	MSQS	CI-17	S05C -	02						
17110019-CI-000-	MSQS	CI-18	S01C -		E51	E51	U		E56	
17110019-CI-000-	MSQS	CI-19	S01C -		U	U	U		U	
17110019-CI-000-	MSQS	CI-20	S05C -		E560	E580	U		E270	
17110019-CI-000-	MSQS	CI-21	S01C -		E55	E230	U		E73	
17110019-CI-000-	MSQS	CI-22	S05C -		E85	E43	U		E85	
17110019-CR-000-	MSQS	CR-11	S01C -		E12	U	U		U	
17110019-CR-000-	MSQS	CR-12	S05C -		U	U	U		U	
17110019-CR-000-	MSQS	CR-13	S01C -		U	E1.3	U		U	
17110019-CR-000-	MSQS	CR-14	S05C -		U	U	U		U	

MAIN SEDIMENT SURVEY TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample	Rep	1-methyl-2-(1-methyl-ethyl) benzene	2-methoxy phenol	penta-chloro-cyclo-pentane	1-methyl naphth-alene	1,1' biphenyl	2,6-di-methyl naphth-alene
17110019-HY-000-	MSQS	HY-11	S01C -							
17110019-HY-000-	MSQS	HY-12	S01C -		E220	U	E11		E24	
17110019-HY-000-	MSQS	HY-13	S01C -							
17110019-HY-000-	MSQS	HY-14	S05C -		E970	U	E4.9		E23	
17110019-HY-000-	MSQS	HY-15	S01C -		E510	U	E22		E100	
17110019-HY-000-	MSQS	HY-16	S01C -		E2000	U	U		U	
17110019-HY-000-	MSQS	HY-17	S01C -		E2800	U	E8.4		E36	
17110019-HY-000-	MSQS	HY-18	S01C -							
17110019-HY-000-	MSQS	HY-19	S01C -		E710	U	U		E20	
17110019-HY-000-	MSQS	HY-20	S01C -	01	E230	U	E18		E50	
17110019-HY-000-	MSQS	HY-20	S01C -	02						
17110019-HY-000-	MSQS	HY-21	S01C -		E190	U	E11		E51	
17110019-HY-000-	MSQS	HY-22	S05C -		E1000	U	E17		E110	
17110019-HY-000-	MSQS	HY-23	S01C -		E87	U	E6.0		U	
17110019-HY-000-	MSQS	HY-24	S01C -		E180	U	E13		U	
17110019-HY-000-	MSQS	HY-25	S01C -		E53	U	E6.7		E17	
17110019-HY-000-	MSQS	HY-26	S01C -		E9.5	U	E1.9		E9.1	
17110019-HY-000-	MSQS	HY-27	S01C -		E300	U	E22		E45	
17110019-HY-000-	MSQS	HY-28	S01C -		E1100	U	E15		E26	
17110019-HY-000-	MSQS	HY-29	S01C -		E550	U	E21		E48	
17110019-HY-000-	MSQS	HY-30	S01C -		E44	U	U		E8.4	
17110019-HY-000-	MSQS	HY-31	S01C -	01	E400	U	E5.8		E15	
17110019-HY-000-	MSQS	HY-31	S01C -	02						
17110019-HY-000-	MSQS	HY-32	S01C -		E13	U	E25		E110	
17110019-HY-000-	MSQS	HY-33	S01C -		E340	U	E30		E54	
17110019-HY-000-	MSQS	HY-34	S01C -		E210	U	E23		E46	
17110019-HY-000-	MSQS	HY-35	S01C -		E150	U	E29		E48	
17110019-HY-000-	MSQS	HY-36	S01C -		E310	U	E200		E310	
17110019-HY-000-	MSQS	HY-37	S01C -		E310	U	E54		E74	
17110019-HY-000-	MSQS	HY-38	S01C -		E140	U	E34		E63	
17110019-HY-000-	MSQS	HY-39	S01C -		E210	U	E52		E41	
17110019-HY-000-	MSQS	HY-40	S01C -		E120	U	E31		U	
17110019-HY-000-	MSQS	HY-41	S01C -		E210	U	E47		E31	
17110019-HY-000-	MSQS	HY-42	S01C -		E82	U	E68		E64	
17110019-HY-000-	MSQS	HY-43	S01C -		E180	U	E72		E63	
17110019-HY-000-	MSQS	HY-44	S01C -		E7.7	U	U		E1.3	
17110019-HY-000-	MSQS	HY-45	S01C -		E150	U	E44		E51	
17110019-HY-000-	MSQS	HY-46	S01C -		E190	U	E270		E41	
17110019-HY-000-	MSQS	HY-47	S05C -		E120	E48	E58		E27	
17110019-HY-000-	MSQS	HY-48	S01C -		U	E41	E17		E30	
17110019-HY-000-	MSQS	HY-49	S01C -							
17110019-HY-000-	MSQS	HY-50	S05C -		E33	E69	U		E19	
17110019-HY-000-	MSQS	HY-51	S01C -							
17110019-MD-000-	MSQS	MD-11	S01C -		E15	E130	U		E150	

MAIN SEDIMENT SURVEY TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample	Rep	1-methyl-2-(1-methyl-ethyl) benzene	2-methoxy phenol	pentachloro-cyclopentane	1-methyl naphthalene	1,1' biphenyl	2,6-dimethyl naphthalene
17110019-MD-000-	MSQS	MD-12	S05C -		E10	E930	U		E260	
17110019-MD-000-	MSQS	MD-13	S01C -		E190	E170	U		E75	
17110019-MI-000-	MSQS	MI-11	S01C -	01	E210	E110	U		E100	
17110019-MI-000-	MSQS	MI-11	S01C -	02						
17110019-MI-000-	MSQS	MI-12	S01C -							
17110019-MI-000-	MSQS	MI-13	S01C -		E310	E190	U		E100	
17110019-MI-000-	MSQS	MI-14	S01C -							
17110019-MI-000-	MSQS	MI-15	S01C -		E260	E180	U		E40	
17110019-RS-000-	MSQS	RS-11	S01C -		E250	E83	U		E61	
17110019-RS-000-	MSQS	RS-12	S01C -		E73	E32	U		E34	
17110019-RS-000-	MSQS	RS-13	S01C -		E150	E58	U		E80	
17110019-RS-000-	MSQS	RS-14	S05C -	01	E170	U	U		E84	
17110019-RS-000-	MSQS	RS-14	S05C -	02						
17110019-RS-000-	MSQS	RS-15	S02C -		E22	U	U		E3.9	
17110019-RS-000-	MSQS	RS-16	S01C -		E2700	U	U		U	
17110019-RS-000-	MSQS	RS-17	S01C -		E140	U	U		E57	
17110019-RS-000-	MSQS	RS-18	S01C -		E570	U	U		E1100	E1900
17110019-RS-000-	MSQS	RS-19	S01C -		E57	E5.0	U		E23	
17110019-RS-000-	MSQS	RS-20	S01C -		U	U	U		E5.2	
17110019-RS-000-	MSQS	RS-21	S01C -		E95	E29	U		E120	
17110019-RS-000-	MSQS	RS-22	S01C -		U	U	U		U	
17110019-RS-000-	MSQS	RS-24	S05C -		E4.5	E1.5	E5.7		E3.0	
17110019-SI-000-	MSQS	SI-11	S05C -		E2300	E300	U		E100	
17110019-SI-000-	MSQS	SI-12	S01C -		E190	E310	U		E56	
17110019-SI-000-	MSQS	SI-13	S01C -							
17110019-SI-000-	MSQS	SI-14	S01C -		E160	E160	U		E210	
17110019-SI-000-	MSQS	SI-15	S05C -		E210	E150	U		E72	
17110019-SP-000-	MSQS	SP-11	S05C -		E560	E370	U		E84	
17110019-SP-000-	MSQS	SP-12	S05C -		E600	E360	U		E85	
17110019-SP-000-	MSQS	SP-13	S01C -		E530	E560	U		E64	
17110019-SP-000-	MSQS	SP-14	S01C -		E6600	E3900	U		E310	
17110019-SP-000-	MSQS	SP-15	S05C -		E1400	E1500	U		U	
17110019-SP-000-	MSQS	SP-16	S05C -		E300	E340	U		E14	
17110019-DP-000-	MSQS	WBS	CTL -	01						
17110019-DP-000-	MSQS	WBS	CTL -	02						

Number of Observations: 123

MAIN SEDIMENT SURVEY TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample		2,3,5-trimethyl naphthalene	dibenzothiophene	2-methyl phenanthrene	1-methyl phenanthrene	9-hexadecenoic acid	isopimaradiene
17110019-BL-000-	MSQS	BL-11	SU5C -			U	E54	E25	E270	E86
17110019-BL-000-	MSQS	BL-12	SO1C -							
17110019-BL-000-	MSQS	BL-13	SU5C -			E26	E83	E59	E410	E1500
17110019-BL-000-	MSQS	BL-14	SO1C -			E72	E98	E92	E720	U
17110019-BL-000-	MSQS	BL-15	SO1C -			E11	E51	E38	U	E110
17110019-BL-000-	MSQS	BL-16	SO1C -			E31	E42	E44	E440	E230
17110019-BL-000-	MSQS	BL-17	SO1C -	01		E20	E18	E38	E180	E97
17110019-BL-000-	MSQS	BL-17	SO1C -	02						
17110019-BL-000-	MSQS	BL-18	SO1C -			E32	E96	E67	E140	E92
17110019-BL-000-	MSQS	BL-19	SO1C -			E15	E63	E49	E110	E120
17110019-BL-000-	MSQS	BL-20	SO1C -			E25	E50	E48	E210	E270
17110019-BL-000-	MSQS	BL-21	SO5C -			E23	E85	E48	E160	E170
17110019-BL-000-	MSQS	BL-22	SO1C -			E32	E92	E37	E91	E230
17110019-BL-000-	MSQS	BL-23	SO1C -			E46	E62	E59	U	E170
17110019-BL-000-	MSQS	BL-24	SO1C -			E43	E130	E110	E85	E240
17110019-BL-000-	MSQS	BL-25	SU5C -			E20	E31	E42	E260	E120
17110019-BL-000-	MSQS	BL-26	SO1C -			E67	E61	E34	E340	E180
17110019-BL-000-	MSQS	BL-27	SO1C -			E19	E38	E24	E30	E84
17110019-BL-000-	MSQS	BL-28	SO5C -			E26	E38	E42	E100	E110
17110019-BL-000-	MSQS	BL-29	SO1C -			E46	E71	E82	E240	E91
17110019-BL-000-	MSQS	BL-30	SO1C -			E20	E26	E29	E170	E140
17110019-BL-000-	MSQS	BL-31	SU5C -			E11	E46	E90	E200	E230
17110019-BL-000-	MSQS	BL-32	SO1C -			E41	E310	E140	E160	E530
17110019-MY-000-	MSQS	CB-11	SO1C -			E19	E26	E42	U	E280
17110019-CB-000-	MSQS	CB-12	SO1C -			E11	E38	E39	U	E130
17110019-CB-000-	MSQS	CB-13	SO1C -			U	E40	E50	E900	E160
17110019-CB-000-	MSQS	CB-14	SO1C -			U	E53	E71	E220	E300
17110019-CI-000-	MSQS	CI-11	SU2C -			E190	U	U	E1200	E240
17110019-CI-000-	MSQS	CI-12	SO1C -			E190	E290	E500	E4300	E600
17110019-CI-000-	MSQS	CI-13	SO5C -			E110	E73	E110	E600	E200
17110019-CI-000-	MSQS	CI-14	SO1C -			E31	E54	U	E460	E190
17110019-CI-000-	MSQS	CI-15	SO1C -			E130	E250	E160	E300	E150
17110019-CW-000-	MSQS	CI-16	SU5C -			E130	U	U	U	E490
17110019-CI-000-	MSQS	CI-17	SO5C -	01		E180	E210	E310	U	E530
17110019-CI-000-	MSQS	CI-17	SU5C -	02						
17110019-CI-000-	MSQS	CI-18	SO1C -			E49	E110	E180	U	E98
17110019-CI-000-	MSQS	CI-19	SO1C -			E89	E180	E180	E720	E430
17110019-CI-000-	MSQS	CI-20	SU5C -			E250	E490	U	U	E1400
17110019-CI-000-	MSQS	CI-21	SO1C -			E100	E110	E380	E690	E190
17110019-CI-000-	MSQS	CI-22	SU5C -			E99	E260	E270	E970	E370
17110019-CR-000-	MSQS	CR-11	SO1C -			U	U	U	E62	U
17110019-CR-000-	MSQS	CR-12	SU5C -			U	U	U	E63	U
17110019-CR-000-	MSQS	CR-13	SO1C -			U	U	U	E530	U
17110019-CR-000-	MSQS	CR-14	SU5C -			U	U	U	E280	U

MAIN SEDIMENT SURVEY TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample		2,3,5-trimethyl naphthalene	dibenzothiophene	2-methyl phenanthrene	1-methyl phenanthrene	9-hexadecenoic acid	isopimaradiene
17110019-HY-000-	MSQS	HY-11	S01C -							
17110019-HY-000-	MSQS	HY-12	S01C -			E110	E63	E170	E1700	E320
17110019-HY-000-	MSQS	HY-13	S01C -							
17110019-HY-000-	MSQS	HY-14	S05C -			U	E120	U	U	E290
17110019-HY-000-	MSQS	HY-15	S01C -			E190	E270	E390	E1600	E820
17110019-HY-000-	MSQS	HY-16	S01C -			U	E310	U	E5700	E4700
17110019-HY-000-	MSQS	HY-17	S01C -			E200	E360	E260	E1300	E310
17110019-HY-000-	MSQS	HY-18	S01C -							
17110019-HY-000-	MSQS	HY-19	S01C -			U	E50	E27	E1300	E170
17110019-HY-000-	MSQS	HY-20	S01C -	01		U	E62	E72	E3500	E85
17110019-HY-000-	MSQS	HY-20	S01C -	02						
17110019-HY-000-	MSQS	HY-21	S01C -			U	E46	E62	E3800	E130
17110019-HY-000-	MSQS	HY-22	S05C -			E320	E740	E530	E850	E480
17110019-HY-000-	MSQS	HY-23	S01C -			E84	U	U	E1500	E62
17110019-HY-000-	MSQS	HY-24	S01C -			E100	E66	E61	E760	E260
17110019-HY-000-	MSQS	HY-25	S01C -			E44	E51	E82	E800	E170
17110019-HY-000-	MSQS	HY-26	S01C -			E33	E56	E39	U	E190
17110019-HY-000-	MSQS	HY-27	S01C -			U	E45	E26	E820	U
17110019-HY-000-	MSQS	HY-28	S01C -			U	E44	U	E1100	U
17110019-HY-000-	MSQS	HY-29	S01C -			U	U	U	E1100	U
17110019-HY-000-	MSQS	HY-30	S01C -			E21	E23	E19	U	E59
17110019-HY-000-	MSQS	HY-31	S01C -	01		E43	E110	U	U	E300
17110019-HY-000-	MSQS	HY-31	S01C -	02						
17110019-HY-000-	MSQS	HY-32	S01C -			E39	E67	E78	U	E220
17110019-HY-000-	MSQS	HY-33	S01C -			E74	E35	U	E640	E200
17110019-HY-000-	MSQS	HY-34	S01C -			U	E100	E93	E2300	E150
17110019-HY-000-	MSQS	HY-35	S01C -			U	E70	E150	E1300	E300
17110019-HY-000-	MSQS	HY-36	S01C -			U	E380	E330	E7300	E1200
17110019-HY-000-	MSQS	HY-37	S01C -			E110	E64	U	E760	E470
17110019-HY-000-	MSQS	HY-38	S01C -			E74	E84	E94	E2300	E270
17110019-HY-000-	MSQS	HY-39	S01C -			E100	U	E110	E880	E210
17110019-HY-000-	MSQS	HY-40	S01C -			E39	E56	E93	E680	E430
17110019-HY-000-	MSQS	HY-41	S01C -			E35	E38	E36	E1400	E420
17110019-HY-000-	MSQS	HY-42	S01C -			E170	E40	E74	E1600	E620
17110019-HY-000-	MSQS	HY-43	S01C -			E110	E140	U	E1500	E630
17110019-HY-000-	MSQS	HY-44	S01C -			U	E6.4	E5.1	E590	E28
17110019-HY-000-	MSQS	HY-45	S01C -			U	E100	E130	U	E200
17110019-HY-000-	MSQS	HY-46	S01C -			E31	E41	E72	E290	E140
17110019-HY-000-	MSQS	HY-47	S05C -			E46	E75	E170	E710	E540
17110019-HY-000-	MSQS	HY-48	S01C -			E19			E470	E190
17110019-HY-000-	MSQS	HY-49	S01C -							
17110019-HY-000-	MSQS	HY-50	S05C -			E26	E32	E69	E760	E150
17110019-HY-000-	MSQS	HY-51	S01C -							
17110019-MD-000-	MSQS	MD-11	S01C -			E260	E180	E210	E750	E230

MAIN SEDIMENT QUALITY SURVEY TENTATIVELY IDENTIFIED ORGANIC CHEMICALS DATA

Drainage	Survey	Station	Sample		2,3,5-trimethyl naphthalene	dibenzothiophene	2-methyl phenanthrene	1-methyl phenanthrene	9-hexadecenoic acid	isopimaradiene
17110019-MD-000-	MSQS	MD-12	S05C -			E240	E470	E220	E1000	E930
17110019-MD-000-	MSQS	MD-13	S01C -			E65	E120	E150	U	E240
17110019-MI-000-	MSQS	MI-11	S01C -	01		E110	E110	E210	E1600	E430
17110019-MI-000-	MSQS	MI-11	S01C -	02						
17110019-MI-000-	MSQS	MI-12	S01C -							
17110019-MI-000-	MSQS	MI-13	S01C -			E68	E110	E150	E560	E560
17110019-MI-000-	MSQS	MI-14	S01C -							
17110019-MI-000-	MSQS	MI-15	S01C -			U	E63	E160	E310	E510
17110019-RS-000-	MSQS	RS-11	S01C -			E70	E180	E320	E230	E190
17110019-RS-000-	MSQS	RS-12	S01C -			E53	E83	E89	E1300	E150
17110019-RS-000-	MSQS	RS-13	S01C -			E98	E180	E200	U	E150
17110019-RS-000-	MSQS	RS-14	S05C -	01		U	E86	E160	E1300	U
17110019-RS-000-	MSQS	RS-14	S05C -	02						
17110019-RS-000-	MSQS	RS-15	S02C -			E5.2	E9.2	E5.2	U	E14
17110019-RS-000-	MSQS	RS-16	S01C -			E130	E130	U	E160	E310
17110019-RS-000-	MSQS	RS-17	S01C -			E97	E180	E120	E340	E170
17110019-RS-000-	MSQS	RS-18	S01C -			E1100	E2400	E1300	U	U
17110019-RS-000-	MSQS	RS-19	S01C -			E97	E100	E140	E670	U
17110019-RS-000-	MSQS	RS-20	S01C -			E16	E38	E52	E66	E14
17110019-RS-000-	MSQS	RS-21	S01C -			E190	E360	E310	U	E81
17110019-RS-000-	MSQS	RS-22	S01C -			U	U	U	E770	U
17110019-RS-000-	MSQS	RS-24	S05C -			U	U	E18	E2800	E36
17110019-SI-000-	MSQS	SI-11	S05C -			E170	E280	E130	E1100	E870
17110019-SI-000-	MSQS	SI-12	S01C -			E76	E130	U	U	E960
17110019-SI-000-	MSQS	SI-13	S01C -							
17110019-SI-000-	MSQS	SI-14	S01C -			E260	E660	E430	E650	E350
17110019-SI-000-	MSQS	SI-15	S05C -			U	E230	E370	E540	E280
17110019-SP-000-	MSQS	SP-11	S05C -			U	E110	U	E2100	E750
17110019-SP-000-	MSQS	SP-12	S05C -			U	E140	E36	E2200	E710
17110019-SP-000-	MSQS	SP-13	S01C -			U	E64	E64	E1300	E410
17110019-SP-000-	MSQS	SP-14	S01C -			U	U	U	E990	E5900
17110019-SP-000-	MSQS	SP-15	S05C -			U	E52	E96	E2000	E550
17110019-SP-000-	MSQS	SP-16	S05C -			U	E40	E61	E1600	E310
17110019-DP-000-	MSQS	WBS	CTL -	01						
17110019-DP-000-	MSQS	WBS	CTL -	02						

Number of Observations: 123

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium
17110019-BL-000-	MSQS	BL-11	S05C	-	0.36	26	15	0.23	3.0	11
17110019-BL-000-	MSQS	BL-12	S01C	-	0.52	31	20	0.27	3.3	13
17110019-BL-000-	MSQS	BL-13	S05C	-	0.70	35	21	0.28	3.4	13
17110019-BL-000-	MSQS	BL-14	S01C	-	0.64	25	21	0.25	3.1	12
17110019-BL-000-	MSQS	BL-15	S01C	-	0.50	36	18	0.25	3.1	11
17110019-BL-000-	MSQS	BL-16	S01C	-	0.78	34	21	0.28	3.3	13
17110019-BL-000-	MSQS	BL-17	S01C	-	0.70	33	21	0.27	3.5	13
17110019-BL-000-	MSQS	BL-18	S01C	-	0.50	36	15	0.20	2.8	10
17110019-BL-000-	MSQS	BL-19	S01C	-	0.68	21	18	0.25	3.1	12
17110019-BL-000-	MSQS	BL-20	S01C	-	0.50	28	18	0.23	2.9	11
17110019-BL-000-	MSQS	BL-21	S05C	-	0.52	18	17	0.22	2.8	11
17110019-BL-000-	MSQS	BL-22	S01C	-	0.66	21	17	0.23	3.0	11
17110019-BL-000-	MSQS	BL-23	S01C	-	0.58	19	18	0.25	3.1	12
17110019-BL-000-	MSQS	BL-24	S01C	-	0.58	16	19	0.24	2.9	13
17110019-BL-000-	MSQS	BL-25	S05C	-	0.60	15	19	0.26	3.2	12
17110019-BL-000-	MSQS	BL-26	S01C	-	0.48	22	18	0.23	3.0	11
17110019-BL-000-	MSQS	BL-27	S01C	-	U0.1	5.4	8.2	0.12	1.6	5.8
17110019-BL-000-	MSQS	BL-28	S05C	-	0.18	7.0	12	0.16	2.0	7.7
17110019-BL-000-	MSQS	BL-29	S01C	-	0.44	13	17	0.22	3.0	11
17110019-BL-000-	MSQS	BL-30	S01C	-	0.34	8.0	17	0.19	1.9	7.6
17110019-BL-000-	MSQS	BL-31	S05C	-	0.34	7.6	18	E0.18	2.1	7.3
17110019-BL-000-	MSQS	BL-32	S01C	-	0.38	12	22	0.21	2.5	8.3
17110019-HY-000-	MSQS	CB-11	S01C	-	0.48	26	32	0.26	2.8	10
17110019-CB-000-	MSQS	CB-12	S01C	-	0.28	8.4	22	0.22	2.3	7.1
17110019-CB-000-	MSQS	CB-13	S01C	-	0.30	9.6	23	0.24	2.4	7.6
17110019-CB-000-	MSQS	CB-14	S01C	-	0.70	14	24	0.25	2.4	9.1
17110019-CI-000-	MSQS	CI-11	S02C	-	0.86	21	42	0.22	4.7	36
17110019-CI-000-	MSQS	CI-12	S01C	-	1.1	25	44	0.27	6.2	37
17110019-CI-000-	MSQS	CI-13	S05C	-	1.2	30	44	0.29	6.7	35
17110019-CI-000-	MSQS	CI-14	S01C	-	1.2	33	47	0.29	6.5	34
17110019-CI-000-	MSQS	CI-15	S01C	-	1.4	33	57	0.29	6.9	35
17110019-CW-000-	MSQS	CI-16	S05C	-	1.0	20.	33	0.21	5.7	27
17110019-CI-000-	MSQS	CI-17	S05C	-	0.96	28.	48	0.26	5.8	29
17110019-CI-000-	MSQS	CI-18	S01C	-	0.94	30.	46	0.29	6.5	31
17110019-CI-000-	MSQS	CI-19	S01C	-	0.78	28.	50	0.25	5.0	26
17110019-CI-000-	MSQS	CI-20	S05C	-	0.88	29.	50	0.27	5.1	27
17110019-CI-000-	MSQS	CI-21	S01C	-	0.28	11.	23	0.16	2.7	12
17110019-CI-000-	MSQS	CI-22	S05C	-	0.22	8.0	16	0.12	1.5	8.4
17110019-CR-000-	MSQS	CR-11	S01C	-	0.13	2.4	5.6	0.082	1.1	9.9
17110019-CR-000-	MSQS	CR-12	S05C	-	U0.1	3.8	6.8	E0.11	1.4	11
17110019-CR-000-	MSQS	CR-13	S01C	-	U0.1	3.8	7.3	E0.073	1.1	9.6
17110019-CR-000-	MSQS	CR-14	S05C	-	0.14	3.8	7.8	E0.082	1.5	11
17110019-HY-000-	MSQS	HY-11	S01C	-	1.7	100	24	0.32	3.4	22
17110019-HY-000-	MSQS	HY-12	S01C	-	1.1	40	28	0.39	2.9	29
17110019-HY-000-	MSQS	HY-13	S01C	-	1.2	60	28	0.36	3.0	27
17110019-HY-000-	MSQS	HY-14	S05C	-	1.0	32	22	0.30	2.5	22
17110019-HY-000-	MSQS	HY-15	S01C	-	1.1	40	22	0.33	2.3	23
17110019-HY-000-	MSQS	HY-16	S01C	-	12	79	25	0.41	3.6	28

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium
17110019-HY-000-	MSQS	HY-17	S01C	-	1.5	86	36	0.40	3.6	29
17110019-HY-000-	MSQS	HY-18	S01C	-	1.5	80	50	0.40	4.0	35
17110019-HY-000-	MSQS	HY-19	S01C	-	3.4	70	29	0.35	3.5	27
17110019-HY-000-	MSQS	HY-20	S01C	-	1.0	52	35	0.41	3.5	32
17110019-HY-000-	MSQS	HY-21	S01C	-	0.82	67	30	0.37	3.0	30
17110019-HY-000-	MSQS	HY-22	S05C	-	1.0	90	32	0.37	3.6	31
17110019-HY-000-	MSQS	HY-23	S01C	-	0.88	66	35	0.39	2.8	26
17110019-HY-000-	MSQS	HY-24	S01C	-	0.96	85	36	0.45	3.4	37
17110019-HY-000-	MSQS	HY-25	S01C	-	0.96	53	27	0.40	2.3	30
17110019-HY-000-	MSQS	HY-26	S01C	-	0.70	44	23	0.31	2.0	21
17110019-HY-000-	MSQS	HY-27	S01C	-	1.1	28	23	0.34	2.2	25
17110019-HY-000-	MSQS	HY-28	S01C	-	1.4	39	27	0.36	2.5	26
17110019-HY-000-	MSQS	HY-29	S01C	-	0.88	26	27	0.31	2.2	22
17110019-HY-000-	MSQS	HY-30	S01C	-	0.78	28	27	0.50	2.1	24
17110019-HY-000-	MSQS	HY-31	S01C	-	0.60	18	18	0.23	1.3	16
17110019-HY-000-	MSQS	HY-32	S01C	-	1.1	27	27	0.30	2.1	24
17110019-HY-000-	MSQS	HY-33	S01C	-	0.50	20	19	0.23	1.7	23
17110019-HY-000-	MSQS	HY-34	S01C	-	0.70	25	13	0.23	1.8	18
17110019-HY-000-	MSQS	HY-35	S01C	-	0.68	22	30	0.29	1.8	22
17110019-HY-000-	MSQS	HY-36	S01C	-	0.74	30	37	0.31	2.1	24
17110019-HY-000-	MSQS	HY-37	S01C	-	1.0	20	28	0.32	2.0	23
17110019-HY-000-	MSQS	HY-38	S01C	-	0.86	18	24	0.24	1.5	17
17110019-HY-000-	MSQS	HY-39	S01C	-	0.38	20	22	0.26	1.5	16
17110019-HY-000-	MSQS	HY-40	S01C	-	0.68	25	47	0.32	1.9	22
17110019-HY-000-	MSQS	HY-41	S01C	-	0.44	22	33	0.26	1.7	18
17110019-HY-000-	MSQS	HY-42	S01C	-	0.72	15	33	0.29	1.8	20
17110019-HY-000-	MSQS	HY-43	S01C	-	0.62	14	39	0.28	1.6	20
17110019-HY-000-	MSQS	HY-44	S01C	-	U0.1	5.8	5.1	0.10	0.62	5.4
17110019-HY-000-	MSQS	HY-45	S01C	-	0.34	20	23	0.27	1.8	14
17110019-HY-000-	MSQS	HY-46	S01C	-	0.32	32	27	0.31	2.3	19
17110019-HY-000-	MSQS	HY-47	S05C	-	0.56	25	32	0.29	1.8	21
17110019-HY-000-	MSQS	HY-48	S01C	-	0.40	20	35	0.24	1.4	14
17110019-HY-000-	MSQS	HY-49	S01C	-	2.4	16	25	0.24	2.6	9.9
17110019-HY-000-	MSQS	HY-50	S05C	-	1.3	12	27	0.25	2.8	9.0
17110019-HY-000-	MSQS	HY-51	S01C	-	0.30	12	24	0.24	1.3	12
17110019-MD-000-	MSQS	MD-11	S01C	-	0.90	15	36	E0.16	3.4	18
17110019-MD-000-	MSQS	MD-12	S05C	-	1.2	39	36	E0.16	3.4	15
17110019-MD-000-	MSQS	MD-13	S01C	-	1.9	67	26	E0.16	3.5	14
17110019-MI-000-	MSQS	MI-11	S01C	-	0.38	10	40	0.27	1.4	13
17110019-MI-000-	MSQS	MI-12	S01C	-	0.54	12	50	0.28	2.0	14
17110019-MI-000-	MSQS	MI-13	S01C	-	0.48	12	41	0.27	1.9	13
17110019-MI-000-	MSQS	MI-14	S01C	-	0.40	10	32	0.27	1.6	15
17110019-MI-000-	MSQS	MI-15	S01C	-	0.48	9.5	28	0.25	1.5	12
17110019-RS-000-	MSQS	RS-11	S01C	-	0.54	16	40	E0.15	2.2	12
17110019-RS-000-	MSQS	RS-12	S01C	-	1.2	16	31	0.22	2.2	16
17110019-RS-000-	MSQS	RS-13	S01C	-	1.4	20	28	E0.15	2.5	18
17110019-RS-000-	MSQS	RS-14	S05C	-	3.1	32	22	0.22	3.1	16
17110019-RS-000-	MSQS	RS-15	S02C	-	0.19	16	11	E0.099	1.4	15

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium
17110019-RS-000-	MSQS	RS-16	S01C -		7.8	136	23	E0.17	3.4	14
17110019-RS-000-	MSQS	RS-17	S01C -		190	12200	56	0.48	76	18
17110019-RS-000-	MSQS	RS-18	S01C -		420	9700	71	0.33	184	23
17110019-RS-000-	MSQS	RS-19	S01C -		36	1550	102	0.20	16	12
17110019-RS-000-	MSQS	RS-20	S01C -		1.8	90	15	E0.18	3.0	15
17110019-RS-000-	MSQS	RS-21	S01C -		205	9000	153	0.55	105	46
17110019-RS-000-	MSQS	RS-22	S01C -		5.3	85	14	0.10	2.2	7.6
17110019-RS-000-	MSQS	RS-24	S05C -		26	700	103	0.28	9.6	15
17110019-SI-000-	MSQS	SI-11	S05C -		1.3	93	19	0.22	4.4	13
17110019-SI-000-	MSQS	SI-12	S01C -		0.82	33	18	0.21	3.2	11
17110019-SI-000-	MSQS	SI-13	S01C -		0.70	28	18	0.21	2.3	11
17110019-SI-000-	MSQS	SI-14	S01C -		1.1	23	26	0.18	1.6	13
17110019-SI-000-	MSQS	SI-15	S05C -		0.46	10	21	0.25	1.6	11
17110019-SP-000-	MSQS	SP-11	S05C -		0.44	6.0	11	0.13	1.3	10
17110019-SP-000-	MSQS	SP-12	S05C -		0.54	7.0	16	0.17	1.7	14
17110019-SP-000-	MSQS	SP-13	S01C -		0.72	12	19	0.20	2.4	18
17110019-SP-000-	MSQS	SP-14	S01C -		0.66	7.0	50	0.18	2.7	21
17110019-SP-000-	MSQS	SP-15	S05C -		0.13	7.4	12	0.12	0.82	6.7
17110019-SP-000-	MSQS	SP-16	S05C -		0.26	5.5	17	0.18	0.86	8.1
17110019-DP-000-	MSQS	WBS	CTL -	02	U1	2.8	10	0.12	0.24	18
17110019-DP-000-	MSQS	WBS	CTL -	01	U1	2.1	9.9	0.11	0.22	17

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MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Copper	Iron	Lead	Manganese	Nickel	Selenium
17110019-BL-000-	MSQS	BL-11	S05C	-	41	17300	46	79	12	U1.0
17110019-BL-000-	MSQS	BL-12	S01C	-	74	18000	66	91	13	U1.0
17110019-BL-000-	MSQS	BL-13	S05C	-	63	19500	64	99	13	U1.0
17110019-BL-000-	MSQS	BL-14	S01C	-	59	16500	53	81	12	U1.0
17110019-BL-000-	MSQS	BL-15	S01C	-	57	17000	54	94	12	U1.0
17110019-BL-000-	MSQS	BL-16	S01C	-	71	18100	73	101	13	U1.0
17110019-BL-000-	MSQS	BL-17	S01C	-	64	18600	61	103	13	U1.0
17110019-BL-000-	MSQS	BL-18	S01C	-	49	14500	41	76	10	U1.0
17110019-BL-000-	MSQS	BL-19	S01C	-	54	16600	53	97		U1.0
17110019-BL-000-	MSQS	BL-20	S01C	-	52	16400	53	99	12	U1.0
17110019-BL-000-	MSQS	BL-21	S05C	-	54	15200	49	92	11	U1.0
17110019-BL-000-	MSQS	BL-22	S01C	-	54	16200	52	93	12	U1.0
17110019-BL-000-	MSQS	BL-23	S01C	-	53	16900	55	104	12	U1.0
17110019-BL-000-	MSQS	BL-24	S01C	-	101	15300	58	100	13	U1.0
17110019-BL-000-	MSQS	BL-25	S05C	-	57	17200	56	106	13	U1.0
17110019-BL-000-	MSQS	BL-26	S01C	-	53	16900	52	105	12	U1.0
17110019-BL-000-	MSQS	BL-27	S01C	-	20	9150	19	75	7.8	U1.0
17110019-BL-000-	MSQS	BL-28	S05C	-	28	11100	27	96	9.2	U1.0
17110019-BL-000-	MSQS	BL-29	S01C	-	48	17500	47	128	13	U1.0
17110019-BL-000-	MSQS	BL-30	S01C	-	32	11700	35	101	9.7	U1.0
17110019-BL-000-	MSQS	BL-31	S05C	-	29	12200	32	114	9.9	U1.0
17110019-BL-000-	MSQS	BL-32	S01C	-	41	14500	39	137	11	U1.0
17110019-HY-000-	MSQS	CB-11	S01C	-	101	14800	54	163	13	U1.0
17110019-CB-000-	MSQS	CB-12	S01C	-	25	12800	26	121	11	U1.0
17110019-CB-000-	MSQS	CB-13	S01C	-	27	13700	27	139	12	U1.0
17110019-CB-000-	MSQS	CB-14	S01C	-	36	14400	30	151	13	U1.0
17110019-CI-000-	MSQS	CI-11	S02C	-	155	16100	725	116	40	U1.0
17110019-CI-000-	MSQS	CI-12	S01C	-	203	16800	595	128	33	U1.0
17110019-CI-000-	MSQS	CI-13	S05C	-	185	19200	450	136	28	U1.0
17110019-CI-000-	MSQS	CI-14	S01C	-	176	19600	388	145	27	U1.0
17110019-CI-000-	MSQS	CI-15	S01C	-	188	22700	453	178	25	U1.0
17110019-CW-000-	MSQS	CI-16	S05C	-	158	15800	240	107	19	U1.0
17110019-CI-000-	MSQS	CI-17	S05C	-	168	17900	300	154	21	U1.0
17110019-CI-000-	MSQS	CI-18	S01C	-	166	17400	291	139	22	U1.0
17110019-CI-000-	MSQS	CI-19	S01C	-	156	16200	204	140	20	U1.0
17110019-CI-000-	MSQS	CI-20	S05C	-	158	17600	211	150	21	U1.0
17110019-CI-000-	MSQS	CI-21	S01C	-	71	11100	88	85	11	U1.0
17110019-CI-000-	MSQS	CI-22	S05C	-	40	8360	49	74	9.0	U1.0
17110019-CR-000-	MSQS	CR-11	S01C	-	4.9	6230	11	83	11	U1.0
17110019-CR-000-	MSQS	CR-12	S05C	-	7.3	8150	13	132	14	U1.0
17110019-CR-000-	MSQS	CR-13	S01C	-	5.2	6530	10	80	12	U1.0
17110019-CR-000-	MSQS	CR-14	S05C	-	7.8	6980	12	76	13	U1.0
17110019-HY-000-	MSQS	HY-11	S01C	-	125	25000	82	204	22	U1.0
17110019-HY-000-	MSQS	HY-12	S01C	-	143	24300	93	145	27	U1.0
17110019-HY-000-	MSQS	HY-13	S01C	-	150	23100	96	144	26	U1.0
17110019-HY-000-	MSQS	HY-14	S05C	-	114	19900	71	131	22	U1.0
17110019-HY-000-	MSQS	HY-15	S01C	-	114	19300	76	124	24	U1.0
17110019-HY-000-	MSQS	HY-16	S01C	-	220	22800	129	134	32	U1.0

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Copper	Iron	Lead	Manganese	Nickel	Selenium
17110019-HY-000-	MSQS	HY-17	S01C	-	204	26700	114	197	30	U1.0
17110019-HY-000-	MSQS	HY-18	S01C	-	264	29900	131	250	39	U1.0
17110019-HY-000-	MSQS	HY-19	S01C	-	186	22700	117	135	29	U1.0
17110019-HY-000-	MSQS	HY-20	S01C	-	177	25700	125	204	36	U1.0
17110019-HY-000-	MSQS	HY-21	S01C	-	153	21500	109	171	38	U1.0
17110019-HY-000-	MSQS	HY-22	S05C	-	239	25500	181	205	52	U1.0
17110019-HY-000-	MSQS	HY-23	S01C	-	147	22000	110	203	56	U1.0
17110019-HY-000-	MSQS	HY-24	S01C	-	192	26400	139	203	39	U1.0
17110019-HY-000-	MSQS	HY-25	S01C	-	122	20900	78	165	30	U1.0
17110019-HY-000-	MSQS	HY-26	S01C	-	91	17800	64	132	24	U1.0
17110019-HY-000-	MSQS	HY-27	S01C	-	118	18000	93	131	25	U1.0
17110019-HY-000-	MSQS	HY-28	S01C	-	125	20100	92	148	23	U1.0
17110019-HY-000-	MSQS	HY-29	S01C	-	107	18000	79	136	22	U1.0
17110019-HY-000-	MSQS	HY-30	S01C	-	98	22400	56	210	25	U1.0
17110019-HY-000-	MSQS	HY-31	S01C	-	60	13700	46	98	15	U1.0
17110019-HY-000-	MSQS	HY-32	S01C	-	110	17000	91	118	21	U1.0
17110019-HY-000-	MSQS	HY-33	S01C	-	79	14800	56	105	22	U1.0
17110019-HY-000-	MSQS	HY-34	S01C	-	62	13700	53	88	14	U1.0
17110019-HY-000-	MSQS	HY-35	S01C	-	99	15600	83	127	20	U1.0
17110019-HY-000-	MSQS	HY-36	S01C	-	106	17100	106	143	20	U1.0
17110019-HY-000-	MSQS	HY-37	S01C	-	98	17000	76	134	23	U1.0
17110019-HY-000-	MSQS	HY-38	S01C	-	76	14400	69	120	15	U1.0
17110019-HY-000-	MSQS	HY-39	S01C	-	73	13700	63	110	18	U1.0
17110019-HY-000-	MSQS	HY-40	S01C	-	262	16500	102	141	21	U1.0
17110019-HY-000-	MSQS	HY-41	S01C	-	78	15000	73	160	18	U1.0
17110019-HY-000-	MSQS	HY-42	S01C	-	96	15600	172	151	21	U1.0
17110019-HY-000-	MSQS	HY-43	S01C	-	115	15000	81	128	20	U1.0
17110019-HY-000-	MSQS	HY-44	S01C	-	14	6790	8.3	55	6.9	U1.0
17110019-HY-000-	MSQS	HY-45	S01C	-	65	20100	56	140	20	U1.0
17110019-HY-000-	MSQS	HY-46	S01C	-	112	23100	134	171	39	U1.0
17110019-HY-000-	MSQS	HY-47	S05C	-	83	14800	69	133	19	U1.0
17110019-HY-000-	MSQS	HY-48	S01C	-	71	13600	48	149	14	U1.0
17110019-HY-000-	MSQS	HY-49	S01C	-	42	14000	42	122	12	U1.0
17110019-HY-000-	MSQS	HY-50	S05C	-	40	14900	42	132	12	U1.0
17110019-HY-000-	MSQS	HY-51	S01C	-	46	14800	23	161	13	U1.0
17110019-MD-000-	MSQS	MD-11	S01C	-	176	14800	188	95	13	U1.0
17110019-MD-000-	MSQS	MD-12	S05C	-	311	12800	303	86	11	U1.0
17110019-MD-000-	MSQS	MD-13	S01C	-	554	13500	190	106	12	U1.0
17110019-MI-000-	MSQS	MI-11	S01C	-	58	13900	49	103	12	U1.0
17110019-MI-000-	MSQS	MI-12	S01C	-	77	15700	75	120	13	U1.0
17110019-MI-000-	MSQS	MI-13	S01C	-	71	14700	78	118	12	U1.0
17110019-MI-000-	MSQS	MI-14	S01C	-	60	15100	62	136	14	U1.0
17110019-MI-000-	MSQS	MI-15	S01C	-	46	14200	48	145	12	U1.0
17110019-RS-000-	MSQS	RS-11	S01C	-	69	10800	80	110	12	U1.0
17110019-RS-000-	MSQS	RS-12	S01C	-	41	12900	58	150	20	U1.0
17110019-RS-000-	MSQS	RS-13	S01C	-	67	10900	99	106	19	U1.0
17110019-RS-000-	MSQS	RS-14	S05C	-	155	14600	104	109	20	U1.0
17110019-RS-000-	MSQS	RS-15	S02C	-	55	8600	38	119	17	U1.0

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Copper	Iron	Lead	Manganese	Nickel	Selenium
17110019-RS-000-	MSQS	RS-16	S01C -		458	12100	155	186	16	U1.0
17110019-RS-000-	MSQS	RS-17	S01C -		8320	50000	2680	202	64	26
17110019-RS-000-	MSQS	RS-18	S01C -		11400	52900	6250	748	93	24
17110019-RS-000-	MSQS	RS-19	S01C -		2240	24000	1020	137	23	1.4
17110019-RS-000-	MSQS	RS-20	S01C -		137	15900	78	232	19	U1.0
17110019-RS-000-	MSQS	RS-21	S01C -		14300	115000	4970	746	350	25
17110019-RS-000-	MSQS	RS-22	S01C -		87	10300	98	99	10	U1.0
17110019-RS-000-	MSQS	RS-24	S05C -		385	37100	531	484	28	U1.0
17110019-SI-000-	MSQS	SI-11	S05C -		292	14200	661	114	12	U1.0
17110019-SI-000-	MSQS	SI-12	S01C -		191	12800	496	118	11	U1.0
17110019-SI-000-	MSQS	SI-13	S01C -		158	12300	310	102	10	U1.0
17110019-SI-000-	MSQS	SI-14	S01C -		148	11700	212	112	12	U1.0
17110019-SI-000-	MSQS	SI-15	S05C -		74	12800	128	105	11	U1.0
17110019-SP-000-	MSQS	SP-11	S05C -		65	8310	24	70	8.3	U1.0
17110019-SP-000-	MSQS	SP-12	S05C -		56	10600	29	88	10	U1.0
17110019-SP-000-	MSQS	SP-13	S01C -		82	11900	52	107	12	U1.0
17110019-SP-000-	MSQS	SP-14	S01C -		275	9270	60	556	40	U1.0
17110019-SP-000-	MSQS	SP-15	S05C -		32	6650	11	83	7.7	U1.0
17110019-SP-000-	MSQS	SP-16	S05C -		29	10000	11	85	8.9	U1.0
17110019-DP-000-	MSQS	WBS	CTL -	02	7.2	9900	2.5	132	29	U1
17110019-DP-000-	MSQS	WBS	CTL -	01	5.2	9420	3.2	128	28	U1

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MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Silver	Thallium	Zinc	Cyanide	Cobalt	Mercury
17110019-BL-000-	MSQS	BL-11	S05C	-	U0.17	U0.1	63			0.069
17110019-BL-000-	MSQS	BL-12	S01C	-	0.30	U0.1	91			0.078
17110019-BL-000-	MSQS	BL-13	S05C	-	0.14	U0.1	85			0.20
17110019-BL-000-	MSQS	BL-14	S01C	-	0.22	U0.1	88			0.22
17110019-BL-000-	MSQS	BL-15	S01C	-	0.26	U0.1	70			0.20
17110019-BL-000-	MSQS	BL-16	S01C	-	0.18	U0.1	88			0.15
17110019-BL-000-	MSQS	BL-17	S01C	-	0.19	U0.1	82			0.16
17110019-BL-000-	MSQS	BL-18	S01C	-	0.18	U0.1	67			0.18
17110019-BL-000-	MSQS	BL-19	S01C	-	0.24	U0.1	68			0.21
17110019-BL-000-	MSQS	BL-20	S01C	-	0.22	U0.1	65			0.20
17110019-BL-000-	MSQS	BL-21	S05C	-	0.17	U0.1	65			0.13
17110019-BL-000-	MSQS	BL-22	S01C	-	0.40	U0.1	69			0.10
17110019-BL-000-	MSQS	BL-23	S01C	-	0.22	U0.1	68			0.15
17110019-BL-000-	MSQS	BL-24	S01C	-	0.34	0.10	90			0.099
17110019-BL-000-	MSQS	BL-25	S05C	-	0.20	0.11	70			0.15
17110019-BL-000-	MSQS	BL-26	S01C	-	0.20	U0.1	66			0.12
17110019-BL-000-	MSQS	BL-27	S01C	-	U0.1	U0.1	29			0.051
17110019-BL-000-	MSQS	BL-28	S05C	-	0.13	U0.1	37			0.070
17110019-BL-000-	MSQS	BL-29	S01C	-	0.18	U0.1	62			0.082
17110019-BL-000-	MSQS	BL-30	S01C	-	0.20	U0.1	39			0.094
17110019-BL-000-	MSQS	BL-31	S05C	-	0.15	U0.1	35			0.085
17110019-BL-000-	MSQS	BL-32	S01C	-	0.22	U0.1	44			0.11
17110019-HY-000-	MSQS	CB-11	S01C	-	0.34	U0.1	72			0.14
17110019-CB-000-	MSQS	CB-12	S01C	-	U0.1	U0.1	26			0.053
17110019-CB-000-	MSQS	CB-13	S01C	-	0.10	U0.1	28			0.063
17110019-CB-000-	MSQS	CB-14	S01C	-	0.11	U0.1	33			0.066
17110019-CI-000-	MSQS	CI-11	S02C	-	U0.1	U0.1	325			0.53
17110019-CI-000-	MSQS	CI-12	S01C	-	0.11	U0.1	282			0.45
17110019-CI-000-	MSQS	CI-13	S05C	-	0.11	U0.1	247			1.1
17110019-CI-000-	MSQS	CI-14	S01C	-	0.11	U0.1	234			0.10
17110019-CI-000-	MSQS	CI-15	S01C	-	U0.1	U0.1	270			0.28
17110019-CW-000-	MSQS	CI-16	S05C	-	U0.1	U0.1	254			0.11
17110019-CI-000-	MSQS	CI-17	S05C	-	U0.1	U0.1	227			0.11
17110019-CI-000-	MSQS	CI-18	S01C	-	0.11	U0.1	236			0.96
17110019-CI-000-	MSQS	CI-19	S01C	-	0.12	U0.1	164			0.20
17110019-CI-000-	MSQS	CI-20	S05C	-	0.13	U0.1	165			0.24
17110019-CI-000-	MSQS	CI-21	S01C	-	0.44	U0.1	72			0.32
17110019-CI-000-	MSQS	CI-22	S05C	-	0.40	U0.1	44			0.22
17110019-CR-000-	MSQS	CR-11	S01C	-	U0.1	0.11	15			0.055
17110019-CR-000-	MSQS	CR-12	S05C	-	U0.1	U0.1	19			0.098
17110019-CR-000-	MSQS	CR-13	S01C	-	U0.1	0.20	15			0.049
17110019-CR-000-	MSQS	CR-14	S05C	-	U0.1	0.24	17			0.034
17110019-HY-000-	MSQS	HY-11	S01C	-	0.24	U0.1	176			0.078
17110019-HY-000-	MSQS	HY-12	S01C	-	0.26	U0.1	198			0.46
17110019-HY-000-	MSQS	HY-13	S01C	-	0.26	U0.1	207			0.39
17110019-HY-000-	MSQS	HY-14	S05C	-	0.24	U0.1	180			0.33
17110019-HY-000-	MSQS	HY-15	S01C	-	0.22	U0.1	186			0.048
17110019-HY-000-	MSQS	HY-16	S01C	-	0.26	0.16	317			0.17

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Silver	Thallium	Zinc	Cyanide	Cobalt	Mercury
17110019-HY-000-	MSQS	HY-17	S01C	-	0.46	U0.1	268			0.30
17110019-HY-000-	MSQS	HY-18	S01C	-	0.24	U0.1	294			0.39
17110019-HY-000-	MSQS	HY-19	S01C	-	0.40	U0.1	273			0.32
17110019-HY-000-	MSQS	HY-20	S01C	-	0.48	U0.1	255			0.28
17110019-HY-000-	MSQS	HY-21	S01C	-	0.42	U0.1	202			0.056
17110019-HY-000-	MSQS	HY-22	S05C	-	0.40	U0.1	242			0.50
17110019-HY-000-	MSQS	HY-23	S01C	-	0.40	U0.1	190			0.40
17110019-HY-000-	MSQS	HY-24	S01C	-	0.42	U0.1	258			0.49
17110019-HY-000-	MSQS	HY-25	S01C	-	0.36	U0.1	149			0.27
17110019-HY-000-	MSQS	HY-26	S01C	-	0.28	U0.1	123			0.25
17110019-HY-000-	MSQS	HY-27	S01C	-	0.24	U0.1	144			0.32
17110019-HY-000-	MSQS	HY-28	S01C	-	0.26	U0.1	146			0.28
17110019-HY-000-	MSQS	HY-29	S01C	-	0.17	U0.1	130			0.28
17110019-HY-000-	MSQS	HY-30	S01C	-	0.16	U0.1	120			0.22
17110019-HY-000-	MSQS	HY-31	S01C	-	0.17	U0.1	77			0.19
17110019-HY-000-	MSQS	HY-32	S01C	-	0.32	U0.1	143			0.38
17110019-HY-000-	MSQS	HY-33	S01C	-	0.18	U0.1	84			0.23
17110019-HY-000-	MSQS	HY-34	S01C	-	0.16	U0.1	105			0.21
17110019-HY-000-	MSQS	HY-35	S01C	-	0.24	U0.1	112			0.30
17110019-HY-000-	MSQS	HY-36	S01C	-	0.36	U0.1	124			0.38
17110019-HY-000-	MSQS	HY-37	S01C	-	0.24	U0.1	109			0.22
17110019-HY-000-	MSQS	HY-38	S01C	-	0.24	U0.1	88			0.22
17110019-HY-000-	MSQS	HY-39	S01C	-	0.32	U0.1	75			0.22
17110019-HY-000-	MSQS	HY-40	S01C	-	0.42	U0.1	116			3.2
17110019-HY-000-	MSQS	HY-41	S01C	-	0.36	U0.1	91			0.34
17110019-HY-000-	MSQS	HY-42	S01C	-	0.30	U0.1	115			0.31
17110019-HY-000-	MSQS	HY-43	S01C	-	0.26	U0.1	107			0.18
17110019-HY-000-	MSQS	HY-44	S01C	-	0.20	U0.1	21			0.20
17110019-HY-000-	MSQS	HY-45	S01C	-	0.26	U0.1	69			0.32
17110019-HY-000-	MSQS	HY-46	S01C	-	0.38	U0.1	89			0.44
17110019-HY-000-	MSQS	HY-47	S05C	-	0.42	U0.1	95			0.21
17110019-HY-000-	MSQS	HY-48	S01C	-	0.34	U0.1	74			0.13
17110019-HY-000-	MSQS	HY-49	S01C	-	0.26	U0.1	43			0.11
17110019-HY-000-	MSQS	HY-50	S05C	-	0.26	U0.1	41			0.11
17110019-HY-000-	MSQS	HY-51	S01C	-	0.24	U0.1	46			0.13
17110019-MD-000-	MSQS	MD-11	S01C	-	0.22	U0.1	178			0.18
17110019-MD-000-	MSQS	MD-12	S05C	-	0.56	U0.1	208			0.32
17110019-MD-000-	MSQS	MD-13	S01C	-	0.26	U0.1	158			3.4
17110019-MI-000-	MSQS	MI-11	S01C	-	0.40	U0.1	105			0.18
17110019-MI-000-	MSQS	MI-12	S01C	-	0.46	U0.1	135			0.17
17110019-MI-000-	MSQS	MI-13	S01C	-	0.50	U0.1	120			0.16
17110019-MI-000-	MSQS	MI-14	S01C	-	0.36	U0.1	88			0.16
17110019-MI-000-	MSQS	MI-15	S01C	-	0.28	U0.1	63			0.12
17110019-RS-000-	MSQS	RS-11	S01C	-	0.26	U0.1	91			0.32
17110019-RS-000-	MSQS	RS-12	S01C	-	0.20	U0.1	60			0.30
17110019-RS-000-	MSQS	RS-13	S01C	-	0.28	U0.1	80			0.39
17110019-RS-000-	MSQS	RS-14	S05C	-	0.44	U0.1	91			0.30
17110019-RS-000-	MSQS	RS-15	S02C	-	0.24	U0.1	32			0.12

MAIN SEDIMENT QUALITY SURVEY INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Silver	Thallium	Zinc	Cyanide	Cobalt	Mercury
17110019-RS-000-	MSQS	RS-16	S01C -		0.26	0.11	103			0.75
17110019-RS-000-	MSQS	RS-17	S01C -		0.36	U0.1	2040			29
17110019-RS-000-	MSQS	RS-18	S01C -		0.30	3.2	3320			52
17110019-RS-000-	MSQS	RS-19	S01C -		0.22	0.46	906			3.2
17110019-RS-000-	MSQS	RS-20	S01C -		0.17	U0.1	140			0.59
17110019-RS-000-	MSQS	RS-21	S01C -		0.20	0.80	4210			17
17110019-RS-000-	MSQS	RS-22	S01C -		0.28	U0.1	201			0.14
17110019-RS-000-	MSQS	RS-24	S05C -		0.44	U0.1	1620			0.41
17110019-SI-000-	MSQS	SI-11	S05C -		0.50	0.16	491			0.29
17110019-SI-000-	MSQS	SI-12	S01C -		0.46	0.14	337			0.20
17110019-SI-000-	MSQS	SI-13	S01C -		0.60	U0.1	254			0.19
17110019-SI-000-	MSQS	SI-14	S01C -		0.54	U0.1	205			0.16
17110019-SI-000-	MSQS	SI-15	S05C -		0.38	U0.1	109			0.16
17110019-SP-000-	MSQS	SP-11	S05C -		0.22	0.11	60			0.17
17110019-SP-000-	MSQS	SP-12	S05C -		0.30	0.14	62			0.35
17110019-SP-000-	MSQS	SP-13	S01C -		0.40	0.16	106			0.36
17110019-SP-000-	MSQS	SP-14	S01C -		0.26	0.12	125			0.14
17110019-SP-000-	MSQS	SP-15	S05C -		0.13	U0.1	29			0.094
17110019-SP-000-	MSQS	SP-16	S05C -		0.17	U0.1	30			0.10
17110019-DP-000-	MSQS	WBS	CTL -	02	U0.2	U0.5	21		5.1	U0.1
17110019-DP-000-	MSQS	WBS	CTL -	01	U0.2	U0.5	20		5.1	U0.1

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MAIN SEDIMENT QUALITY SURVEY SEDIMENT GRAIN SIZE

Drainage	Survey	Station	Sample	Rep	% Rocks	% Sand	% Silt	% Clay
17110019-BL-000-	MSQS	BL-11	S05C -		0.210	44.587	39.347	15.855
17110019-BL-000-	MSQS	BL-12	S01C -		0.806	13.908	60.738	24.548
17110019-BL-000-	MSQS	BL-13	S05C -		0.478	15.517	61.660	22.345
17110019-BL-000-	MSQS	BL-14	S01C -		2.144	23.600	54.416	19.840
17110019-BL-000-	MSQS	BL-15	S01C -		0.809	17.430	61.256	20.505
17110019-BL-000-	MSQS	BL-16	S01C -	02	1.370	10.311	58.713	29.606
17110019-BL-000-	MSQS	BL-16	S01C -	01	0.127	8.317	65.714	25.841
17110019-BL-000-	MSQS	BL-17	S01C -		0.189	11.524	63.287	25.000
17110019-BL-000-	MSQS	BL-18	S01C -		0.020	48.129	36.431	15.420
17110019-BL-000-	MSQS	BL-19	S01C -		0.000	13.579	63.669	22.752
17110019-BL-000-	MSQS	BL-20	S01C -		0.000	24.321	54.604	21.074
17110019-BL-000-	MSQS	BL-21	S05C -		0.140	35.761	45.848	18.251
17110019-BL-000-	MSQS	BL-22	S01C -		0.810	35.995	43.403	19.792
17110019-BL-000-	MSQS	BL-23	S01C -		0.000	32.400	39.864	27.735
17110019-BL-000-	MSQS	BL-24	S01C -		0.115	10.957	66.032	22.895
17110019-BL-000-	MSQS	BL-25	S05C -		0.350	11.830	63.811	24.009
17110019-BL-000-	MSQS	BL-26	S01C -		0.174	33.481	49.638	16.708
17110019-BL-000-	MSQS	BL-27	S01C -		0.625	75.463	18.904	5.008
17110019-BL-000-	MSQS	BL-28	S05C -		0.575	62.920	26.548	9.957
17110019-BL-000-	MSQS	BL-29	S01C -	02	0.000	24.166	62.603	13.231
17110019-BL-000-	MSQS	BL-29	S01C -	01	0.166	24.570	62.119	13.145
17110019-BL-000-	MSQS	BL-30	S01C -		0.420	42.318	46.146	11.117
17110019-BL-000-	MSQS	BL-31	S05C -		0.258	39.845	50.258	9.639
17110019-BL-000-	MSQS	BL-32	S01C -		0.000	21.017	64.089	14.894
17110019-HY-000-	MSQS	CB-11	S01C -		0.363	15.375	61.138	23.123
17110019-CB-000-	MSQS	CB-12	S01C -		0.055	30.482	56.743	12.719
17110019-CB-000-	MSQS	CB-13	S01C -		0.334	18.955	66.426	14.286
17110019-CB-000-	MSQS	CB-14	S01C -		0.164	16.393	67.213	16.230
17110019-CI-000-	MSQS	CI-11	S02C -		2.377	58.270	29.387	9.965
17110019-CI-000-	MSQS	CI-12	S01C -		0.168	29.629	55.196	15.008
17110019-CI-000-	MSQS	CI-13	S05C -		0.063	21.631	60.071	18.234
17110019-CI-000-	MSQS	CI-14	S01C -		0.077	12.519	66.046	21.359
17110019-CI-000-	MSQS	CI-15	S01C -		4.933	32.350	47.581	15.136
17110019-CW-000-	MSQS	CI-16	S05C -		1.626	24.723	54.482	19.168
17110019-CI-000-	MSQS	CI-17	S05C -		0.221	27.466	54.637	17.676
17110019-CI-000-	MSQS	CI-18	S01C -		0.071	29.192	54.278	16.459
17110019-CI-000-	MSQS	CI-19	S01C -		0.178	16.968	65.669	17.185
17110019-CI-000-	MSQS	CI-20	S05C -		0.500	19.782	63.443	16.275
17110019-CI-000-	MSQS	CI-21	S01C -		0.218	57.578	32.918	9.285
17110019-CI-000-	MSQS	CI-22	S05C -		0.191	71.784	22.396	5.629
17110019-CR-000-	MSQS	CR-11	S01C -		0.361	95.299	4.340	0.000
17110019-CR-000-	MSQS	CR-12	S05C -		0.110	87.076	12.814	0.000
17110019-CR-000-	MSQS	CR-13	S01C -		0.095	92.243	7.662	0.000
17110019-CR-000-	MSQS	CR-14	S05C -	01	0.086	76.022	18.495	5.396
17110019-CR-000-	MSQS	CR-14	S05C -	02	0.000	78.696	21.304	0.000
17110019-HY-000-	MSQS	HY-11	S01C -		0.173	30.255	46.828	22.745
17110019-HY-000-	MSQS	HY-12	S01C -		0.166	21.307	45.984	32.543

MAIN SEDIMENT QUALITY SURVEY SEDIMENT GRAIN SIZE

Drainage	Survey	Station	Sample	Rep	% Rocks	% Sand	% Silt	% Clay
17110019-HY-000-	MSQS	HY-13	S01C -		0.625	23.290	43.962	32.122
17110019-HY-000-	MSQS	HY-14	S05C -		1.857	50.208	29.619	18.316
17110019-HY-000-	MSQS	HY-15	S01C -		0.384	31.464	40.532	27.619
17110019-HY-000-	MSQS	HY-16	S01C -		17.134	38.596	27.828	16.442
17110019-HY-000-	MSQS	HY-17	S01C -		5.925	27.142	40.833	26.101
17110019-HY-000-	MSQS	HY-18	S01C -	01	2.525	26.573	41.934	28.969
17110019-HY-000-	MSQS	HY-18	S01C -	02	0.411	25.585	44.353	29.651
17110019-HY-000-	MSQS	HY-19	S01C -		0.770	36.062	41.647	21.521
17110019-HY-000-	MSQS	HY-20	S01C -		0.114	12.986	55.027	31.874
17110019-HY-000-	MSQS	HY-21	S01C -		1.118	18.392	54.634	25.856
17110019-HY-000-	MSQS	HY-22	S05C -		2.106	22.367	50.364	25.163
17110019-HY-000-	MSQS	HY-23	S01C -		0.390	13.160	67.965	18.485
17110019-HY-000-	MSQS	HY-24	S01C -		0.281	18.203	50.772	30.744
17110019-HY-000-	MSQS	HY-25	S01C -		0.765	8.563	57.722	32.951
17110019-HY-000-	MSQS	HY-26	S01C -		6.838	36.391	38.192	18.579
17110019-HY-000-	MSQS	HY-27	S01C -		9.374	27.760	44.214	18.652
17110019-HY-000-	MSQS	HY-28	S01C -		6.976	31.924	45.226	15.873
17110019-HY-000-	MSQS	HY-29	S01C -	01	1.895	35.213	42.976	19.917
17110019-HY-000-	MSQS	HY-29	S01C -	02	4.460	34.812	40.258	20.469
17110019-HY-000-	MSQS	HY-30	S01C -		0.000	18.323	47.035	34.642
17110019-HY-000-	MSQS	HY-31	S01C -		2.329	47.634	34.548	15.490
17110019-HY-000-	MSQS	HY-32	S01C -		5.284	33.568	40.623	20.525
17110019-HY-000-	MSQS	HY-33	S01C -		52.933	26.409	13.940	6.718
17110019-HY-000-	MSQS	HY-34	S01C -		4.892	46.379	36.213	12.516
17110019-HY-000-	MSQS	HY-35	S01C -		0.914	28.926	46.545	23.615
17110019-HY-000-	MSQS	HY-36	S01C -		1.887	31.855	44.182	22.075
17110019-HY-000-	MSQS	HY-37	S01C -		0.811	21.703	51.081	26.405
17110019-HY-000-	MSQS	HY-38	S01C -		1.737	45.264	39.495	13.504
17110019-HY-000-	MSQS	HY-39	S01C -	01	11.709	44.429	30.287	13.575
17110019-HY-000-	MSQS	HY-39	S01C -	02	8.080	45.517	32.295	14.108
17110019-HY-000-	MSQS	HY-40	S01C -		0.499	19.040	55.157	25.304
17110019-HY-000-	MSQS	HY-41	S01C -		0.820	38.020	42.857	18.303
17110019-HY-000-	MSQS	HY-42	S01C -		0.604	21.330	55.699	22.366
17110019-HY-000-	MSQS	HY-43	S01C -		6.121	36.725	38.156	18.998
17110019-HY-000-	MSQS	HY-44	S01C -		2.448	91.935	5.617	0.000
17110019-HY-000-	MSQS	HY-45	S01C -		1.018	30.365	48.912	19.706
17110019-HY-000-	MSQS	HY-46	S01C -		6.278	31.627	55.043	7.051
17110019-HY-000-	MSQS	HY-47	S05C -		0.388	21.324	55.663	22.625
17110019-HY-000-	MSQS	HY-48	S01C -		1.235	39.689	41.492	17.585
17110019-HY-000-	MSQS	HY-49	S01C -		3.512	13.929	62.798	19.762
17110019-HY-000-	MSQS	HY-50	S05C -		0.302	13.975	66.546	19.177
17110019-HY-000-	MSQS	HY-51	S01C -	01	0.164	20.526	61.179	18.131
17110019-HY-000-	MSQS	HY-51	S01C -	02	0.093	20.980	60.327	18.600
17110019-MD-000-	MSQS	MD-11	S01C -	01	0.078	25.039	57.903	16.980
17110019-MD-000-	MSQS	MD-11	S01C -	02	3.774	38.572	43.912	13.743
17110019-MD-000-	MSQS	MD-12	S05C -		0.653	43.205	46.268	9.874
17110019-MD-000-	MSQS	MD-13	S01C -		35.355	40.046	17.543	7.056
17110019-MI-000-	MSQS	MI-11	S01C -		0.048	13.951	62.500	23.501

MAIN SEDIMENT QUALITY SURVEY SEDIMENT GRAIN SIZE

Drainage	Survey	Station	Sample	Rep	% Rocks	% Sand	% Silt	% Clay
17110019-MI-000-	MSQS	MI-12	S01C -		0.144	8.833	63.658	27.365
17110019-MI-000-	MSQS	MI-13	S01C -		0.103	10.432	64.234	25.231
17110019-MI-000-	MSQS	MI-14	S01C -		0.121	14.095	68.297	17.486
17110019-MI-000-	MSQS	MI-15	S01C -		0.000	14.892	69.155	15.953
17110019-RS-000-	MSQS	RS-11	S01C -		3.878	68.839	18.251	9.031
17110019-RS-000-	MSQS	RS-12	S01C -		1.723	68.998	21.220	8.060
17110019-RS-000-	MSQS	RS-13	S01C -		0.389	87.043	12.569	0.000
17110019-RS-000-	MSQS	RS-14	S05C -		29.864	46.359	12.456	11.321
17110019-RS-000-	MSQS	RS-15	S05C -		0.080	96.259	3.661	0.000
17110019-RS-000-	MSQS	RS-16	S01C -		12.157	64.969	14.292	8.582
17110019-RS-000-	MSQS	RS-17	S01C -		9.912	67.661	14.666	7.762
17110019-RS-000-	MSQS	RS-18	S01C -		7.744	58.912	25.209	8.134
17110019-RS-000-	MSQS	RS-19	S01C -		7.339	89.469	3.192	0.000
17110019-RS-000-	MSQS	RS-20	S01C -		5.193	88.993	5.814	0.000
17110019-RS-000-	MSQS	RS-21	S01C -		1.844	48.593	36.375	13.188
17110019-RS-000-	MSQS	RS-22	S01C -		38.860	59.863	1.277	0.000
17110019-RS-000-	MSQS	RS-24	S05C -		8.961	74.976	11.828	4.235
17110019-SI-000-	MSQS	SI-11	S05C -		0.068	20.059	62.754	17.119
17110019-SI-000-	MSQS	SI-12	S01C -		0.172	23.747	59.367	16.714
17110019-SI-000-	MSQS	SI-13	S01C -		0.081	18.261	65.779	15.880
17110019-SI-000-	MSQS	SI-14	S01C -		1.531	47.859	40.848	9.762
17110019-SI-000-	MSQS	SI-15	S05C -		1.155	18.328	61.876	18.641
17110019-SP-000-	MSQS	SP-11	S05C -		6.015	65.887	19.746	8.352
17110019-SP-000-	MSQS	SP-12	S05C -		3.140	47.518	40.175	9.166
17110019-SP-000-	MSQS	SP-13	S05C -		1.118	29.538	57.223	12.121
17110019-SP-000-	MSQS	SP-14	S01C -		1.500	31.900	50.750	15.850
17110019-SP-000-	MSQS	SP-15	S05C -		1.014	73.085	25.901	0.000
17110019-SP-000-	MSQS	SP-16	S05C -		0.000	45.149	46.759	8.092
17110019-DP-000-	MSQS	WBS	CTL -	01	0.000	97.188	2.812	0.000
17110019-DP-000-	MSQS	WBS	CTL -	02	0.000	97.971	2.029	0.000
17110019-DP-000-	MSQS	WBS	CTL -	03	0.000	97.274	2.726	0.000

Number of Observations: 126

MAIN SEDIMENT QUALITY SURVEY SEDIMENT CONVENTIONALS

Drainage	Survey	Station	Sample	Rep	Total Solids %	Total Volatile Solids %	Total Organic Carbon %	Carbonate %	Hydrogen %	Nitrogen %
17110019-BL-000-	MSQS	BL-11	S05C	-	55.5	3.2	1.29			0.16
17110019-BL-000-	MSQS	BL-12	S01C	-	48.6	4.9	2.21			0.19
17110019-BL-000-	MSQS	BL-13	S05C	-	49.2	5.1	2.03			0.088
17110019-BL-000-	MSQS	BL-14	S01C	-	48.8	5.2	2.12			0.10
17110019-BL-000-	MSQS	BL-15	S01C	-	53.1	3.8	1.39			0.063
17110019-BL-000-	MSQS	BL-16	S01C	-	47.9	5.0	1.96			0.10
17110019-BL-000-	MSQS	BL-17	S01C	-	49.6	4.4	1.71			0.10
17110019-BL-000-	MSQS	BL-18	S01C	-	59.5	3.1	1.03			0.062
17110019-BL-000-	MSQS	BL-19	S01C	-	53.6	3.7	1.40			0.082
17110019-BL-000-	MSQS	BL-20	S01C	-	56.5	3.4	1.35			0.077
17110019-BL-000-	MSQS	BL-21	S05C	-	59.9	3.2	1.14			0.064
17110019-BL-000-	MSQS	BL-22	S01C	-	59.6	3.2	1.27			0.069
17110019-BL-000-	MSQS	BL-23	S01C	-	56.1	3.8	1.49			0.089
17110019-BL-000-	MSQS	BL-24	S01C	-	49.3	4.1	1.76			0.10
17110019-BL-000-	MSQS	BL-25	S05C	-	54.2	3.4	1.47			0.083
17110019-BL-000-	MSQS	BL-26	S01C	-	55.5	3.4	1.43			0.087
17110019-BL-000-	MSQS	BL-27	S01C	-	78.7	1.4	0.48			0.046
17110019-BL-000-	MSQS	BL-28	S05C	-	73.2	1.9	0.73			0.047
17110019-BL-000-	MSQS	BL-29	S01C	-	63.4	2.6	1.12			0.072
17110019-BL-000-	MSQS	BL-30	S01C	-	64.5	2.5	1.09			0.067
17110019-BL-000-	MSQS	BL-31	S05C	-	65.8	2.7	1.09			0.066
17110019-BL-000-	MSQS	BL-32	S01C	-	60.8	3.4	1.42			0.082
17110019-HY-000-	MSQS	CB-11	S01C	-	56.7	5.0	2.46			0.71
17110019-CB-000-	MSQS	CB-12	S01C	-	66.4	3.4	1.28			0.076
17110019-CB-000-	MSQS	CB-13	S01C	-	64.3	3.3	1.27			1.15
17110019-CB-000-	MSQS	CB-14	S01C	-	63.6	3.4	1.24			0.073
17110019-CI-000-	MSQS	CI-11	S02C	-	45.3	13.5	8.86			0.35
17110019-CI-000-	MSQS	CI-12	S01C	-	42.0	12.3	7.71			0.34
17110019-CI-000-	MSQS	CI-13	S05C	-	38.2	11.4	6.50			0.29
17110019-CI-000-	MSQS	CI-14	S01C	-	35.0	11.0	6.24			0.34
17110019-CI-000-	MSQS	CI-15	S01C	-	40.6	11.0	5.94			0.28
17110019-CW-000-	MSQS	CI-16	S05C	-	28.6	17.3	10.9			0.49
17110019-CI-000-	MSQS	CI-17	S05C	-	41.8	9.8	5.64			0.27
17110019-CI-000-	MSQS	CI-18	S01C	-	42.8	10.3	5.94			0.22
17110019-CI-000-	MSQS	CI-19	S01C	-	41.7	8.8	4.90			0.22
17110019-CI-000-	MSQS	CI-20	S05C	-	44.7	8.5	4.59			0.20
17110019-CI-000-	MSQS	CI-21	S01C	-	57.7	0.3	2.82			0.13
17110019-CI-000-	MSQS	CI-22	S05C	-	70.4	3.2	1.21			0.16
17110019-CR-000-	MSQS	CR-11	S01C	-	75.7	0.9	0.35			0.24
17110019-CR-000-	MSQS	CR-12	S05C	-	75.6	1.0	0.26			0.035
17110019-CR-000-	MSQS	CR-13	S01C	-	76.8	0.77	0.19			0.024
17110019-CR-000-	MSQS	CR-14	S05C	-	73.8	1.2	0.43			0.052
17110019-HY-000-	MSQS	HY-11	S01C	-	42.9	16.0	6.81			0.25
17110019-HY-000-	MSQS	HY-12	S01C	-	41.2	11.7	5.72			0.21
17110019-HY-000-	MSQS	HY-13	S01C	-	40.8	12.3	5.49			0.21
17110019-HY-000-	MSQS	HY-14	S05C	-	51.5	8.4	4.51			0.17

MAIN SEDIMENT QUALITY SURVEY SEDIMENT CONVENTIONALS

Drainage	Survey	Station	Sample	Rep	Total Solids %	Total Volatile Solids %	Total Organic Carbon %	Carbonate %	Hydrogen %	Nitrogen %
17110019-HY-000-	MSQS	HY-15	S01C	-	49.0	8.0	3.78			0.15
17110019-HY-000-	MSQS	HY-16	S01C	-	38.7	25.9	12.21			0.22
17110019-HY-000-	MSQS	HY-17	S01C	-	39.1	12.2	5.22			0.18
17110019-HY-000-	MSQS	HY-18	S01C	-	37.2	15.1	6.39			0.22
17110019-HY-000-	MSQS	HY-19	S01C	-	33.8	20.9	9.01			0.24
17110019-HY-000-	MSQS	HY-20	S01C	-	40.1	11.0	4.45			0.19
17110019-HY-000-	MSQS	HY-21	S01C	-	37.1	11.4	4.59			0.19
17110019-HY-000-	MSQS	HY-22	S05C	-	37.6	11.3	4.44			0.18
17110019-HY-000-	MSQS	HY-23	S01C	-	36.9	10.5	3.78			0.16
17110019-HY-000-	MSQS	HY-24	S01C	-	38.0	11.4	5.12			0.22
17110019-HY-000-	MSQS	HY-25	S01C	-	45.1	7.8	3.15			0.17
17110019-HY-000-	MSQS	HY-26	S01C	-	51.8	7.5	3.24			0.13
17110019-HY-000-	MSQS	HY-27	S01C	-	46.5	8.7	2.24			0.13
17110019-HY-000-	MSQS	HY-28	S01C	-	38.5	14.6	3.10			0.13
17110019-HY-000-	MSQS	HY-29	S01C	-	47.6	8.6	2.84			0.12
17110019-HY-000-	MSQS	HY-30	S01C	-	40.6	8.0	2.28			0.11
17110019-HY-000-	MSQS	HY-31	S01C	-	59.9	4.4	1.65			.092
17110019-HY-000-	MSQS	HY-32	S01C	-	51.1	8.1	3.83			0.12
17110019-HY-000-	MSQS	HY-33	S01C	-	59.3	6.1	1.81			0.075
17110019-HY-000-	MSQS	HY-34	S01C	-	52.6	10.8	6.47			0.16
17110019-HY-000-	MSQS	HY-35	S01C	-	52.6	6.6	2.62			0.12
17110019-HY-000-	MSQS	HY-36	S01C	-	47.8	7.7	3.74			0.15
17110019-HY-000-	MSQS	HY-37	S01C	-	51.5	6.4	2.48			0.12
17110019-HY-000-	MSQS	HY-38	S01C	-	47.7	9.4	4.09			0.14
17110019-HY-000-	MSQS	HY-39	S01C	-	61.4	4.2	1.57			0.079
17110019-HY-000-	MSQS	HY-40	S01C	-	51.4	6.7	2.25			0.11
17110019-HY-000-	MSQS	HY-41	S01C	-	57.8	5.4	1.96			0.10
17110019-HY-000-	MSQS	HY-42	S01C	-	49.7	6.3	2.39			0.12
17110019-HY-000-	MSQS	HY-43	S01C	-	55.2	5.7	2.89			0.11
17110019-HY-000-	MSQS	HY-44	S01C	-	78.4	1.3	0.26			0.021
17110019-HY-000-	MSQS	HY-45	S01C	-	54.5	5.2	1.55			0.085
17110019-HY-000-	MSQS	HY-46	S01C	-	51.6	6.5	0.43			0.11
17110019-HY-000-	MSQS	HY-47	S05C	-	51.8	6.5	1.84			0.89
17110019-HY-000-	MSQS	HY-48	S01C	-	63.4	4.6	2.39			0.12
17110019-HY-000-	MSQS	HY-49	S01C	-	55.5	6.0	2.36			0.11
17110019-HY-000-	MSQS	HY-50	S05C	-	56.9	5.7	2.25			0.11
17110019-HY-000-	MSQS	HY-51	S01C	-	59.9	4.8	1.81			0.091
17110019-MD-000-	MSQS	MD-11	S01C	-	38.8	11.4	7.27			0.44
17110019-MD-000-	MSQS	MD-12	S05C	-	49.2	6.8	4.04			0.16
17110019-MD-000-	MSQS	MD-13	S01C	-	63.0	5.3	7.26			0.04
17110019-MI-000-	MSQS	MI-11	S01C	-	55.9	8.8	2.30			0.11
17110019-MI-000-	MSQS	MI-12	S01C	-	53.3	10.1	2.26			0.13
17110019-MI-000-	MSQS	MI-13	S01C	-	57.4	11.0	2.17			0.12
17110019-MI-000-	MSQS	MI-14	S01C	-	55.7	5.3	1.97			0.11
17110019-MI-000-	MSQS	MI-15	S01C	-	60.7	4.7	1.52			0.076

MAIN SEDIMENT QUALITY SURVEY SEDIMENT CONVENTIONALS

Drainage	Survey	Station	Sample	Rep	Total Solids %	Total Volatile Solids %	Total Organic Carbon %	Carbonate %	Hydrogen %	Nitrogen %
17110019-RS-000-	MSQS	RS-11	SO1C -		72.4	3.7	2.35			0.59
17110019-RS-000-	MSQS	RS-12	SO1C -		68.3	4.8	2.57			0.087
17110019-RS-000-	MSQS	RS-13	SO1C -		60.1	9.1	0.69			0.11
17110019-RS-000-	MSQS	RS-14	SO5C -		40.6	22.2	15.1			0.28
17110019-RS-000-	MSQS	RS-15	SO2C -		76.3	1.2	0.36			0.028
17110019-RS-000-	MSQS	RS-16	SO1C -		30.8	28.6	20.5			0.29
17110019-RS-000-	MSQS	RS-17	SO1C -		59.5	3.9	1.90			0.079
17110019-RS-000-	MSQS	RS-18	SO1C -		42.0	19.6	8.83			0.20
17110019-RS-000-	MSQS	RS-19	SO1C -		79.4	1.0	0.58			0.032
17110019-RS-000-	MSQS	RS-20	SO1C -		77.3	1.5	0.28			0.024
17110019-RS-000-	MSQS	RS-21	SO1C -		42.1	11.2	3.13			0.16
17110019-RS-000-	MSQS	RS-22	SO1C -		85.3	0.8	0.28			0.020
17110019-RS-000-	MSQS	RS-24	SO5C -		66.9	2.7	0.80			0.070
17110019-SI-000-	MSQS	SI-11	SO5C -		60.0	4.8	2.10			0.11
17110019-SI-000-	MSQS	SI-12	SO1C -		62.2	3.7	1.56			.095
17110019-SI-000-	MSQS	SI-13	SO1C -		62.4	4.1	1.79			1.60
17110019-SI-000-	MSQS	SI-14	SO1C -		68.1	3.7	1.61			.084
17110019-SI-000-	MSQS	SI-15	SO5C -		61.5	4.9	2.46			0.13
17110019-SP-000-	MSQS	SP-11	SO5C -		57.2	7.9	3.50			0.12
17110019-SP-000-	MSQS	SP-12	SO5C -		55.0	8.6	4.67			.16
17110019-SP-000-	MSQS	SP-13	SO1C -		46.8	13.2	5.67			.19
17110019-SP-000-	MSQS	SP-14	SO1C -		30.5	44.7	16.0			.79
17110019-SP-000-	MSQS	SP-15	SO5C -		65.8	4.3	2.06			.084
17110019-SP-000-	MSQS	SP-16	SO5C -		64.4	3.6	1.47			1.19
17110019-UP-000-	MSQS	WBS	CTL -	01	80.6	0.56	0.07			
17110019-UP-000-	MSQS	WBS	CTL -	02	80.2	0.57	0.17			Q0.01

Number of Observations: 117

a. Reference:
Tetra Tech, Inc. 1985. Commencement Bay nearshore tideflats remedial investigation. Final Report Prepared for Washington Department of Ecology and U.S. EPA by Tetra Tech, Inc. Bellevue, WA.

Table A-2. COMMENCEMENT BAY - BLAIR WATERWAY DREDGING STUDY [a]

STATION#	TOX CODE	BENTHIC CODE	MICRO CODE
2 B03	1	1	0
2 B04	1	1	0
2 B09	1	1	0
2 B10	1	1	0
2 B12	1	1	0
2 B15	3	1	0

The 6 stations listed on this page have biological effects data and are used for this report. Additional stations and associated chemical data are include on subsequent pages of this Table A-1. Where replicate data have been provided, the mean value is used for calculations..

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	phenol	2,4-di-methyl-phenol
17110019-BL-UUO-	URS001	B02	S01C -			
17110019-BL-OOU-	URS001	B02	S01C -		U10	U10
17110019-BL-OOO-	URS001	B03	S05C -		Z40	4.8
17110019-BL-OUO-	URS001	B04	S01C -	01	Z65	4.2
17110019-BL-OUO-	URS001	B04	S01C -	02	Z29	9.8
17110019-BL-OUU-	URS001	B04	S01C -	03	Z43	U2
17110019-BL-OOO-	URS001	B04	S01C -	04	U10	U10
17110019-BL-OOO-	URS001	B04	S01C -	05	U10	U10
17110019-BL-UUO-	URS001	B07	S01C -			
17110019-BL-OOU-	URS001	B07	S01C -		U10	U10
17110019-BL-OOO-	URS001	B09	S05C -			
17110019-BL-OOO-	URS001	B09	S05C -		U20	U20
17110019-BL-OOO-	URS001	B10	S05C -	01	Z400	2.3
17110019-BL-OOO-	URS001	B10	S05C -	02	Z370	U1
17110019-BL-UUO-	URS001	B11	S01C -	02		
17110019-BL-OOU-	URS001	B11	S01C -	01	Z4	U2
17110019-BL-OOU-	URS001	B12	S05C -		Z22	U1
17110019-BL-OOO-	URS001	B14	S01C -		Z56	3.0
17110019-BL-OOO-	URS001	B15	S05C -		Z53	7.2
17110019-BL-OUU-	URS001	B17	S01C -	01	U1	U2
17110019-BL-OOU-	URS001	B17	S01C -	02	Z34	2.3
17110019-BL-UOO-	URS001	B18	S01C -		Z30	U2

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
PHENOLS

Drainage	Survey	Station	Sample	Rep	2-methyl-phenol	4-methyl-phenol
17110019-BL-000-	URS001	B02	S01C -		U10	U10
17110019-BL-000-	URS001	B03	S05C -			
17110019-BL-000-	URS001	B04	S01C -	01		
17110019-BL-000-	URS001	B04	S01C -	02		
17110019-BL-000-	URS001	B04	S01C -	03		
17110019-BL-000-	URS001	B04	S01C -	04	U10	160
17110019-BL-000-	URS001	B04	S01C -	05	U10	240
17110019-BL-000-	URS001	B07	S01C -		U10	110
17110019-BL-000-	URS001	B09	S05C -		U20	92
17110019-BL-000-	URS001	B10	S05C -	01		
17110019-BL-000-	URS001	B10	S05C -	02		
17110019-BL-000-	URS001	B11	S01C -	01		
17110019-BL-000-	URS001	B12	S05C -			
17110019-BL-000-	URS001	B14	S01C -			
17110019-BL-000-	URS001	B15	S05C -			
17110019-BL-000-	URS001	B17	S01C -	01		
17110019-BL-000-	URS001	B17	S01C -	02		
17110019-BL-000-	URS001	B18	S01C -			

Number of Observations: 18

BLAIR DREDING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
SUBSTITUTED PHENOLS

Drainage	Survey	Station	Sample	Rep	2-chloro-phenol	2,4-di-chloro-phenol	4-chloro-3-methyl phenol	2,4,6-tri-chloro-phenol	penta-chloro-phenol	2-nitro-phenol	2,4-di-nitro-phenol	4,6-di-nitro-o-cresol	4-nitro-phenol
17110019-BL-000-	URSO01	B02	SO1C -										
17110019-BL-000-	URSO01	B02	SO1C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	URSO01	B03	SO5C -		U1	U2	6.1	U1	5	U2	U100	U5	U70
17110019-BL-000-	URSO01	B04	SO1C -	01	U2	U4	U1	U1	U2	U5	U150	U60	U1300
17110019-BL-000-	URSO01	B04	SO1C -	02	U2	U4	B1	U1	U6	U3	U2	U2	U20
17110019-BL-000-	URSO01	B04	SO1C -	03	U2	U5	U2	U3	U3	U5	U150	U100	U1500
17110019-BL-000-	URSO01	B04	SO1C -	04	U5	U10	U10	U10	31	U10		U100	U100
17110019-BL-000-	URSO01	B04	SO1C -	05	U5	U10	U10	U10	50	U10		U100	U100
17110019-BL-000-	URSO01	B07	SO1C -										
17110019-BL-000-	URSO01	B07	SO1C -		U5	U10	U10	U10	U25	U10		U100	U100
17110019-BL-000-	URSO01	B09	SO5C -										
17110019-BL-000-	URSO01	B09	SO5C -		U10	U20	U20	U20	U50	U20		U100	U200
17110019-BL-000-	URSO01	B10	SO5C -	01	U1	U2	U2	U1	U1	U2	U60	U30	U6
17110019-BL-000-	URSO01	B10	SO5C -	02	U1	U1	U1	U1	U1	U1	U60	U30	U20
17110019-BL-000-	URSO01	B11	SO1C -	02									
17110019-BL-000-	URSO01	B11	SO1C -	01	U3	U6	U2	U2	U3	U6	U190	U100	U1900
17110019-BL-000-	URSO01	B12	SO5C -		U1	U2	U1	U1	U2	U2	U90	U40	U9
17110019-BL-000-	URSO01	B14	SO1C -		U2	U2	U1	U1	U1	U3	U90	U40	U23
17110019-BL-000-	URSO01	B15	SO5C -		U3	U4	U1	U1	U1	U5	U100	U50	U22
17110019-BL-000-	URSO01	B17	SO1C -	01	U1	U5	U2	U1	U1	U2	U130	U70	U1300
17110019-BL-000-	URSO01	B17	SO1C -	02	U1	U1	U1	U1	U1	U1	U60	U1	U13
17110019-BL-000-	URSO01	B18	SO1C -		U2	U3	U1	U1	U2	U4	U80	U40	U80

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
LOW MOLECULAR WEIGHT AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	2-methyl naphth-alene	naphtha-lene	acenaph-thylene	acenaph-thene	fluorene	phenan-threne	anthra-cene
17110019-BL-000-	URS001	B02	S01C -								
17110019-BL-000-	URS001	B02	S01C -		75	Z590	20	13	20	78	33
17110019-BL-000-	URS001	B03	S05C -		50	200	15	44	63	330	130
17110019-BL-000-	URS001	B04	S01C -	01	67	680	13	140	150	540	260
17110019-BL-000-	URS001	B04	S01C -	02	110	45	20	220	190	690	310
17110019-BL-000-	URS001	B04	S01C -	03	100	710	35	310	320	1400	720
17110019-BL-000-	URS001	B04	S01C -	04	240	Z970	70	230	210	440	230
17110019-BL-000-	URS001	B04	S01C -	05	180	Z570	80	240	230	430	260
17110019-BL-000-	URS001	B07	S01C -								
17110019-BL-000-	URS001	B07	S01C -		100	B5	40	52	84	290	120
17110019-BL-000-	URS001	B09	S05C -		100						
17110019-BL-000-	URS001	B09	S05C -			85	40	86	140	280	84
17110019-BL-000-	URS001	B10	S05C -	01	46	81	5.9	10	16	110	18
17110019-BL-000-	URS001	B10	S05C -	02	51	80	6.0	11	17	120	22
17110019-BL-000-	URS001	B11	S01C -	02							
17110019-BL-000-	URS001	B11	S01C -	01	27	79	11	14	22	150	65
17110019-BL-000-	URS001	B12	S05C -		24	110	7.8	19	27	170	48
17110019-BL-000-	URS001	B14	S01C -		65	310	17	76	92	430	130
17110019-BL-000-	URS001	B15	S05C -		44	210	14	93	120	570	290
17110019-BL-000-	URS001	B17	S01C -	01	27	66	2.0	14	15	97	28
17110019-BL-000-	URS001	B17	S01C -	02	34	62	11	12	16	82	30
17110019-BL-000-	URS001	B18	S01C -		48	370	5.0	140	110	350	95

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	fluor-anthene	pyrene	benzo(a) anthra-cene	chrysene	benzo(b) fluor-anthene	benzo(k) fluor-anthene	benzo(a) pyrene	indeno-(1,2,3-cd) pyrene
17110019-BL-000-	URS001	B02	S01C -									
17110019-BL-000-	URS001	B02	S01C -		210	220	82	160	C	C	120	55
17110019-BL-000-	URS001	B03	S05C -		480	470	160	400	C	C	140	120
17110019-BL-000-	URS001	B04	S01C -	01	1400	1100	680	680	630	580	540	310
17110019-BL-000-	URS001	B04	S01C -	02	1900	1700	710	1300	C	C	570	330
17110019-BL-000-	URS001	B04	S01C -	03	2900	2100	880	1600	C	C	750	510
17110019-BL-000-	URS001	B04	S01C -	04	2200	1600	810	980	C	C	850	280
17110019-BL-000-	URS001	B04	S01C -	05	2300	1800	750	1100	C	C	860	390
17110019-BL-000-	URS001	B07	S01C -									
17110019-BL-000-	URS001	B07	S01C -		670	580	230	410	C	C	360	130
17110019-BL-000-	URS001	B09	S05C -									
17110019-BL-000-	URS001	B09	S05C -		910	640	310	350	C	C	360	150
17110019-BL-000-	URS001	B10	S05C -	01	120	110	41	81	C	C	45	U1
17110019-BL-000-	URS001	B10	S05C -	02	120	110	42	92	C	C	49	29
17110019-BL-000-	URS001	B11	S01C -	02								
17110019-BL-000-	URS001	B11	S01C -	01	250	240	110	300	C	C	120	86
17110019-BL-000-	URS001	B12	S05C -		320	260	110	260	C	C	130	58
17110019-BL-000-	URS001	B14	S01C -		670	550	220	430	C	C	210	130
17110019-BL-000-	URS001	B15	S05C -		1100	730	340	720	380	300	250	150
17110019-BL-000-	URS001	B17	S01C -	01	160	150	70	130	C	C	73	55
17110019-BL-000-	URS001	B17	S01C -	02	140	130	62	110	87	72	69	48
17110019-BL-000-	URS001	B18	S01C -		470	310	140	190	C	C	110	52

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
HIGH MOLECULAR WEIGHT PAH

Drainage	Survey	Station	Sample	Rep	dibenzo-(a,h)anthracene	benzo-(ghi)perylene	total benzofluoranthenes
17110019-BL-000-	URS001	B02	S01C -				
17110019-BL-000-	URS001	B02	S01C -		16	57	240
17110019-BL-000-	URS001	B03	S05C -		45	110	550
17110019-BL-000-	URS001	B04	S01C -	01	130	310	
17110019-BL-000-	URS001	B04	S01C -	02	120	320	1700
17110019-BL-000-	URS001	B04	S01C -	03	160	470	2400
17110019-BL-000-	URS001	B04	S01C -	04	93	250	1300
17110019-BL-000-	URS001	B04	S01C -	05	110	320	1400
17110019-BL-000-	URS001	B07	S01C -				
17110019-BL-000-	URS001	B07	S01C -		32	130	500
17110019-BL-000-	URS001	B09	S05C -				
17110019-BL-000-	URS001	B09	S05C -		56	140	490
17110019-BL-000-	URS001	B10	S05C -	01	U1	25	110
17110019-BL-000-	URS001	B10	S05C -	02	14	26	110
17110019-BL-000-	URS001	B11	S01C -	02			
17110019-BL-000-	URS001	B11	S01C -	01	40	83	490
17110019-BL-000-	URS001	B12	S05C -		U1	U1	330
17110019-BL-000-	URS001	B14	S01C -		44	120	640
17110019-BL-000-	URS001	B15	S05C -		50	130	
17110019-BL-000-	URS001	B17	S01C -	01	19	23	730
17110019-BL-000-	URS001	B17	S01C -	02	6.6	41	
17110019-BL-000-	URS001	B18	S01C -		9.8	45	260

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
CHLORINATED AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	1,3-di-chloro-benzene	1,4-di-chloro-benzene	1,2-di-chloro-benzene	1,2,4-tri-chloro-benzene	2-chloro-naph-thalene	hexa-chloro-benzene
17110019-BL-000-	URS001	B02	S01C -							
17110019-BL-000-	URS001	B02	S01C -		U10	U10	U10	U5	U5	U10
17110019-BL-000-	URS001	B03	S05C -		25	21	50	U1	U1	U1
17110019-BL-000-	URS001	B04	S01C -	01	U1	21	U1	U1	U1	U1
17110019-BL-000-	URS001	B04	S01C -	02	U2	32	U1	U1	U1	U1
17110019-BL-000-	URS001	B04	S01C -	03	U1	25	U1	U1	U1	U30
17110019-BL-000-	URS001	B04	S01C -	04	130	110	U5	U5	U5	U10
17110019-BL-000-	URS001	B04	S01C -	05	170	63	U5	U5	U5	U10
17110019-BL-000-	URS001	B07	S01C -							
17110019-BL-000-	URS001	B07	S01C -		U5	U5	U5	U5	U5	U10
17110019-BL-000-	URS001	B09	S05C -							
17110019-BL-000-	URS001	B09	S05C -		U5	U5	U5	U5	U5	U10
17110019-BL-000-	URS001	B10	S05C -	01	U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B10	S05C -	02	U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B11	S01C -	02						
17110019-BL-000-	URS001	B11	S01C -	01	U2	U2	U2	U2	U1	U1
17110019-BL-000-	URS001	B12	S05C -		U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B14	S01C -		U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B15	S05C -		U1	U1	U1	U2	U1	U1
17110019-BL-000-	URS001	B17	S01C -	01	U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B17	S01C -	02	U1	U1	U1	U1	U1	U1
17110019-BL-000-	URS001	B18	S01C -		U1	U1	U1	U1	U1	U1

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
CHLORINATED ALIPHATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	hexa-chloro-ethane	hexa-chloro-buta-diene	hexa-chloro-cyclo-penta-diene
17110019-BL-000-	URS001	B02	S01C -				
17110019-BL-000-	URS001	B02	S01C -		U50	U25	
17110019-BL-000-	URS001	B03	S05C -		U4	U2	
17110019-BL-000-	URS001	B04	S01C -	01	U5	U2	
17110019-BL-000-	URS001	B04	S01C -	02	U80	U4	
17110019-BL-000-	URS001	B04	S01C -	03	U6	U3	
17110019-BL-000-	URS001	B04	S01C -	04	U50	U25	
17110019-BL-000-	URS001	B04	S01C -	05	U50	U25	
17110019-BL-000-	URS001	B07	S01C -				
17110019-BL-000-	URS001	B07	S01C -		U50	U25	
17110019-BL-000-	URS001	B09	S05C -				
17110019-BL-000-	URS001	B09	S05C -		U50	U25	
17110019-BL-000-	URS001	B10	S05C -	01	U20	U2	
17110019-BL-000-	URS001	B10	S05C -	02	U20	U1	
17110019-BL-000-	URS001	B11	S01C -	02			
17110019-BL-000-	URS001	B11	S01C -	01	U80	U6	
17110019-BL-000-	URS001	B12	S05C -		U4	U2	
17110019-BL-000-	URS001	B14	S01C -		U30	U3	
17110019-BL-000-	URS001	B15	S05C -		U40	U4	
17110019-BL-000-	URS001	B17	S01C -	01	U5	U2	
17110019-BL-000-	URS001	B17	S01C -	02	U25	U1	
17110019-BL-000-	URS001	B18	S01C -		U30	U3	

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
PHTHALATES

Drainage	Survey	Station	Sample	Rep	dimethyl phthalate	diethyl phthalate	di-n-butyl phthalate	butyl benzyl phthalate	bis(2-ethyl-hexyl)-phthalate	di-n-octyl phthalate
17110019-BL-000-	URS001	B02	S01C -							
17110019-BL-000-	URS001	B02	S01C -		B50	U10	Z67	73	Z380	U25
17110019-BL-000-	URS001	B03	S05C -		24	Z73	Z30	Z46	Z1300	Z17
17110019-BL-000-	URS001	B04	S01C -	01	29	U1	Z170	Z19	Z580	U1
17110019-BL-000-	URS001	B04	S01C -	02	48	U1	Z430	Z42	Z370	Z22
17110019-BL-000-	URS001	B04	S01C -	03	23	U1	Z260	Z420	Z1300	U1
17110019-BL-000-	URS001	B04	S01C -	04	B50	U10	Z34	61	Z760	U25
17110019-BL-000-	URS001	B04	S01C -	05	Z47	U10	Z64	81	1200	U25
17110019-BL-000-	URS001	B07	S01C -							
17110019-BL-000-	URS001	B07	S01C -		B50	U10	U10	26	Z230	U25
17110019-BL-000-	URS001	B09	S05C -							
17110019-BL-000-	URS001	B09	S05C -		Z160	U10	Z1300	U25	Z180	420
17110019-BL-000-	URS001	B10	S05C -	01	U1	U1	B1	Z22	Z110	Z7
17110019-BL-000-	URS001	B10	S05C -	02	U1	1.9	Z40	Z60	Z80	Z5
17110019-BL-000-	URS001	B11	S01C -	02						
17110019-BL-000-	URS001	B11	S01C -	01	9.7	8.8	B1	Z160	Z600	Z10
17110019-BL-000-	URS001	B12	S05C -		15	4.7	Z260	Z50	Z330	Z6
17110019-BL-000-	URS001	B14	S01C -		40	4.8	U1	Z17	Z260	Z10
17110019-BL-000-	URS001	B15	S05C -		41	2.9	B1	Z14	Z240	260
17110019-BL-000-	URS001	B17	S01C -	01	U1	U1	Z60	B1	Z10	Z6
17110019-BL-000-	URS001	B17	S01C -	02	2.6	U1	B1	Z3	B1	U1
17110019-BL-000-	URS001	B18	S01C -		5.6	1.6	Z120	Z80	Z160	B1

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
MISCELLANEOUS OXYGENATED COMPOUNDS

Drainage	Survey	Station	Sample	Rep	benzyl alcohol	benzoic acid	dibenzo-furan
17110019-BL-000-	URS001	B02	S01C -		U10	U25	25
17110019-BL-000-	URS001	B03	S05C -				
17110019-BL-000-	URS001	B04	S01C -	01			
17110019-BL-000-	URS001	B04	S01C -	02			
17110019-BL-000-	URS001	B04	S01C -	03			
17110019-BL-000-	URS001	B04	S01C -	04	U10	U25	190
17110019-BL-000-	URS001	B04	S01C -	05	U10	U25	220
17110019-BL-000-	URS001	B07	S01C -		U10	U25	80
17110019-BL-000-	URS001	B09	S05C -		U10	U25	110
17110019-BL-000-	URS001	B10	S05C -	01			
17110019-BL-000-	URS001	B10	S05C -	02			
17110019-BL-000-	URS001	B11	S01C -	01			
17110019-BL-000-	URS001	B12	S05C -				
17110019-BL-000-	URS001	B14	S01C -				
17110019-BL-000-	URS001	B15	S05C -				
17110019-BL-000-	URS001	B17	S01C -	01			
17110019-BL-000-	URS001	B17	S01C -	02			
17110019-BL-000-	URS001	B18	S01C -				

Number of Observations: 18

BLAIN DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
ORGANONITROGEN COMPOUNDS

Drainage	Survey	Station	Sample	Rep	nitro-benzene	N-nitroso-dipropyl-amine	2,6-di-nitro-toluene	2,4-di-nitro-toluene	N-nitroso-diphenyl-amine	1,2-di-phenyl-hydra-zine	benzi-dine	3,3'-di-chloro-benzi-dine	N-nitroso-dimethyl amine
17110019-BL-000-	URS001	B02	S01C -										
17110019-BL-000-	URS001	B02	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	URS001	B03	S05C -		U1	U1	U1	U10	24	U1			
17110019-BL-000-	URS001	B04	S01C -	01	U1	U1	U2	U10	U1	U1			
17110019-BL-000-	URS001	B04	S01C -	02	U1	U2	U1	U2	46	U1			
17110019-BL-000-	URS001	B04	S01C -	03	U1	U1	U20	U1	37	U1			
17110019-BL-000-	URS001	B04	S01C -	04	U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	URS001	B04	S01C -	05	U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	URS001	B07	S01C -										
17110019-BL-000-	URS001	B07	S01C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	URS001	B09	S05C -										
17110019-BL-000-	URS001	B09	S05C -		U5	U10	U10	U5	U5	U5		U100	
17110019-BL-000-	URS001	B10	S05C -	01	U1	U1	U1	U1	6.7	U1			
17110019-BL-000-	URS001	B10	S05C -	02	U1	U1	U1	U1	U1	6.1			
17110019-BL-000-	URS001	B11	S01C -	02									
17110019-BL-000-	URS001	B11	S01C -	01	U2	U2	U1	U1	9.9	U1			
17110019-BL-000-	URS001	B12	S05C -		U1	13	U1	U1	13	U1			
17110019-BL-000-	URS001	B14	S01C -		U1	U1	U1	U1	15	U1			
17110019-BL-000-	URS001	B15	S05C -		U1	U1	U1	U1	20	U1			
17110019-BL-000-	URS001	B17	S01C -	01	U1	U1	U1	U1	U1	U1			
17110019-BL-000-	URS001	B17	S01C -	02	U1	4.5	U1	U1	3.9	U1			
17110019-BL-000-	URS001	B18	S01C -		U1	U1	U1	U1	5.0	U1			

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
PESTICIDES I

Drainage	Survey	Station	Sample	Rep	4,4'-DDE	4,4'-DDD	4,4'-DDT	aldrin	dieldrin	a-HCH	b-HCH	d-HCH	g-HCH
17110019-BL-000-	URS001	B02	S01C -										
17110019-BL-000-	URS001	B02	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	URS001	B03	S05C -		U0.02	U0.05	1.3	U0.02	U0.02	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B04	S01C -	01	0.27	U0.04	2.2	U0.01	U0.01	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B04	S01C -	02	0.55	3.1	7.1	U0.01	U0.01	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B04	S01C -	03	1.7	0.8	2.5	U0.01	U0.01	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B04	S01C -	04	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	URS001	B04	S01C -	05	U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	URS001	B07	S01C -										
17110019-BL-000-	URS001	B07	S01C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	URS001	B09	S05C -										
17110019-BL-000-	URS001	B09	S05C -		U50	U50	U50	U50	U50	U50	U50	U50	U50
17110019-BL-000-	URS001	B10	S05C -	01	U0.01	U0.04	U0.04	U0.01	U0.01	U0.01	U0.04	U0.03	U0.02
17110019-BL-000-	URS001	B10	S05C -	02	U0.01	U0.04	1.6	U0.01	U0.01	U0.01	U0.04	U0.03	U0.02
17110019-BL-000-	URS001	B11	S01C -	02									
17110019-BL-000-	URS001	B11	S01C -	01	U0.02	U0.04	U0.05	U0.01	U0.01	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B12	S05C -		U0.01	U0.04	1.4	U0.01	U0.01	U0.01	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B14	S01C -		U0.02	U0.04	3.0	U0.01	U0.01	U0.02	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B15	S05C -		0.73	1.7	5.8	0.44	U0.01	U0.01	U0.05	U0.03	U0.02
17110019-BL-000-	URS001	B17	S01C -	01	U0.01	U0.03	1.2	U0.01	U0.01	U0.01	U0.03	U0.02	U0.01
17110019-BL-000-	URS001	B17	S01C -	02	U0.01	U0.03	U0.03	U0.01	U0.01	U0.01	U0.03	U0.02	U0.01
17110019-BL-000-	URS001	B18	S01C -		0.12	1.3	15	U0.01	U0.01	U0.01	U0.03	U0.02	U0.01

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
PCBS

Drainage	Survey	Station	Sample	Rep	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCBs
17110019-BL-000-	URS001	B02	S01C -									
17110019-BL-000-	URS001	B02	S01C -							C		7.0
17110019-BL-000-	URS001	B03	S05C -		U22	U22	U22	U22	U22	U22	U22	
17110019-BL-000-	URS001	B04	S01C -	01	U20	U20	47	U20	46	U20	U20	
17110019-BL-000-	URS001	B04	S01C -	02	U20	U20	U20	U20	69	U20	U20	
17110019-BL-000-	URS001	B04	S01C -	03	U20	U20	U20	U20	210	U20	U20	
17110019-BL-000-	URS001	B04	S01C -	04					84	19		
17110019-BL-000-	URS001	B04	S01C -	05					60	16		
17110019-BL-000-	URS001	B07	S01C -									
17110019-BL-000-	URS001	B07	S01C -							C		11
17110019-BL-000-	URS001	B09	S05C -									
17110019-BL-000-	URS001	B09	S05C -									U5
17110019-BL-000-	URS001	B10	S05C -	01	U17	U17	U17	U17	U17	U17	U17	
17110019-BL-000-	URS001	B10	S05C -	02	U17	U17	U17	U17	U17	U17	U17	
17110019-BL-000-	URS001	B11	S01C -	02								
17110019-BL-000-	URS001	B11	S01C -	01	U21	U21	14	U21	U21	U21	U21	
17110019-BL-000-	URS001	B12	S05C -		U19	U19	U19	U19	U19	U19	U19	
17110019-BL-000-	URS001	B14	S01C -		U20	U20	U20	U20	26	U20	U20	
17110019-BL-000-	URS001	B15	S05C -		U18	U18	U18	U18	36	U18	U18	
17110019-BL-000-	URS001	B17	S01C -	01	U14	U14	U14	U14	U14	U14	U14	
17110019-BL-000-	URS001	B17	S01C -	02	U14	U14	U14	U14	8.2	U14	U14	
17110019-BL-000-	URS001	B18	S01C -		U14	U14	U14	U14	U14	U14	U14	

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE HALOGENATED ALKENES

Drainage	Survey	Station	Sample	Rep	vinyl chloride	1,1-di-chloro-ethene	1,2-trans-dichloro ethylene	cis-1,3-di-chloro-propene	trans-1,3-di-chloro-propene	tri-chloro-ethene	tetra-chloro-ethene
17110019-BL-000-	URS001	B02	S01C -		U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B02	S01C -								
17110019-BL-000-	URS001	B03	S05C -		U5	B5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	01	U5	B5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	02	U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	03	U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	04							
17110019-BL-000-	URS001	B04	S01C -	05							
17110019-BL-000-	URS001	B07	S01C -		U5	U5	U5	U5	U5	U5	U5
17110019-BL-000-	URS001	B07	S01C -								
17110019-BL-000-	URS001	B09	S05C -		U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B09	S05C -								
17110019-BL-000-	URS001	B10	S05C -	01	U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B10	S05C -	02							
17110019-BL-000-	URS001	B11	S01C -	02	U5	B5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B11	S01C -	01	U5	B5	Z1.1	U5	U5	U5	U5
17110019-BL-000-	URS001	B12	S05C -		U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B14	S01C -		U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B15	S05C -		U5	U5	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B17	S01C -	01	U5	Z0.50	B5	U5	U5	U5	U5
17110019-BL-000-	URS001	B17	S01C -	02							
17110019-BL-000-	URS001	B18	S01C -		U5	U5	B5	U5	U5	U5	U5

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT ORGANIC CHEMICALS - Values in ppb dry weight
VOLATILE AROMATIC HYDROCARBONS

Drainage	Survey	Station	Sample	Rep	benzene	toluene	ethyl-benzene
17110019-BL-000-	URS001	B02	S01C -		B5	U5	U5
17110019-BL-000-	URS001	B02	S01C -				
17110019-BL-000-	URS001	B03	S05C -		B5	Z0.19	0.08
17110019-BL-000-	URS001	B04	S01C -	01	Z1.6	Z0.36	U5
17110019-BL-000-	URS001	B04	S01C -	02	B5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	03	U5	U5	U5
17110019-BL-000-	URS001	B04	S01C -	04			
17110019-BL-000-	URS001	B04	S01C -	05			
17110019-BL-000-	URS001	B07	S01C -		Z0.35	U5	U5
17110019-BL-000-	URS001	B07	S01C -				
17110019-BL-000-	URS001	B09	S05C -		B5	B5	U5
17110019-BL-000-	URS001	B09	S05C -				
17110019-BL-000-	URS001	B10	S05C -	01	B5	U5	U5
17110019-BL-000-	URS001	B10	S05C -	02			
17110019-BL-000-	URS001	B11	S01C -	02	Z0.15	U5	U5
17110019-BL-000-	URS001	B11	S01C -	01	B5	U5	U5
17110019-BL-000-	URS001	B12	S05C -		B5	U5	U5
17110019-BL-000-	URS001	B14	S01C -		B5	Z0.35	U5
17110019-BL-000-	URS001	B15	S05C -		U5	U5	U5
17110019-BL-000-	URS001	B17	S01C -	01	Z3.2	U5	U5
17110019-BL-000-	URS001	B17	S01C -	02			
17110019-BL-000-	URS001	B18	S01C -		B5	B5	U5

Number of Observations: 22

BLAIR DREDGING PROJECT SURFACE SEDIMENT TENTATIVELY IDENTIFIED ORGANIC CHEMICALS - Values in ppb dry weight

Drainage	Survey	Station	Sample	Rep	1-methyl-2-(1-methyl-ethyl) benzene	2-methoxy phenol	penta-chloro-cyclo-pentane	1-methyl naphth-alene	1,1' biphenyl	2,6-di-methyl naphth-alene
17110019-BL-000-	URS001	B02	S01C -							
17110019-BL-000-	URS001	B03	S05C -					68		64
17110019-BL-000-	URS001	B04	S01C -	01				23		77
17110019-BL-000-	URS001	B04	S01C -	02				130		130
17110019-BL-000-	URS001	B04	S01C -	03				140		94
17110019-BL-000-	URS001	B04	S01C -	04						
17110019-BL-000-	URS001	B04	S01C -	05						
17110019-BL-000-	URS001	B07	S01C -							
17110019-BL-000-	URS001	B09	S05C -							
17110019-BL-000-	URS001	B10	S05C -	01				53		69
17110019-BL-000-	URS001	B10	S05C -	02				58		66
17110019-BL-000-	URS001	B11	S01C -	01				30		33
17110019-BL-000-	URS001	B12	S05C -					6.9		16
17110019-BL-000-	URS001	B14	S01C -					88		78
17110019-BL-000-	URS001	B15	S05C -					80		76
17110019-BL-000-	URS001	B17	S01C -	01				32		8.8
17110019-BL-000-	URS001	B17	S01C -	02				35		45
17110019-BL-000-	URS001	B18	S01C -					17		42

Number of Observations: 18

BLAIR DREDGING PROJECT SURFACE SEDIMENT TENTATIVELY IDENTIFIED ORGANIC CHEMICALS - Values in ppb dry weight

Drainage	Survey	Station	Sample		2,3,5-trimethyl naphthalene	dibenzothiophene	2-methyl phenanthrene	1-methyl phenanthrene	9-hexadecenoic acid	isopimaradiene
17110019-BL-000-	URS001	B02	S01C -							
17110019-BL-000-	URS001	B03	S05C -		23	32		82		
17110019-BL-000-	URS001	B04	S01C -	01	50	60		47		
17110019-BL-000-	URS001	B04	S01C -	02	62	85		76		
17110019-BL-000-	URS001	B04	S01C -	03	50	120		90		
17110019-BL-000-	URS001	B04	S01C -	04						
17110019-BL-000-	URS001	B04	S01C -	05						
17110019-BL-000-	URS001	B07	S01C -							
17110019-BL-000-	URS001	B09	S05C -							
17110019-BL-000-	URS001	B10	S05C -	01	29	8.5		60		
17110019-BL-000-	URS001	B10	S05C -	02	42	U1		36		
17110019-BL-000-	URS001	B11	S01C -	01	29	11		48		
17110019-BL-000-	URS001	B12	S05C -		18	15		23		
17110019-BL-000-	URS001	B14	S01C -		66	37		16		
17110019-BL-000-	URS001	B15	S05C -		56	49		69		
17110019-BL-000-	URS001	B17	S01C -	01	16	40		14		
17110019-BL-000-	URS001	B17	S01C -	02	31	9.7		34		
17110019-BL-000-	URS001	B18	S01C -		24	38		42		

Number of Observations: 18

BLAIR DREDGING PROJECT SURFACE SEDIMENTS INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium
17110019-BL-000-	URS001	B02	S01C -		0.1	38	23.1	0.14	0.18	18.9
17110019-BL-000-	URS001	B03	S05C -		0.5	49	25.1	0.15	0.44	20.0
17110019-BL-000-	URS001	B04	S01C -	01	0.7	53	22.4	0.12	0.50	18.0
17110019-BL-000-	URS001	B04	S01C -	02	0.7	52	23.0	0.13	0.60	19.6
17110019-BL-000-	URS001	B04	S01C -	03	0.7	53	23.5	0.15	0.51	18.6
17110019-BL-000-	URS001	B07	S01C -		0.4	35	24.1	0.11	0.17	18.5
17110019-BL-000-	URS001	B09	S05C -		0.3	15	14.5	0.08	U0.10	11.1
17110019-BL-000-	URS001	B10	S05C -		0.3	25	25.2	0.14	U0.10	13.0
17110019-BL-000-	URS001	B11	S01C -		0.5	48	21.5	0.13	0.30	18.2
17110019-BL-000-	URS001	B12	S05C -		0.5	44	22.6	0.14	0.27	17.5
17110019-BL-000-	URS001	B14	S01C -		0.4	39	28.1	0.15	0.28	18.7
17110019-BL-000-	URS001	B15	S05C -		0.8	46	29.0	0.13	0.50	18.4
17110019-BL-000-	URS001	B17	S01C -		0.3	16	16.1	U0.05	U0.10	10.4
17110019-BL-000-	URS001	B18	S01C -		0.3	9.5	10.9	U0.05	U0.10	11.2

Number of Observations: 14

BLAIR DREDGING PROJECT SURFACE SEDIMENTS INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Copper	Iron	Lead	Manganese	Nickel	Selenium
17110019-BL-000-	URS001	B02	S01C -		52.9	20700	31.9	114	13.6	U0.05
17110019-BL-000-	URS001	B03	S05C -		75.7	20400	46.0	110	12.5	U0.05
17110019-BL-000-	URS001	B04	S01C -	01	62.8	19800	49.4	111	12.3	U0.05
17110019-BL-000-	URS001	B04	S01C -	02	62.5	19600	52.2	112	12.3	U0.05
17110019-BL-000-	URS001	B04	S01C -	03	66.0	20500	52.4	115	12.7	U0.05
17110019-BL-000-	URS001	B07	S01C -		60.6	19800	36.7	135	12.5	U0.05
17110019-BL-000-	URS001	B09	S05C -		25.8	12000	15.5	87.4	9.0	U0.05
17110019-BL-000-	URS001	B10	S05C -		31.7	15800	18.1	125	11.0	U0.05
17110019-BL-000-	URS001	B11	S01C -		55.5	22000	38.0	108	12.4	U0.05
17110019-BL-000-	URS001	B12	S05C -		53.2	19600	31.3	103	12.2	U0.05
17110019-BL-000-	URS001	B14	S01C -		68.0	21800	43.0	142	12.7	U0.05
17110019-BL-000-	URS001	B15	S05C -		11.0	20200	59.0	138	12.1	U0.05
17110019-BL-000-	URS001	B17	S01C -		23.6	11600	12.6	83.7	8.4	U0.05
17110019-BL-000-	URS001	B18	S01C -		15.2	9620	8.1	75.7	8.5	U0.05

Number of Observations: 14

BLAIR DREDGING PROJECT SURFACE SEDIMENTS INORGANIC CHEMICALS - Values in ppm dry weight

Drainage	Survey	Station	Sample	Rep	Silver	Thallium	Zinc	Cyanide	Cobalt	Mercury
17110019-BL-000-	URS001	B02	S01C -		0.14	U0.1	79.7			0.15
17110019-BL-000-	URS001	B03	S05C -		0.32	U0.1	91.2			0.22
17110019-BL-000-	URS001	B04	S01C -	01	0.27	U0.1	89.3			0.23
17110019-BL-000-	URS001	B04	S01C -	02	0.28	U0.1	90.6			0.15
17110019-BL-000-	URS001	B04	S01C -	03	0.27	U0.1	90.8			0.14
17110019-BL-000-	URS001	B07	S01C -		0.26	U0.1	72.3			0.21
17110019-BL-000-	URS001	B09	S05C -		0.08	U0.1	37.6			0.08
17110019-BL-000-	URS001	B10	S05C -		0.16	U0.1	40.3			0.13
17110019-BL-000-	URS001	B11	S01C -		0.19	U0.1	87.8			0.19
17110019-BL-000-	URS001	B12	S05C -		0.18	U0.1	73.9			0.12
17110019-BL-000-	URS001	B14	S01C -		0.27	U0.1	91.0			0.22
17110019-BL-000-	URS001	B15	S05C -		0.22	U0.1	118.3			0.22
17110019-BL-000-	URS001	B17	S01C -		0.08	U0.1	33.3			0.28
17110019-BL-000-	URS001	B18	S01C -		0.05	U0.1	26.6			U0.04

Number of Observations: 14

BLAIR DREDGING PROJECT SURFACE SEDIMENT GRAIN SIZE

Drainage	Survey	Station	Sample	Rep	% Rocks	% Sand	% Silt	% Clay
17110019-BL-000-	URS001	B02	S01C -		0.606	18.025	61.001	20.367
17110019-BL-000-	URS001	B03	S05C -		1.316	15.900	63.552	19.232
17110019-BL-000-	URS001	B04	S01C -		0.397	29.892	53.739	15.972
17110019-BL-000-	URS001	B07	S01C -		0.212	11.992	70.239	17.557
17110019-BL-000-	URS001	B09	S05C -		0.032	61.591	32.398	5.979
17110019-BL-000-	URS001	B10	S05C -		0.008	27.553	61.803	10.636
17110019-BL-000-	URS001	B11	S01C -		0.372	29.980	48.970	20.678
17110019-BL-000-	URS001	B12	S05C -		0.219	18.997	61.325	19.459
17110019-BL-000-	URS001	B14	S01C -		0.356	8.964	70.387	20.293
17110019-BL-000-	URS001	B15	S05C -		0.014	28.714	54.846	16.427
17110019-BL-000-	URS001	B17	S01C -		0.196	67.464	27.815	4.525
17110019-BL-000-	URS001	B18	S01C -		0.192	75.608	21.189	3.010

Number of Observations: 12

BLAIR DREDGING PROJECT SURFACE SEDIMENT CONVENTIONALS

Drainage	Survey	Station	Sample	Rep	Total Solids %	Total Volatile Solids %	Total Organic Carbon %	Carbon-ate %	Hydrogen %	Nitrogen %
17110019-BL-000-	URS001	B02	S01C -		52.1	4.04	1.23			0.065
17110019-BL-000-	URS001	B03	S05C -		46.0	5.66	2.18			0.104
17110019-BL-000-	URS001	B04	S01C -	01	51.1	5.02	1.70			0.079
17110019-BL-000-	URS001	B04	S01C -	02	51.4	4.54	1.69			0.077
17110019-BL-000-	URS001	B04	S01C -	03	51.1	4.64	1.63			0.095
17110019-BL-000-	URS001	B07	S01C -		51.6	4.19	1.49			0.083
17110019-BL-000-	URS001	B09	S05C -		66.3	2.14	0.73			0.031
17110019-BL-000-	URS001	B10	S05C -		58.5	3.90	1.32			0.069
17110019-BL-000-	URS001	B11	S01C -		48.4	4.82	1.72			0.085
17110019-BL-000-	URS001	B12	S05C -		53.6	3.97	1.41			0.082
17110019-BL-000-	URS001	B14	S01C -		49.5	4.53	1.69			0.083
17110019-BL-000-	URS001	B02	S01C -		52.1	4.04	1.23			0.065
17110019-BL-000-	URS001	B03	S05C -		46.0	5.66	2.18			0.104
17110019-BL-000-	URS001	B04	S01C -	01	51.1	5.02	1.70			0.079
17110019-BL-000-	URS001	B04	S01C -	02	51.4	4.54	1.69			0.077
17110019-BL-000-	URS001	B04	S01C -	03	51.1	4.64	1.63			0.095
17110019-BL-000-	URS001	B07	S01C -		51.6	4.19	1.49			0.083
17110019-BL-000-	URS001	B09	S05C -		66.3	2.14	0.73			0.031
17110019-BL-000-	URS001	B10	S05C -		58.5	3.90	1.32			0.069
17110019-BL-000-	URS001	B11	S01C -		48.4	4.82	1.72			0.085
17110019-BL-000-	URS001	B12	S05C -		53.6	3.97	1.41			0.082
17110019-BL-000-	URS001	B14	S01C -		49.5	4.53	1.69			0.083
17110019-BL-000-	URS001	B15	S05C -		54.6	4.91	1.48			0.202
17110019-BL-000-	URS001	B17	S01C -		80.0	1.91	0.70			0.136
17110019-BL-000-	URS001	B18	S01C -		72.8	1.29	0.29			0.006

Number of Observations: 14

a. Reference:
Tetra Tech, Inc. 1985. Commencement Bay nearshore tideflats remedial investigation. Final Report Prepared for Washington Department of Ecology and U.S. EPA by Tetra Tech, Inc. Bellevue, WA.

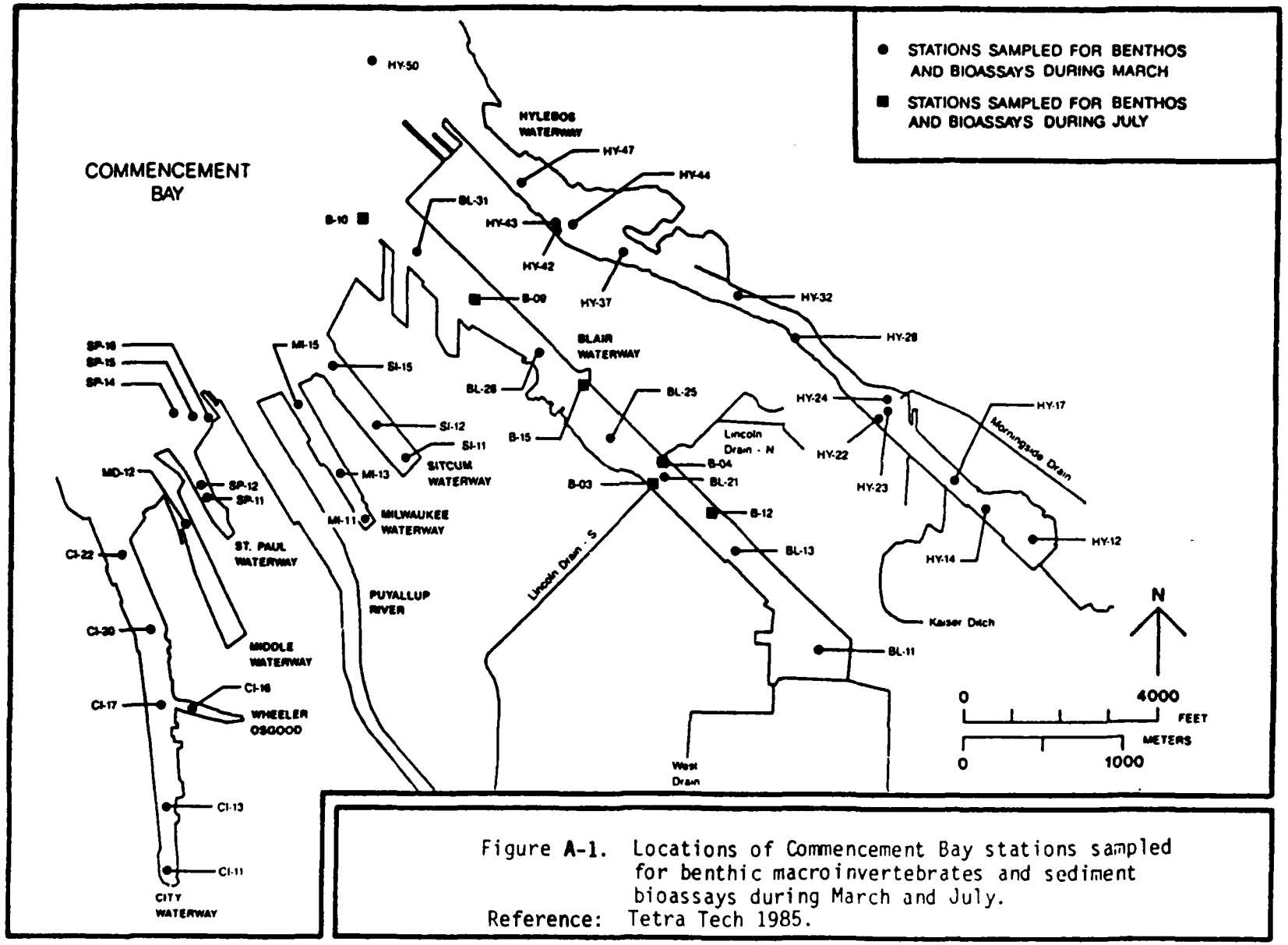


Figure A-1. Locations of Commencement Bay stations sampled for benthic macroinvertebrates and sediment bioassays during March and July.

Reference: Tetra Tech 1985.

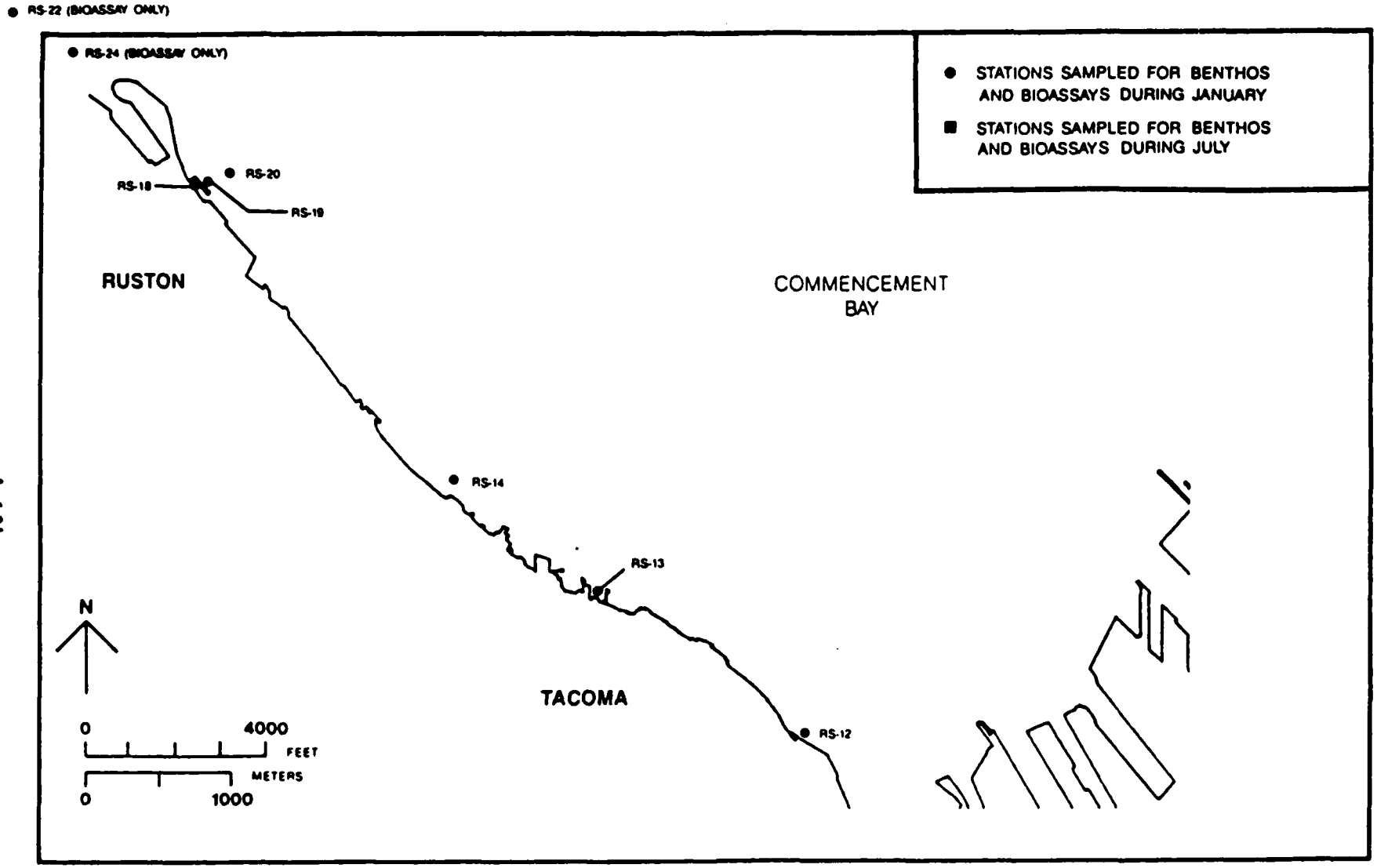


Figure A-1. (Continued).

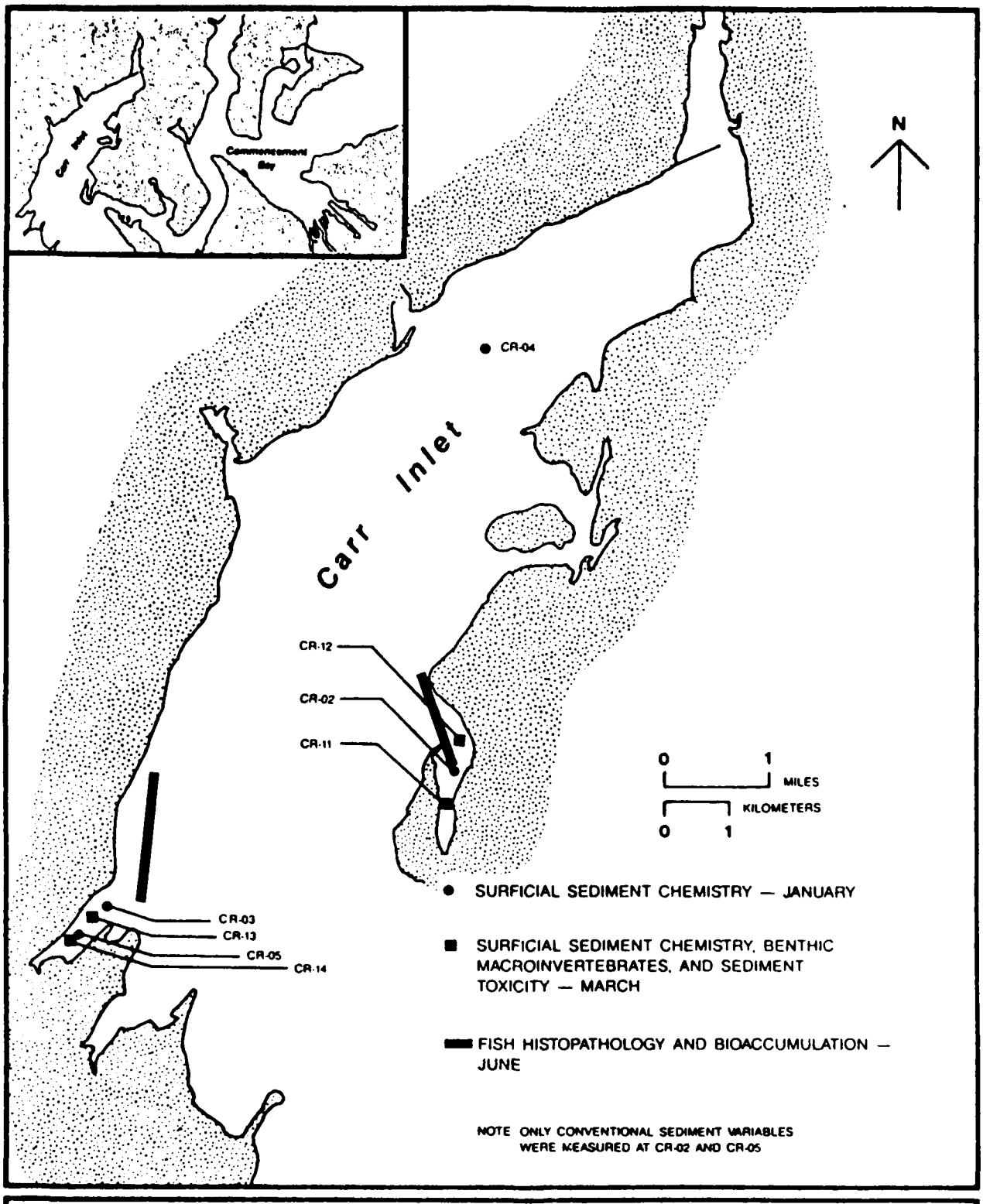


Figure A-2. Locations of reference stations sampled in Carr Inlet.

Reference: Tetra Tech 1985.

TABLE A 3 EIGHT BAY[a]

STATION#	total PCBs[b]	4,4' DDT	4,4' DDE	4,4' DDD	2,4,6-tri chloro phenol	2,4,-di-methyl phenol	penta-chloro phenol	phenol	acenaph-thene	1,2,4 tri-chloro-benzene	hexa-chloro benzene
3 SQ 14	U[c] 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 SQ-17	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 SQ-18	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 SQ-20	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 SC-06	1253	U 1	U 1	U 1	U 400	U 200	U1600	L[d] 200	U 200	U 200	U 800
3 SC-07	588	U 1	U 1	U 1	U 400	U 200	U1600	U 200	L 200	U 200	U 800
3 SC 08	646	U 1	U 1	U 1	U 400	U 200	U1600	220	U 200	U 200	U 800
3 SC-14	1672	U 1	U 1	U 1					U 200	U 200	U 800
3 SC-17	231	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U1000
3 SC-18	229	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 SC 19	U 60	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U1000
3 SC-20	384	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U1200	U 200	U1000
3 CS-01	U 20	U 1	U 1	U 1	U 500	U 250	U1500	560	U 100	U 200	U 800
3 CS 11	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 CS-15	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 CS-17	U 20	U 1	U 1	U 1	U 500	U 250	U1500	U 100	U 100	U 200	U 800
3 DB-01	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 DB-05	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 DB 07	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 DB-15	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 EB-09	330	U 1	U 1	U 1	U 400	U 200	U1200	U 80	U 80	U 160	U 800
3 EB-10	279	U 1	U 1	U 1	U 400	U 200	U1200	U 80	630	U 160	U 800
3 EB-12	78	U 1	U 1	U 1	U 400	U 200	U1200	U 80	U 80	U 160	U 800
3 EB-17	646	U 1	U 1	U 1	U 400	U 200	U1200	U 80	U 80	U 160	U 800
3 EB 20	640	U 1	U 1	U 1	U 200	U 100	U 800	U 100	U 100	U 100	U 400
3 EB 22	687	U 1	U 1	U 1	U 200	U 100	U 800	U 100	L 100	U 100	U 400
3 EB 23	148	U 1	U 1	U 1	U 200	U 100	U 800	U 100	U 100	U 100	U 400
3 EB 24	69	U 1	U 1	U 1	U 200	U 100	U 800	U 120	L 100	U 100	U 400
3 SM 01	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 SM-03	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 SM 07	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 SM-20	U 20	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 EV-01	445	U 1	U 1	U 1	U	U	U	250	370	U	U
3 EV-02	84	U 1	U 1	U 1	U	U	U	190	110	U	U
3 EV-03	516	U 1	U 1	U 1	U	U	U	U	280	U	U
3 EV 04	965	U 1	U 1	U 1	U	U	U	1400	3300	U	U
3 EV-05	394	U 1	U 1	U 1	U	U	U	U	240	U	U
3 EV-06	124	U 1	U 1	U 1	U	U	U	U	120	U	U
3 EV 07	155	U 1	U 1	U 1	U	U	U	U	480	U	U
3 EV 11	171	U 1	U 1	U 1	U	U	U	U	U	U	U
3 BH 03	74	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 BH 04	54	U 1	U 1	U 1	U 200	U 100	U 600	U 40	150	U 80	U 400
3 BH 05	27	U 1	U 1	U 1	U 200	U 100	U 600	U 40	U 40	U 80	U 400
3 BH 07	31	U 1	U 1	U 1	U 200	U 100	U 600	U 40	110	U 80	U 400
3 BH 11	54	U 1	U 1	U 1	U 100	U 50	U 300	U 20	L 20	U 40	U 200
3 BH 12	53	U 1	U 1	U 1	U 100	U 50	U 300	U 20	U 20	U 40	U 200
3 BH 23	U 20	U 1	U 1	U 1	U 100	U 50	U 300	U 20	U 20	U 40	U 200
3 BH 24	U 20	U 1	U 1	U 1	U 100	U 50	U 300	U 20	U 20	U 40	U 200

STATIONS	1,2 di chloro- benzene	1,3 di chloro- benzene	1,4 di chloro benzene	2,6 di nitro- toluene	1,2 di phenyl hydra zine	fluor- anthene	hexa chloro buta diene	hexa chloro cyclo penta diene	iso phorone	naphtha- lene	n nitro sodi phenyl amine	bis (2 ethyl hexyl) phtha late
3 SQ-14	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 SQ-17	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 SQ-18	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 SQ 20	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 SC-06	U 200	U 200	U 200	U 400	U 200	200	U 400	U1200	U 200	L 200	U2000	940
3 SC-07	U 200	U 200	U 200	U 400	U 200	1300	U 400	U1200	U 200	L 200	U2000	420
3 SC-08	U 200	U 200	U 200	U 400	U 200	490	U 400	U1200	U 200	L 200	U2000	380
3 SC-14	U 200	U 200	U 200	U 400	U 200	650	U 400	U1200	U 200	U 200	U2000	740
3 SC 17	U 200	U 200	U 200	U 500	U 250	520	U 400	U1500	U 100	U 100	U2500	U1100
3 SC 18	U 40	U 40	U 40	U 200	U 100	640	U 160	U 600	U 40	57	U1000	U 600
3 SC-19	U 200	U 200	U 200	U 500	U 250	200	U 400	U1500	U 100	U 100	U2500	U 100
3 SC 20	U 200	U 200	U 200	U 500	U 250	5200	U 400	U1500	U 100	1200	U2500	U 780
3 CS-01	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 CS-11	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 CS-15	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 CS-17	U 100	U 100	U 100	U 500	U 250	U 100	U 400	U1500	U 100	U 100	U2500	U 200
3 DB-01	U 40	U 40	U 40	U 200	U 100	U 40	U 160	U 600	U 40	U 40	U1000	U 120
3 DB-05	U 40	U 40	U 40	U 200	U 100	U 40	U 160	U 600	U 40	U 40	U1000	U 190
3 DB-07	U 40	U 40	U 40	U 200	U 100	U 40	U 160	U 600	U 40	U 40	U1000	U 310
3 DB-15	U 40	U 40	U 40	U 200	U 100	U 40	U 160	U 600	U 40	U 40	U1000	U 360
3 EB-09	U 80	U 80	U 80	U 400	U 200	610	U 320	U1200	U 80	U 80	U2000	310
3 EB-10	U 80	U 80	U 80	U 400	U 200	2300	U 320	U1200	U 80	420	U2000	U 80
3 EB-12	U 80	U 80	U 80	U 400	U 200	220	U 320	U1200	U 80	U 80	U2000	530
3 EB 17	U 80	U 80	U 80	U 400	U 200	U 50	U 320	U1200	U 80	U 80	U2000	U 80
3 EB-20	U 100	U 100	U 100	U 200	U 100	820	U 200	U 600	U 100	120	U1000	U 100
3 EB 22	U 100	U 100	U 100	U 200	U 100	370	U 200	U 600	U 100	100	U1000	210
3 EB-23	U 100	U 100	U 100	U 200	U 100	240	U 200	U 600	U 100	L 100	U1000	U 100
3 EB-24	U 100	U 100	U 100	U 200	U 100	190	U 200	U 600	U 100	L 100	U1000	L 100
3 SM 01	U 40	U 40	U 40	U 100	U 100	76	U 160	U 600	U 40	U 40	U1000	2800
3 SM 03	U 40	U 40	U 40	U 100	U 100	97	U 160	U 600	U 40	U 40	U1000	340
3 SM 07	U 40	U 40	U 40	U 100	U 100	68	U 160	U 600	U 40	U 40	U1000	180
3 SM 20	U 40	U 40	U 40	U 100	U 100	U 40	U 160	U 600	U 40	U 40	U1000	740
3 EV-01	U	U	U	U	U	4800	U	U	U	1300	U	U
3 EV-02	U	U	U	U	U	770	U	U	U	750	U	U
3 EV-03	U	U	U	U	U	830	U	U	U	1800	U	U
3 EV 04	U	U	U	U	U	4100	U	U	U	5900	U	U
3 EV-05	U	U	U	U	U	1800	U	U	U	590	U	830
3 EV 06	U	U	U	U	U	790	U	U	U	790	U	190
3 EV-07	U	U	U	U	U	1400	U	U	U	1400	U	290
3 EV 11	U	U	U	U	U	200	U	U	U	U	U	870
3 BH 03	U 40	U 40	U 40	U 100	U 100	710	U 160	U 600	U 40	220	U1000	390
3 BH 04	U 40	U 40	U 40	U 100	U 100	1400	U 160	U 600	U 40	370	U1000	290
3 BH 05	U 40	U 40	U 40	U 100	U 100	480	U 160	U 600	U 40	260	U1000	260
3 BH 07	U 40	U 40	U 40	U 100	U 100	1500	U 160	U 600	U 40	290	U1000	310
3 BH 11	U 20	U 20	U 20	U 100	U 50	550	U 80	U 300	U 20	91	U 500	U 70
3 BH 12	U 20	U 20	U 20	U 100	U 50	200	U 80	U 300	U 20	100	U 500	U 160
3 BH 23	U 20	U 20	U 20	U 100	U 50	200	U 80	U 300	U 20	95	U 500	U 200
3 BH 24	U 20	U 20	U 20	U 100	U 50	U 20	U 80	U 300	U 20	140	U 500	U 760

STATIONS	benzyl butyl phthalate	di n-butyl phthalate	di n-octyl phthalate	diethyl phthalate	dimethyl phthalate	benzo(a) anthracene	benzo(a) pyrene	total benzo fluoranthenes	chrysene	acenaphthylene	anthracene	benzo (ghi) perylene
3 SQ 14	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 SQ 17	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 SQ-18	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 SQ 20	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 SC 06	U 200	U 200	U 200	U 200	U 200	L 200	350	570	L 200	U 200	U 200	U 800
3 SC-07	U 200	U 200	U 200	U 200	U 200	1000	1100	1600	1000	U 200	580	L 800
3 SC-08	U 200	U 200	U 200	U 200	U 200	380	360	590	340	U 200	U 200	U 800
3 SC-14	U 200	U 200	U 200	U 200	U 200	490	480	980	510	U 200	U 200	U 800
3 SC-17	U 100	U 100	U 100	U 100	U 100	350	380	980	370	U 100	U 100	U 500
3 SC-18	U 40	U 40	U 40	U 40	U 40	550	220	630	450	U 40	200	U 200
3 SC-19	U 100	U 100	U 100	U 100	U 100	230	U 250	U 100	190	U 100	U 100	U 500
3 SC-20	U 100	U 100	U 100	U 100	U 100	1900	1100	1900	2000	U 100	U 100	1000
3 CS-01	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 CS-11	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 CS-15	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 CS-17	U 100	U 100	U 100	U 100	U 100	U 100	U 250	U 200	U 100	U 100	U 100	U 500
3 DB-01	U 40	U 40	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 DB-05	U 40	U 75	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 DB-07	U 40	U 40	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 DB-15	U 40	U 40	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 EB-09	U 80	U 80	U 80	U 80	U 80	350	U 200	490	370	U 80	U 80	U 400
3 EB-10	U 80	U 80	U 80	U 80	U 80	1400	1400	2200	1500	U 80	460	U 400
3 EB-12	U 80	U 80	U 80	U 80	U 80	U 80	U 200	U 80	U 80	U 80	U 80	U 400
3 EB-17	U 80	U 80	U 80	U 80	U 80	U 80	U 200	U 80	U 80	U 80	U 80	U 400
3 EB-20	U 100	U 100	U 100	U 100	U 100	690	U 100	700	560	U 100	180	U 400
3 EB-22	U 100	U 100	U 100	U 100	U 100	320	200	370	220	U 100	L 100	U 400
3 EB-23	U 100	U 100	U 100	U 100	U 100	U 100	U 100	U 100	U 100	U 100	U 100	U 400
3 EB-24	U 100	U 100	U 100	U 100	U 100	150	140	240	140	L 100	L 100	L 400
3 SM-01	U 40	U 40	69	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 SM 03	U 40	U 40	160	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 SM-07	U 40	U 40	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 SM-20	U 40	U 40	100	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 EV-01	U	U	U	U	U	810	250	620	650	U	700	U
3 EV-02	U	U	U	U	U	160	U	150	160	U	27	U
3 EV-03	U	U	60	U	U	U	U	U	210	U	110	U
3 EV-04	440	U	U	U	U	370	U	310	340	770	410	U
3 EV-05	U	U	U	U	U	910	U	1000	750	U	890	U
3 EV-06	U	U	U	U	U	U	U	U	U	U	U	U
3 EV-07	U	U	U	U	U	540	U	460	460	120	480	U
3 EV-11	U	U	U	U	U	U	U	U	U	U	U	U
3 BH-03	U 40	U 40	U 40	U 40	U 40	250	U 100	U 40	250	U 40	U 40	U 200
3 BH-04	U 40	U 40	U 40	U 40	U 40	430	U 100	U 40	540	U 40	110	U 200
3 BH-05	U 40	U 40	U 40	U 40	U 40	U 40	U 100	U 40	U 40	U 40	U 40	U 200
3 BH 07	U 40	U 40	590	U 40	U 40	700	U 100	770	820	U 40	280	U 200
3 BH 11	U 20	U 20	U 20	U 20	U 20	150	U 50	190	170	U 20	130	U 100
3 BH-12	U 20	U 20	U 20	U 20	U 20	80	U 50	U 20	93	U 20	38	U 100
3 BH 23	U 20	U 20	300	U 20	U 20	U 20	U 50	U 20	U 20	U 20	U 20	U 100
3 BH 24	U 20	U 20	U 20	U 20	U 20	U 20	U 50	U 20	U 20	U 20	U 20	U 100

STATION#	fluorene	phenanthrene	dibenzo (a,h)anthracene	indeno (1,2,3 cd) pyrene	pyrene	chloroform	ethylbenzene	tetrachloroethene	trichloroethylene	antimony	arsenic	beryllium
3 SQ-14	U 100	U 100	U 500	U 500	U 100	U 13	U 13	U 13	U 13	U 0.1	5.6	4.6
3 SQ-17	U 100	U 100	U 500	U 500	U 100	U 13	U 13	U 13	U 13	U 0.1	7.3	5.5
3 SQ-18	U 100	U 100	U 500	U 500	U 100	U 13	U 13	U 13	U 13	U 0.1	6.9	5.5
3 SQ-20	U 100	U 100	U 500	U 500	U 100	U 15	U 15	U 15	U 15	U 0.1	6.9	5.3
3 SC-06	U 200	150	U 800	U 800	580	U 12	U 12	U 12	U 12	0.2	9	0.31
3 SC-07	L 200	1200	U 800	L 800	1800	U 11	U 11	U 11	U 11	2.0	67	0.29
3 SC 08	U 200	L 200	U 800	U 800	570	U 14	U 14	U 14	U 14	U 0.1	14	0.34
3 SC-14	U 200	520	U 800	U 800	1000	U 16	U 16	U 16	U 16	0.2	14	0.31
3 SC-17	U 100	1200	U 500	U 500	620	U 14	U 14	U 14	U 14	1.4	39	4.8
3 SC-18	U 40	510	U 200	U 200	680	U 13	U 13	U 13	U 13	0.1	15	4.1
3 SC-19	U 100	110	U 500	U 500	330	U 10	U 10	U 10	U 10	2.0	25	3.6
3 SC-20	980	8900	U 500	640	6400	U 7.7	U 7.7	U 7.7	U 7.7	0.3	14	4.5
3 CS-01	U 100	U 100	U 500	U 500	U 100	U 14	U 14	U 14	U 14	U 0.1	8.2	3.7
3 CS-11	U 100	U 100	U 500	U 500	U 100	U 14	U 14	U 14	U 14	U 0.1	6.9	3.5
3 CS-15	U 100	U 100	U 500	U 500	U 100	U 17	U 17	U 17	U 17	U 0.1	6.5	4.7
3 CS-17	U 100	U 100	U 500	U 500	U 100	U 18	U 18	U 18	U 18	U 0.1	8.1	4.2
3 DB-01	U 40	U 40	U 200	U 200	U 40	U 7.2	U 7.2	U 7.2	U 7.2	U 0.1	1.9	3.9
3 DB-05	U 40	U 40	U 200	U 200	U 40	U 7.9	U 7.9	U 7.9	U 7.9	U 0.1	2.1	4.0
3 DB-07	U 40	U 40	U 200	U 200	U 40	U 10	U 10	U 10	U 10	U 0.1	3.4	4.7
3 DB-15	U 40	U 40	U 200	U 200	U 40	U 16	U 16	U 16	U 16	U 0.1	5.6	5.5
3 EB-09	U 80	300	U 400	U 400	1100	U 11	U 11	U 11	U 11	0.1	12	0.31
3 EB-10	490	2100	U 400	U 400	3400	U 12	U 12	U 12	U 12	0.1	11	0.31
3 EB-12	U 80	210	U 400	U 400	300	U 14	U 14	U 14	U 14	U 0.1	7.2	0.39
3 EB-17	U 80	U 80	U 400	U 400	U 80	U 10	U 10	U 10	U 10	U 0.1	14	0.31
3 EB-20	U 100	480	U 400	U 400	1400	U 10	U 10	U 10	U 10	1.3	31	0.33
3 EB-22	L 100	190	U 400	U 400	550	U 11	U 11	U 11	U 11	U 0.1	9	0.32
3 EB-23	U 100	U 100	U 400	U 400	670	U 8	U 8	U 8	U 8	U 0.1	6.6	0.24
3 EB-24	L 100	200	L 400	L 400	300	U 6.9	U 6.9	U 6.9	U 6.9	U 0.1	5.7	0.20
3 SM 01	U 40	170	U 200	U 200	88	U 4.1	U 4.1	U 4.1	U 4.1	U 0.1	4.5	0.36
3 SM-03	U 40	U 40	U 200	U 200	120	U 13	U 13	U 13	U 13	U 0.1	8.0	0.34
3 SM-07	U 40	U 40	U 200	U 200	U 40	U 4.3	U 4.3	U 4.3	U 4.3	U 0.1	4.6	0.37
3 SM-20	U 40	U 40	U 200	U 200	U 40	U 4.5	U 4.5	U 4.5	U 4.5	U 0.1	5.5	0.38
3 EV-01	410	1900	U	U	2500	U 15	U 15	U 15	U 15	U 0.1	12.	0.37
3 EV 02	140	380	U	U	510	U 15	U 15	U 15	U 15	U 0.1	9.9	0.36
3 EV 03	290	970	U	U	880	U 13	U 13	U 13	U 13	U 0.1	14.	0.30
3 EV-04	2100	4700	U	U	2100	L 18	L 18	U 18	U 18	0.1	18.	0.25
3 EV-05	250	U	U	U	1500	U 16	U 16	U 16	U 16	0.2	8.5	0.28
3 EV-06	U	630	U	U	630	U 9.3	U 9.3	U 9.3	U 9.3	U 0.1	6.1	0.18
3 EV 07	400	1600	U	U	1600	U 12	U 12	U 12	U 12	U 0.1	7.7	0.28
3 EV 11	U	370	U	U	200	U 10	U 10	U 10	U 10	U 0.1	6.8	0.25
3 BH-03	U 40	240	U 200	U 200	620	U 15	U 15	U 15	U 15	U 0.1	8.5	0.31
3 BH 04	210	570	U 200	U 200	1100	U 5.0	L 5.0	L 5.0	L 5.0	U 0.1	7.9	0.37
3 BH-05	U 40	210	U 200	U 200	390	U 5.2	U 5.2	U 5.2	U 5.2	U 0.1	11	0.41
3 BH 07	150	880	U 200	U 200	1300	U 5	U 5	L 5	U 5	U 0.1	8.9	0.41
3 BH 11	32	170	U 100	U 100	380	U 10	U 10	U 10	U 10	0.2	10	0.53
3 BH 12	66	170	U 100	U 100	230	U 10	U 10	U 10	U 10	0.2	6.9	0.38
3 BH 23	U 20	110	U 100	U 100	180	U 10	U 10	U 10	U 10	0.2	10.	0.52
3 BH 24	U 20	230	U 100	U 100	180	U 10	U 10	L 10	U 10	U 0.1	8.5	0.49

STATION#	cadmium	chromium	copper	lead	mercury	nickel	selenium	silver[e]	thallium	zinc
3 SQ 14	0.9	60	43	6.8	0.041	37	0.8	0.107	0.2	76
3 SQ 17	0 9	67	48	9.0	0.068	41	1 0	0.226	U C 1	88
3 SQ-18	1.1	66	48	8.5	0.060	39	0.7	0.223	U 0.1	85
3 SQ-20	0.9	65	44	9.0	0.055	38	0.4	0.2	U 0.1	83
3 SC-06	3.6	93	205	132	1.38	44	0.4	3.7	0.2	330
3 SC-07	1.1	79	807	233	1.28	39	0.3	2.3	U 0.1	873
3 SC-08	0.9	71	231	151	1.21	45	0.2	2.29	0.1	311
3 SC-14	1.2	65	299	175	1.57	43	0.3	2.32	U 0.1	272
3 SC-17	1.8	129	240	194	0.70	43	0.6	1.29	0.1	328
3 SC-18	1.2	73	170	131	0.72	39	0.7	1.56	0.1	227
3 SC-19	2.3	80	293	360	2.07	45	0.1	1.36	0.2	343
3 SC-20	2.0	86	198	163	1.64	44	0.7	2.67	U 0.1	235
3 CS-01	0.7	38	56	23	0.12	21	0.4	0.569	U 0.1	82
3 CS-11	0.6	41	30	9.3	0.054	22	0.3	0.119	0.1	57
3 CS-15	1.1	57	59	19	0.11	33	0.7	0.364	U 0.1	98
3 CS-17	1.9	57	52	13	0.082	31	0.7	0.262	U 0.1	84
3 DB-01	0.1	49	28	0.4	0.016	27	0.3	0.37	U 0.1	72
3 DB-05	0 1	51	33	U 0.1	0.022	30	0.1	0.37	0.1	77
3 DB-07	0.2	60	50	5.6	0.029	33	0.6	0.78	0.1	86
3 DB-15	0.4	76	74	9.9	0.047	46	1.0	0.218	0.1	102
3 EL-09	1.0	41	112	245	1.69	33	0.1	0.741	U 0.1	434
3 EL-10	2.0	41	165	607	1.08	33	0.3	0.651	U 0.1	687
3 EL-12	0.4	43	106	35	0.28	37	0.3	0.675	U 0.1	120
3 EL-17	0.7	40	101	100	0.58	26	0.1	0.65	U 0.1	192
3 EL-20	0.7	49	152	176	0.78	24	U 0.1	0.6	0.1	460
3 EL-22	0.5	38	89	51	0.51	27	0.2	0.671	U 0.1	116
3 EL-23	0.2	25	39	29	0.16	18	U 0.1	0.176	U 0.1	69
3 EL-24	0.2	22	20	23	0.16	17	0.1	0.254	U 0.1	44
3 SM-01	0.14	32	33	5	0.080	20.	0.4	0.104	U 0.1	74
3 SM-03	0.21	43	40	5	0.073	27.	0.3	0.13	U 0.1	75
3 SM-07	0.17	35	33	6	0.069	19.	U 0.1	0.108	U 0.1	76
3 SM-20	0.14	40	40	6	0.063	21.	U 0.1	0.118	U 0.1	81
3 EV-01	1.9	50	85	38	0.21	44	0.2	0.368	0.5	313
3 EV 02	0.83	54	81	25	0.20	48	U 0.1	0.218	0.2	141
3 EV-03	1.5	48	82	47	0.23	43	0.2	0.334	0.2	237
3 EV-04	1.1	67	111	82	0.26	45	0.2	0.155	0.3	1074
3 EV-05	3.1	62	101	40	0.18	51	0.4	0.415	0.5	249
3 EV-06	1.1	34	49	25	0.20	34	U 0.1	0.184	0.2	78
3 EV-07	1.9	53	79	34	0.23	50	0.2	0.372	0.4	132
3 EV-11	0.9	48	70	15	0.12	46	U 0.1	0.344	U 0.1	88
3 BH-03	0.98	68	400	46	1.35	73.	0.4	0.254	0.1	102
3 BH-04	1.2	81	72	37	1.69	89.	0.2	0.377	0.2	135
3 BH-05	0.55	86	69	13	0.81	111	0.1	0.221	0.2	111
3 BH-07	0.88	82	72	18	0.97	105	0.1	0.28	0.1	117
3 BH-11	0.31	63	79	13	0.54	118	U 0.1	0.203	U 0.1	113
3 BH-12	0.50	57	61	11	0.64	72	0.3	0.207	0.1	97
3 BH-23	0.33	66	62	10	0.54	102	0.2	0.236	0.1	114
3 BH-24	0.36	69	67	8	0.59	117	U 0.1	0.217	0.1	115

STATION#	depth (m)	% total volatile solids	% silt	% clay	% total organic carbon	BENTHIC CODE	TOX CODE	MICRO CODE
3 SQ-14	23.8	9.19	35.18	28.71	2.09	0	1	0
3 SQ-17	25.6	10.44	47.81	35.25	2.30	0	1	0
3 SQ-18	24.7	11.58	45.52	33.93	2.28	0	1	0
3 SQ-20	18.9	9.55	48.40	35.47	2.23	0	1	0
3 SC-06	6.7	9.78	60.30	26.46	2.93	0	3	0
3 SC-07	7.6	8.23	30.85	24.63	2.12	0	1	0
3 SC-08	13.4	11.08	52.04	37.83	2.87	0	1	0
3 SC-14	14.9	12.93	58.36	33.20	3.04	0	3	0
3 SC-17	14.6	9.63	45.21	33.02	2.40	0	1	0
3 SC-18	16.8	9.59	46.04	31.77	2.58	0	1	0
3 SC-19	15.8	7.82	29.93	19.07	2.33	0	1	0
3 SC-20	18.3	10.92	39.82	28.74	3.28	0	3	0
3 CS-01	40.5	10.33	54.61	34.79	2.01	0	1	0
3 CS-11	21.3	6.18	21.01	17.96	1.36	0	1	0
3 CS-15	28.3	11.84	43.71	37.64	2.42	0	3	0
3 CS-17	24.1	11.87	31.42	46.71	2.69	0	3	0
3 DB-01	112.8	4.14	12.43	7.82	0.83	0	1	0
3 DB-05	88.4	5.51	13.25	10.41	1.39	0	1	0
3 DB-07	97.5	7.66	24.51	24.45	2.14	0	1	0
3 DB-15	109.7	13.24	49.37	40.31	2.65	0	1	0
3 EL-09	173.1	7.02	31.96	23.72	1.77	0	1	0
3 EL-10	184.1	6.68	41.80	27.10	2.35	0	1	0
3 EL-12	189.0	9.89	50.94	37.68	2.14	0	1	0
3 EL-17	170.7	7.32	34.01	21.90	1.92	0	1	0
3 EL-20	173.7	6.76	34.00	18.34	1.39	0	1	0
3 EL-22	179.2	8.20	36.65	25.72	1.93	0	1	0
3 EL-23	121.9	8.01	13.82	10.67	1.11	0	1	0
3 EL-24	137.2	6.22	6.40	7.27	3.80	0	1	0
3 SM-01	13.4	5.71	61.58	19.59	1.32	0	1	0
3 SM-03	10.1	7.50	55.15	25.73	1.89	0	3	0
3 SM-07	23.5	6.12	57.53	27.38	1.32	0	1	0
3 SM-20	30.5	6.64	61.43	25.84	1.39	0	1	0
3 EV-01	16.8	20.14	42.86	20.02	8.98	0	3	0
3 EV-02	16.8	13.42	62.37	20.73	4.17	0	1	0
3 EV-03	13.4	25.44	40.98	22.56	11.00	0	1	0
3 EV-04	13.7	35.06	34.24	30.58	15.42	0	3	0
3 EV-05	10.1	25.99	45.49	21.83	9.22	0	3	0
3 EV-06	11.9	10.52	28.22	11.96	4.51	0	1	0
3 EV-07	16.5	18.13	48.29	19.25	6.67	0	1	0
3 EV-11	97.5	7.36	50.69	18.39	2.29	0	1	0
3 BH-03	5.5	26.93	50.03	16.88	12.15	0	1	0
3 BH-04	11.9	13.72	58.66	24.93	4.83	0	1	0
3 BH-05	11.9	9.20	71.35	25.17	2.34	0	1	0
3 BH-07	10.1	10.67	63.57	28.12	3.15	0	1	0
3 BH-11	7.0	7.25	60.65	37.42	2.07	0	1	0
3 BH-12	6.1	9.33	36.14	28.08	3.69	0	1	0
3 BH-23	17.4	8.14	67.44	27.92	2.01	0	3	0
3 BH-24	11.0	6.50	64.97	32.48	2.09	0	1	0

a. Reference:
Battelle Marine Research Laboratory. 1985. Detailed chemical and biological analyses of selected sediments from Puget Sound. Draft Final Report. U.S. EPA Region X, Seattle, WA. 300 pp.

b. Total PCBs are the sum of detected Aroclors.

c. U = undetected at detection limit shown. Detection limits were not available for all the chemicals for the "EV" stations.

d. L = less than the value shown. For purposes of this report, these were considered undetected.

e. Silver data were supplied by Eric Crecelius, Battelle Pacific NW Laboratories, personnal communication by H. Beller, November 22,1985.

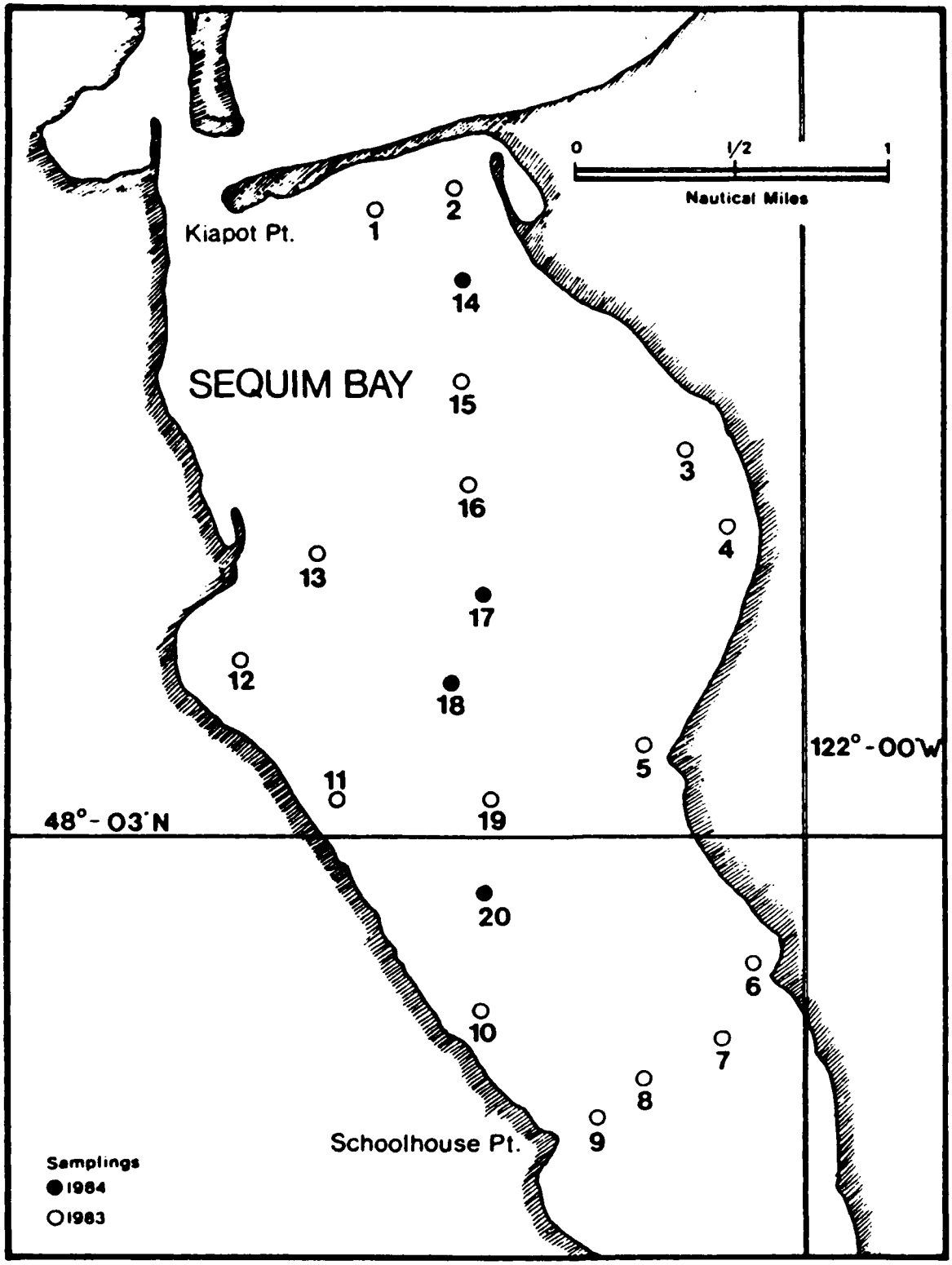


Figure A-3. Sequim Bay Sampling Stations

Reference: Battelle 1985.

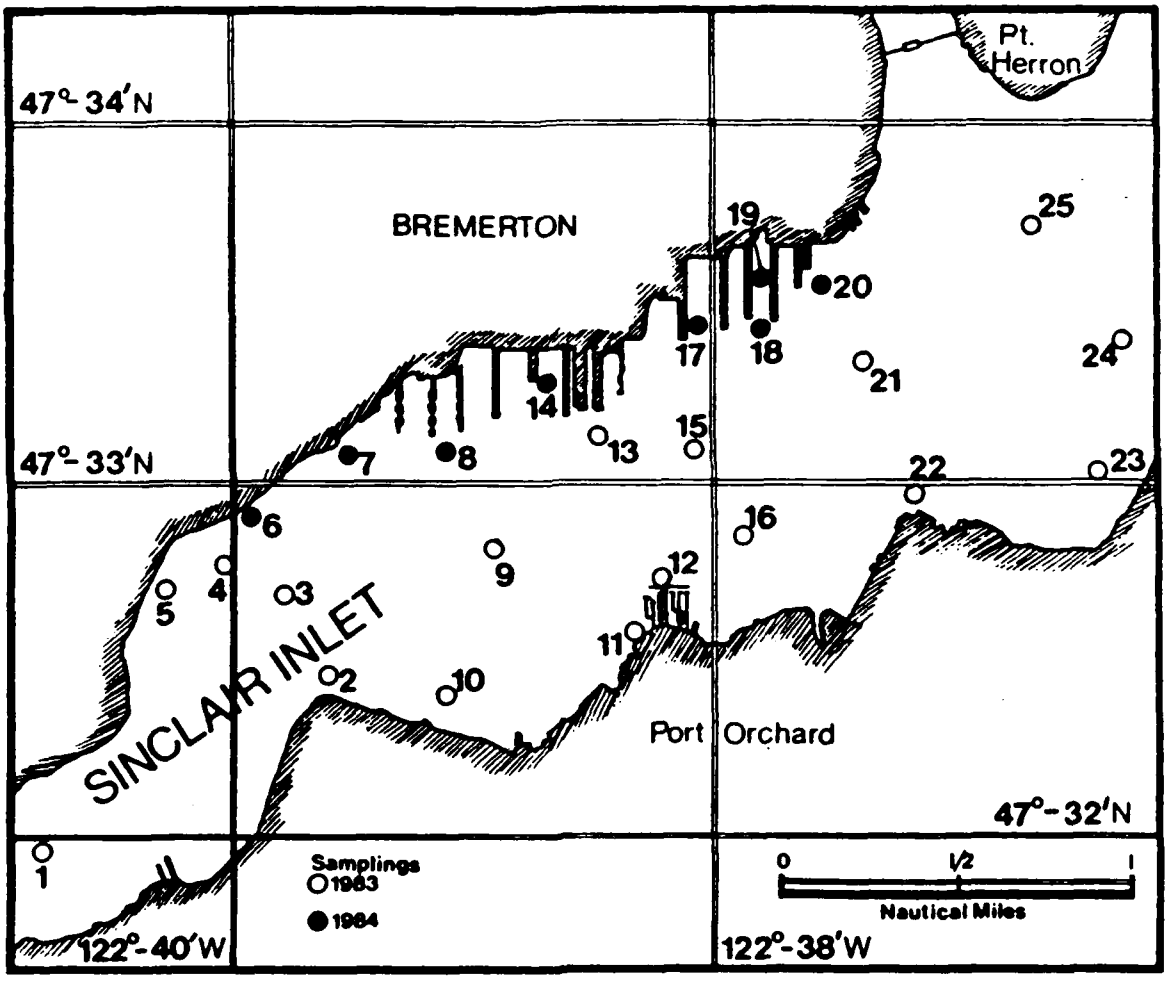


Figure A-4. Sinclair Inlet Sampling Stations

Reference: Battelle 1985.

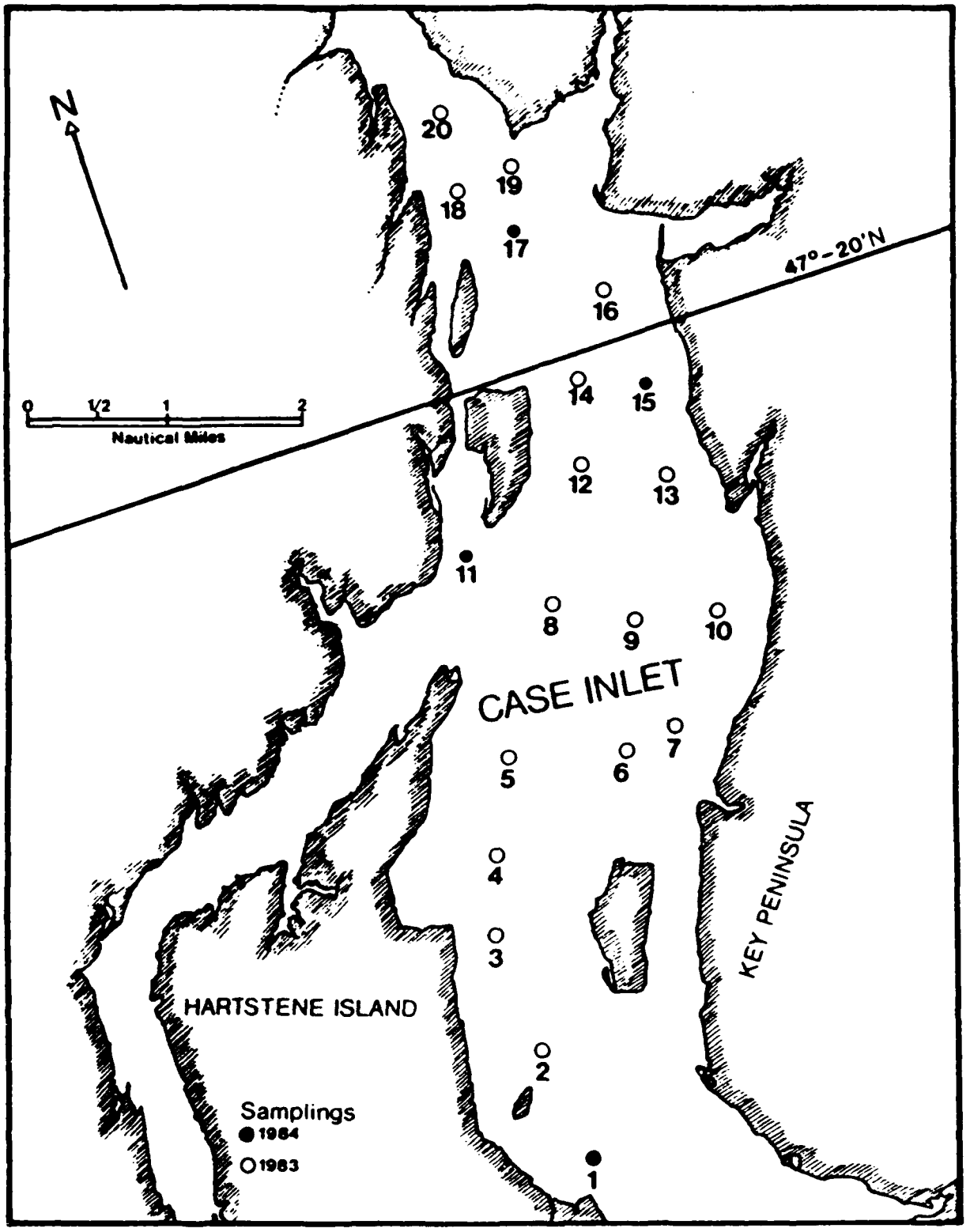


Figure A-5. Case Inlet Sampling Stations

Reference: Battelle 1985.

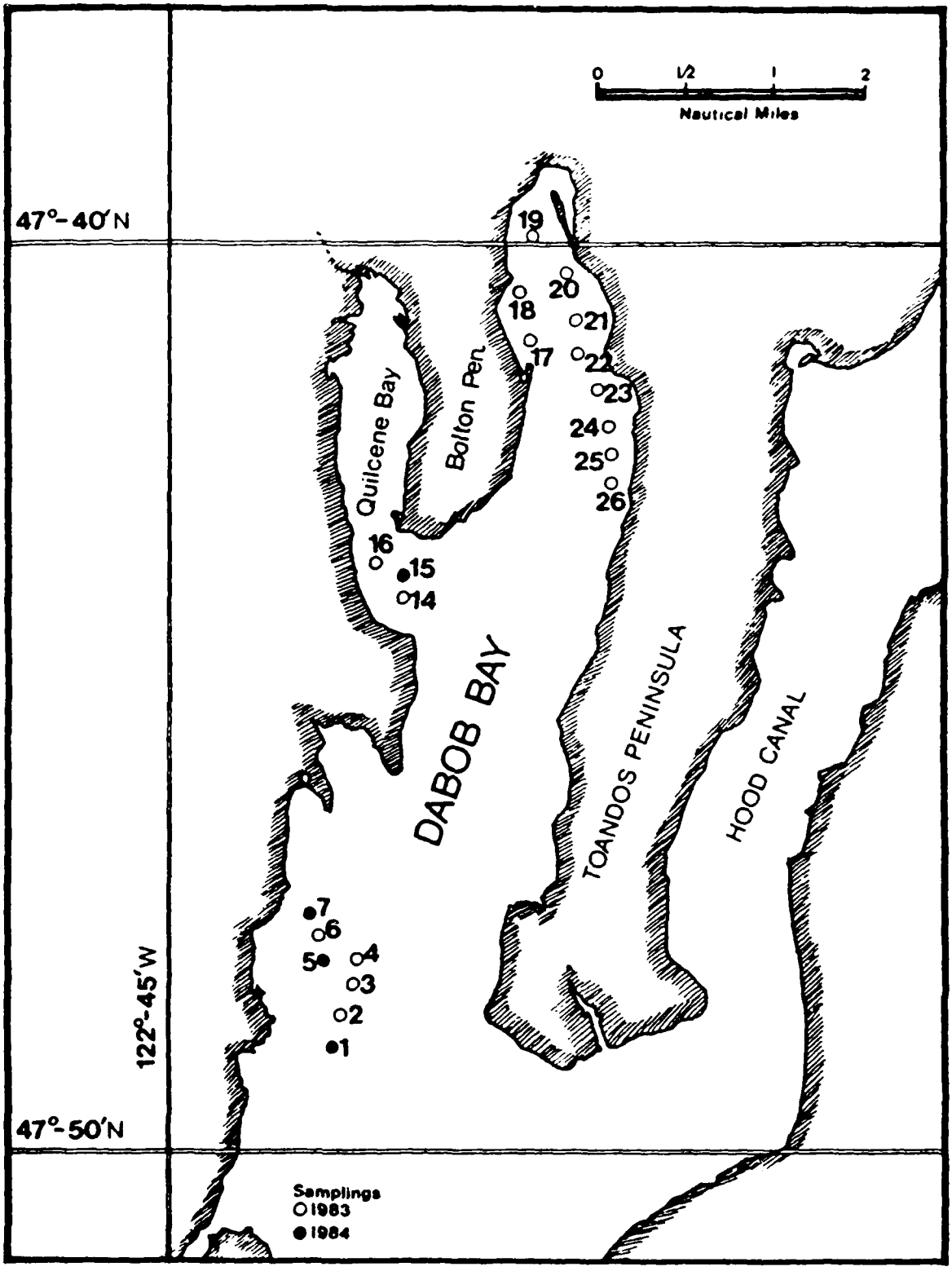


Figure A-6. Dabob Bay Sampling Stations

Reference: Battelle 1985.

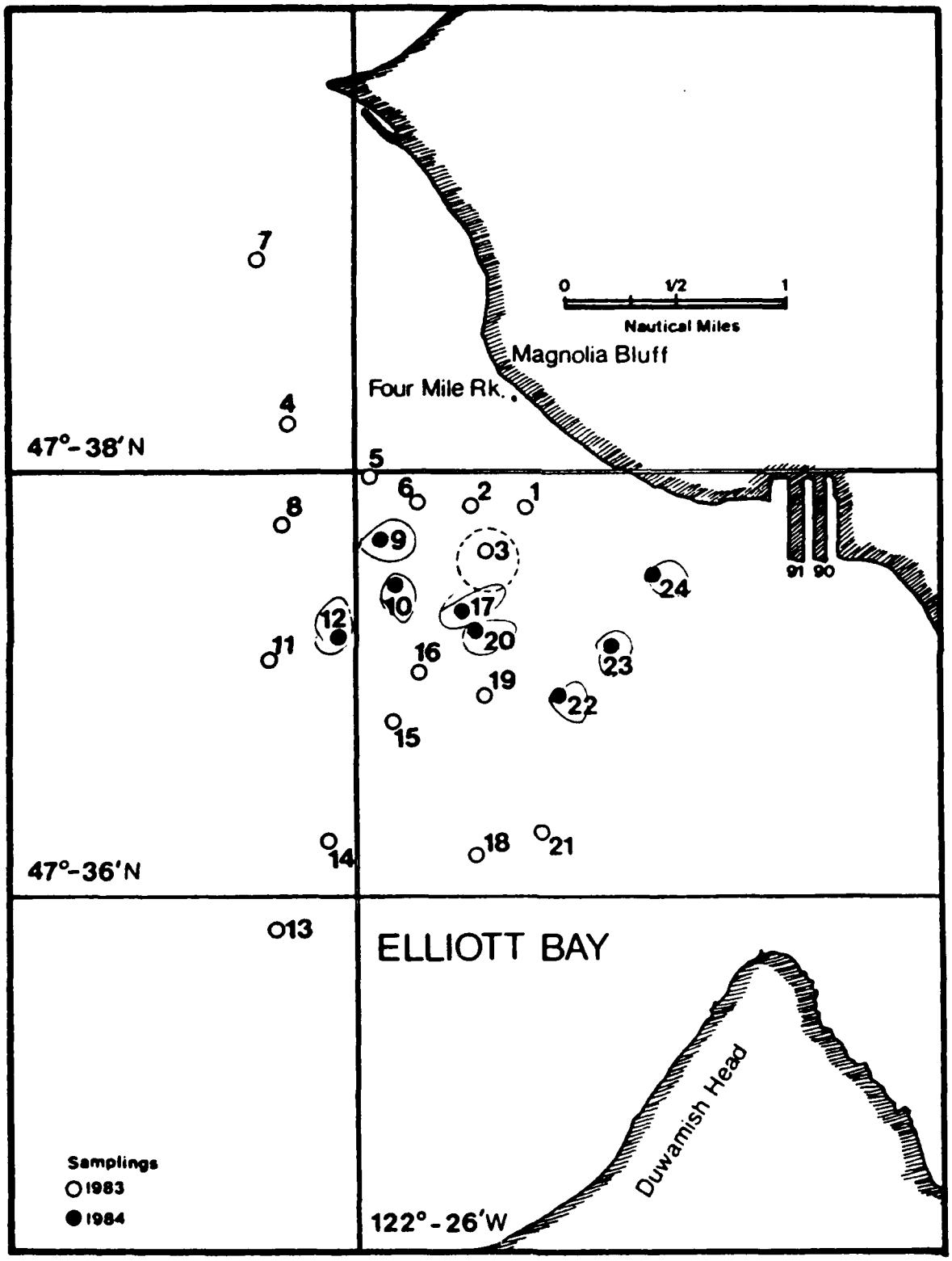


Figure A-7. Elliott Bay - Fourmile Rock Sampling Stations

Reference: Battelle 1985.

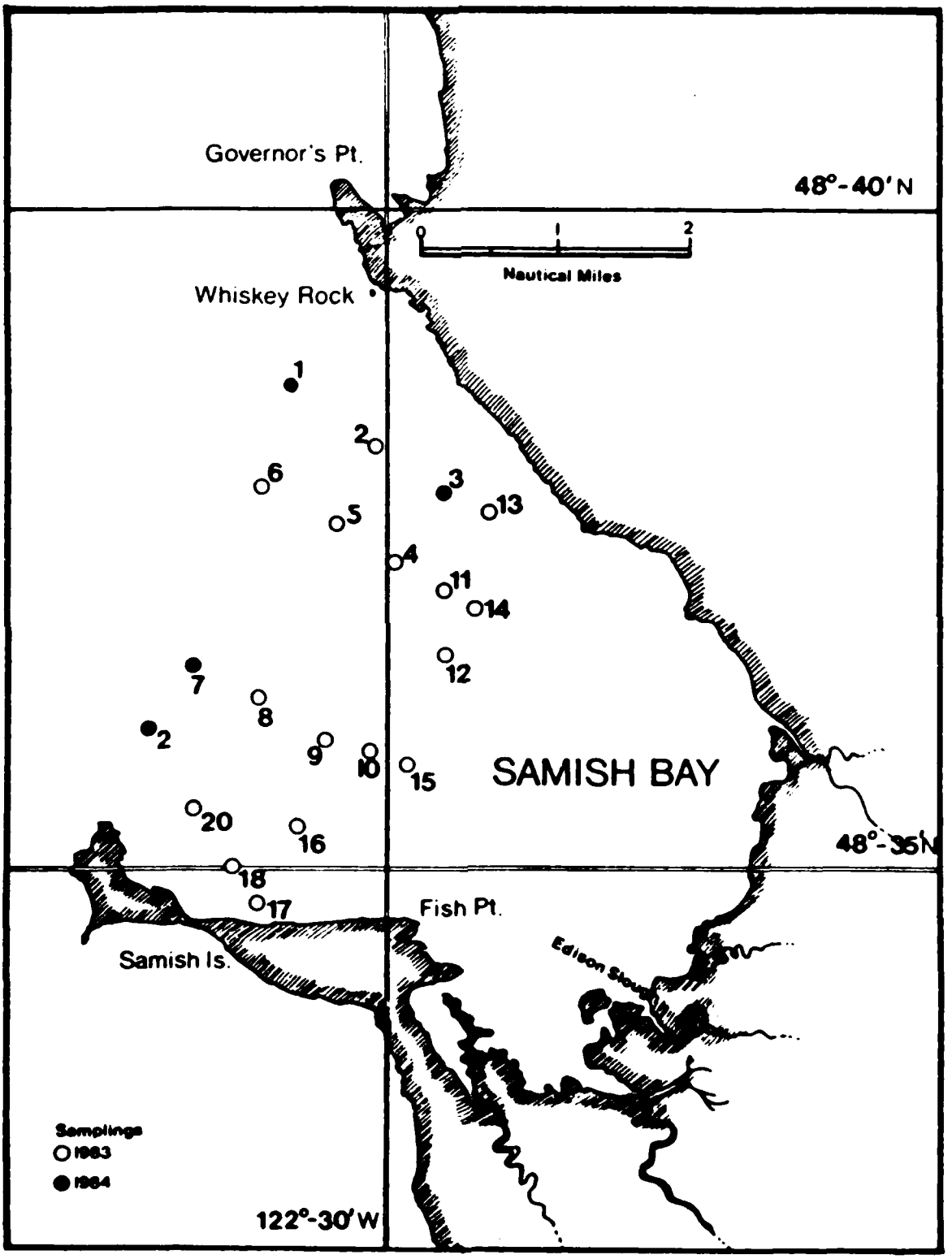


Figure A-8. Samish Bay Sampling Stations

Reference: Battelle 1985.

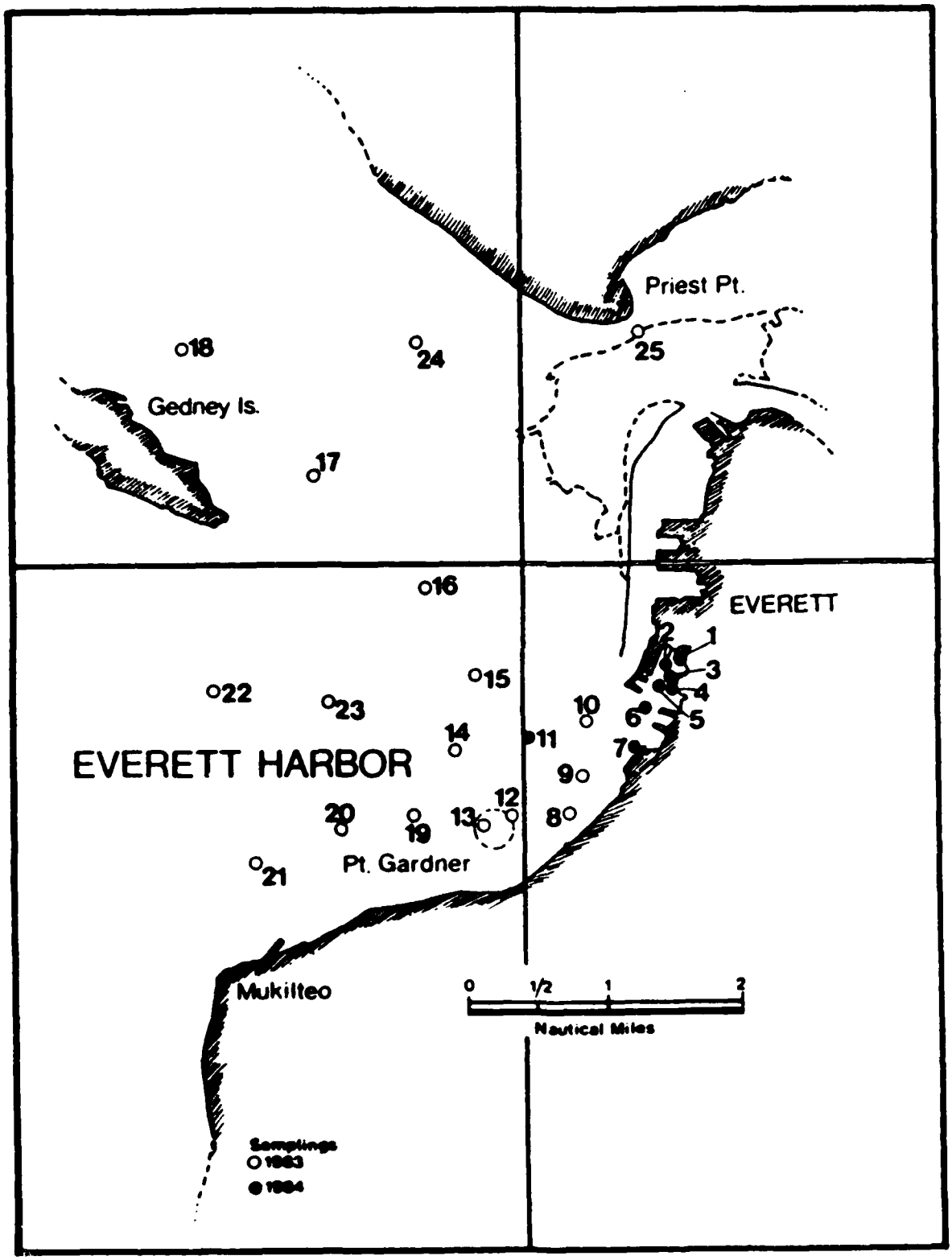


Figure A-9. Everett Harbor - Port Gardner Sampling Stations

Reference: Battelle 1985.

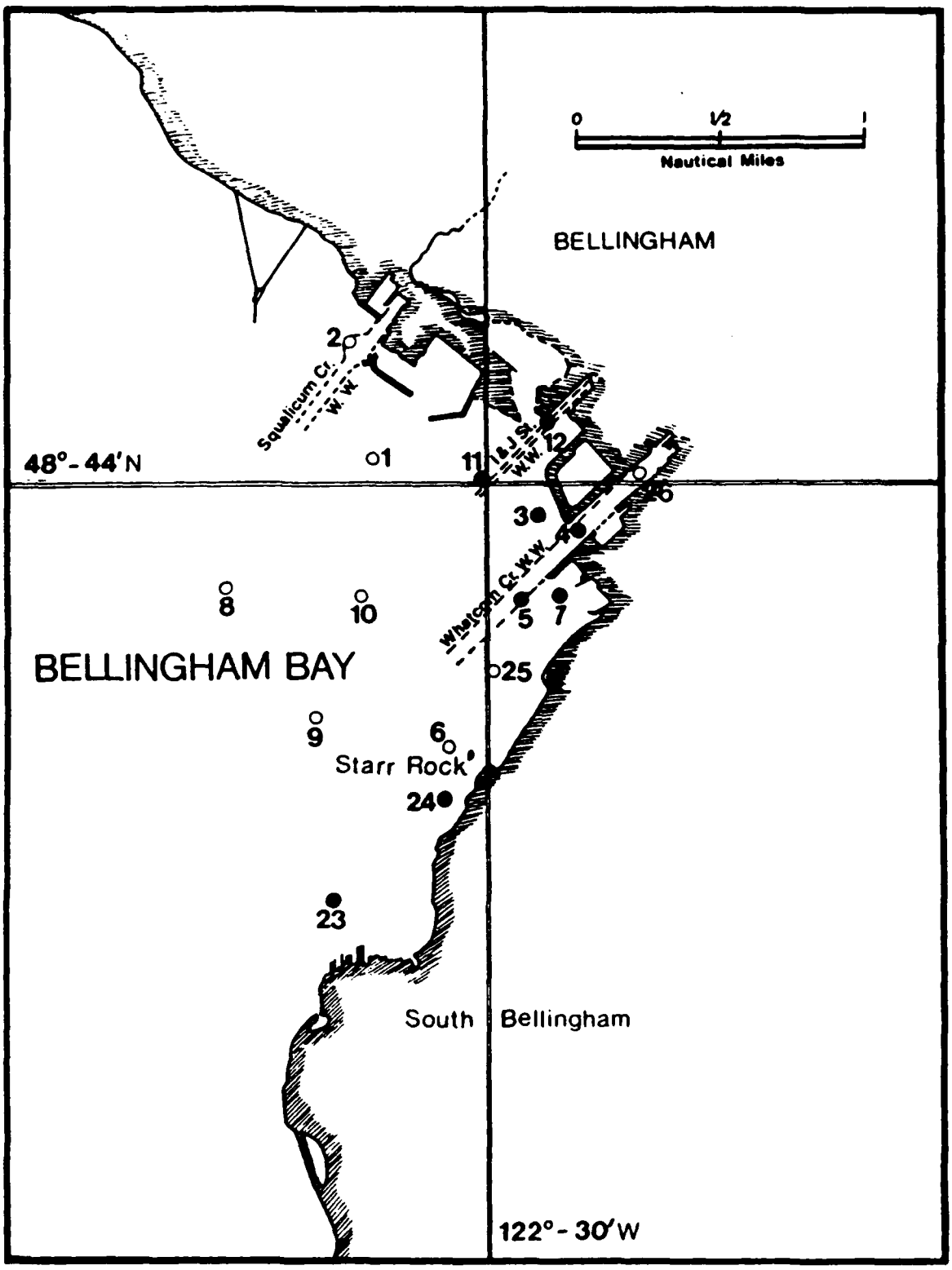


Figure A-10. Bellingham Bay Sampling Stations (Inner Harbor)

Reference: Battelle 1985.

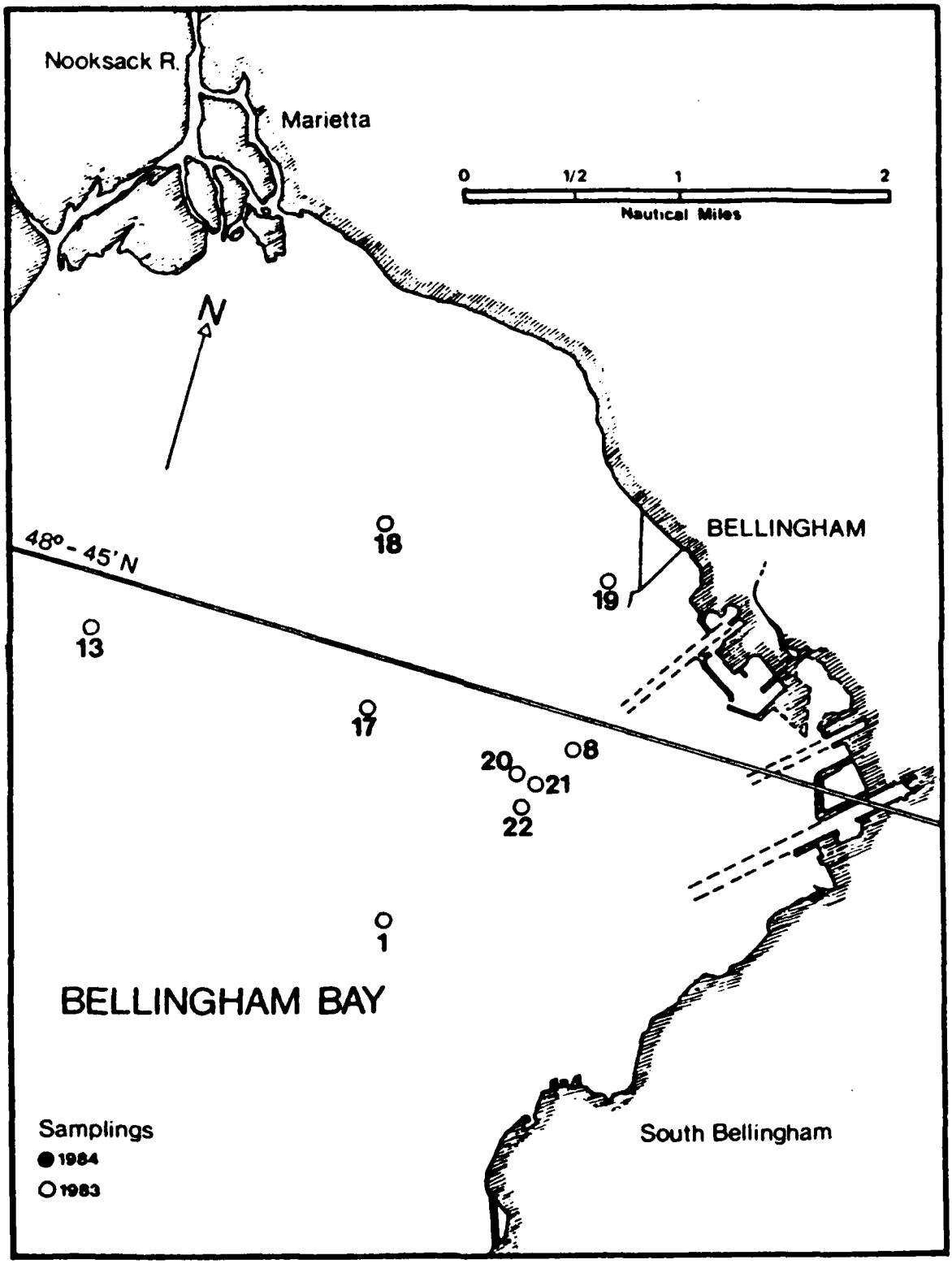


Figure A-11. Bellingham Bay Sampling Stations (Outer Harbor)

Reference: Battelle 1985.

TABLE A 4 DUWAMISH RIVER I[a]

STATION #	dimethyl phthalate	diethyl phthalate	di n-butyl phthalate	bis(2 ethyl-hexyl phthalate	hexa-chloro-butadiene	2,6-di nitro-toluene	1,3 di chloro-benzene	1,4 di-chloro-benzene	1,2-di-chloro benzene	isophorone	hexa-chloro-benzene
4 DR 01 C1	8.5	4.5	13	280	U[b] 1.3	U 3.0	U 40	U 40	U 40	U 2.0	U 0.5
4 DR 02 C2	3 1	1.7	7.2	120	U 0.8	U 2.6	U 40	U 40	U 94	U 2.0	U 0.5
4 DR 03 C3	11	4.4	36	1000	U 1.3	U 5.3	U 40	U 40	U 40	U 2.7	U 0.5
4 DR 04 C4	6.4	1.9	13	260	U 1.3	U 3.3	U 40	U 40	U 40	U 1.9	U 0.5
4 DR 05 C5	8.2	2.4	24	500	U 1.3	U 2.9	U 40	U 40	U 40	U 3.0	U 0.5
4 DR 06 C6	11	4.7	130	580	U 1.3	U 4.7	U 40	U 40	U 40	U 2.7	U 0.5
4 DR 07 C7	12	3.6	31	740	U 1.9	U 5.1	U 40	U 40	U 40	U 3.3	U 0.5
4 DR 08 C8	4 8	18	60	2800	U 10	U 5.3	U 40	U 40	U 40	U 3.5	1.7
4 SQ 09 C9	11	15	17	100	U 1.3	U 3.2	U 40	U 40	U 40	U 3.3	U 0.5

STATION #	anthracene	1-methyl-phenanthrene	fluoranthene	pyrene	benzo(a) anthracene	chrysene	total benzo-fluoranthenes	benzo(a) pyrene	indeno-(1,2, 3-cd) pyrene	dibenzo-(a,h)anthracene	benzo-(ghi) perylene
4 DR 01 C1	2 1	U 1.3	37	31	7.4	21	7.4	5.6	U 3.0	U 3.0	4.5
4 DR 02 C2	7 6	10	64	52	17	36	18	7.2	4.4	U 2.9	12
4 DR 03 C3	15	32	220	230	100	260	150	61	44	U 7.0	93
4 DR 04 C4	6.5	9 4	110	120	33	57	29	26	21	U 3.0	42
4 DR 05 C5	13	24	160	160	140	110	76	49	29	U 3.3	92
4 DR 06 C6	7 4	13	170	160	50	120	59	44	19	U 5.9	80
4 DR 07 C7	26	27	300	270	180	250	200	95	59	U 4.3	67
4 DR 08 C8	210	170	1100	1200	590	1400	720	400	170	42	180
4 SQ 09 C9	U 2.3	4.4	53	35	U 2.7	16	9.1	8.3	6.6	U 3.3	8.3

STATION #	4,4' DDE	4,4' DDD	4,4'-DDT	Total PCBs	naphthalene	2-methyl naphthalene	1,1' biphenyl	acenaphthylene	acenaphthene	fluorene	phenanthrene
4 DR 01 C1	U 0 5	0.6	U 0.5	23	2.6	5.5	U 1.8	U 1.9	U 1.9	U 1.7	23
4 DR 02 C2	U 0.5	0.9	U 0.5	38	71	110	2.7	U 1.9	U 1.9	2.6	54
4 DR 03 C3	U 0 5	3 9	U 0.5	31	11	13	7.4	U 3.9	U 3.9	U 3.5	150
4 DR 04 C4	U 0 5	0 6	U 0.5	13	5 8	2.8	U 2.2	U 2.3	U 2.3	U 2.1	80
4 DR 05 C5	U 0 5	2.6	U 0.5	76	12	14	6.8	U 1.7	9.4	U 2.1	120
4 DR 06 C6	U 0.5	3.2	U 0.5	41.6	6 0	9.2	U 14	U 3.6	3.6	4.8	97
4 DR 07 C7	U 0.5	5.6	22	120	8 3	9.7	U 4.3	1.7	23	14	190
4 DR 08 C8	U 0.5	71	0 8	3900	99	140	29	2400	100	91	560
4 SQ 09 C9	U 0 5	U 0.5	U 0.5	2.7	U 3.0	9.1	U 7.9	U 37	U 2.8	2.5	U 40

STATION #	% silt	% clay	% total organic carbon	% total volatile solids	ARSENIC	CADMIUM	COPPER	LEAD	ZINC	MERCURY	TOX CODE	BENTHIC CODE	MICRO CODE
4 DR-01 C1	0	13.1	0.36	2.6	8.6	0.13	14	9.4	57	0.01	3	0	0
4 DR-02 C2	0	9.9	0.63	3.1	12	0.15	16	8.9	57	0.01	1	0	0
4 DR-03 C3	2.6	34.5	3.5	11	17	0.45	32	20	91	0.04	1	0	0
4 DR-04 C4	2.9	13.7	2.8	7.2	14	0.26	22	14	71	0.02	1	0	0
4 DR-05 C5	3.4	42.3	2.1	8.2	18	0.42	32	17	84	0.04	1	0	0
4 DR-06 C6	5.0	39.9	2.3	8.2	17	0.35	32	17	79	0.07	1	0	0
4 DR-07 C7	4.6	49.2	1.8	8.1	20	0.40	35	24	90	0.05	3	0	0
4 DR-08 C8	2.8	84.8	2.2	8.7	34	3.1	120	160	270	0.42	3	0	0
4 SQ-09 C9	4.5	66.6	1.4	7.6	22	0.64	35	12	93	U0.03	1	0	0

a. Reference:
Chan, S.-L., M.H. Schiewe, D.W. Brown. 1985. Analyses of sediment samples for U.S. Army Corps of Engineers Seattle Harbor navigation project operations and maintenance sampling and testing of Duwamish River sediments. Draft report. 15 pp. plus appendices.

b. U = undetected at detection limit shown.

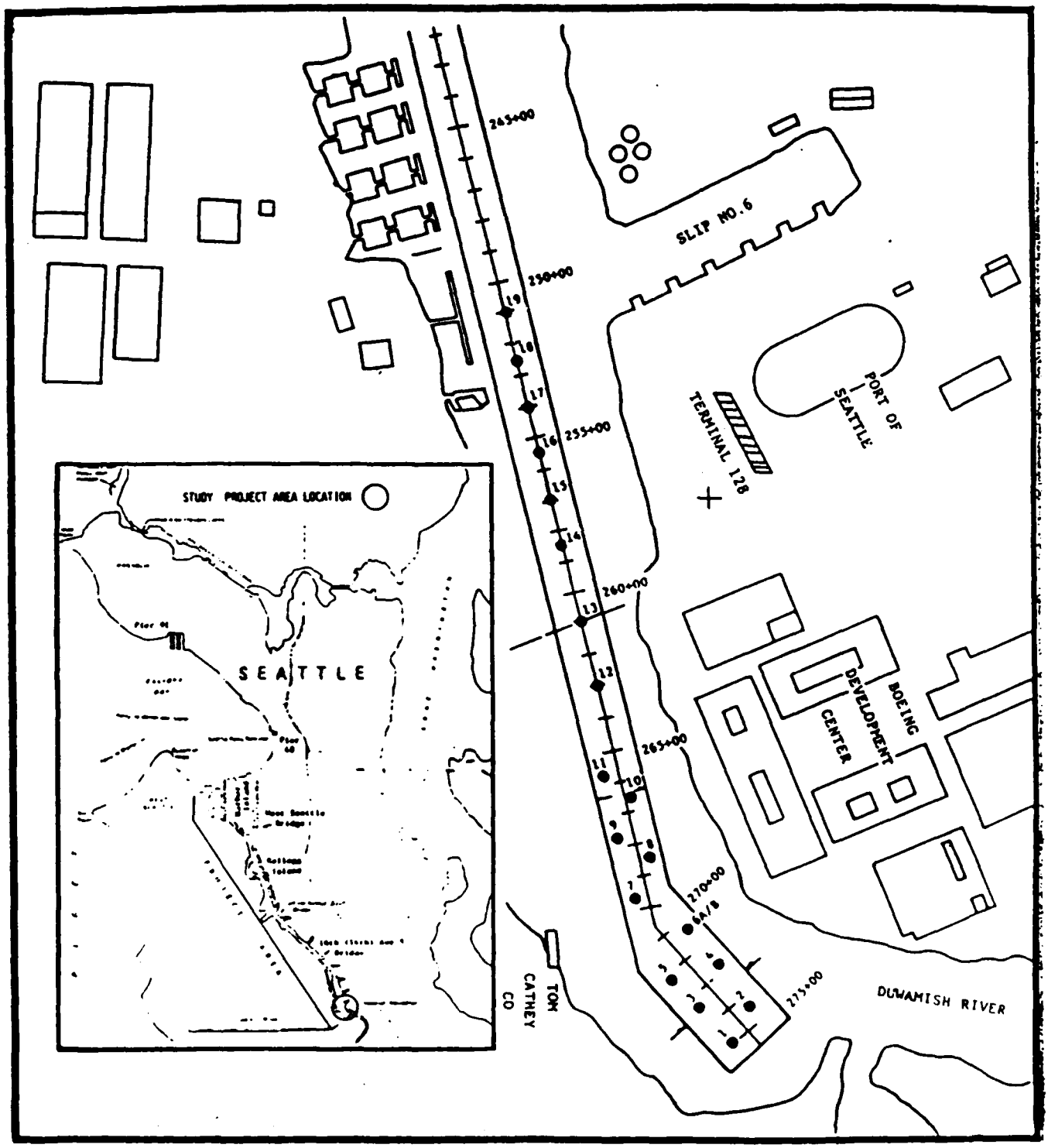


Figure A-12. **Sediment Sampling Station Locations for Dredged Material Characterization.**

Reference: Chan et al. 1985.

TABLE A 5 ALKI EXTENSION[a]

STATION#		phenol	1,2-di phenyl hydra zine	1,4 di chloro benzene	fluorene	naphtha lene	acenaph- thene	acenaph- thylene	anthra- cene	phenan- threne	fluor- anthene	pyrene	chrysene
5 AP-01	LSKR04	74.1	U 5.8	27.3	3.9	3.9	U 3	U 2.7	9.1	35.1	42.9	49.4	20.8
5 AP-02	LSKR05	U[b]4.3	U 5.8	2.7	U 3.4	U 1.6	U 3	U 2.7	U 2.9	1.3	2.6	5.3	U 18
5 AP-03	LSKR06	5.3	U 5.8	U 3	U 3.4	U 1.6	U 3	U 2.7	U 2.9	1.3	2.7	2.6	1.3
5 AP-04	LSJR02	74.2	U 5.8	82.3	25.8	U 1.6	11.3	4.8	95.2	172.	206.	338.	101.
5 AP-05	LSLR02	1.7	0.2	13.8	U 3.4	6.3	U 3	U 2.7	10.0	10.0	12.6	20.1	43.9
5 AP-06	LSLP02	U 4.3	U 5.8	10.4	U 3.4	U 1.6	U 3	U 2.7	9.1	7.8	11.7	20.8	22.1
5 AP-07	LSKN02	U 4.3	U 5.8	6.6	U 3.4	14.5	U 3	U 2.7	4.0	14.5	19.8	36.9	17.2
5 PW-01	LSUV01	U 4.3	U 5.8	U 3	U 3.4	U 1.6	U 3	U 2.7	U 2.9	2.6	21.9	21.9	3.9
5 PW 02	LSUU01	31.7	U 5.8	U 3	2.6	1.3	1.3	U 2.7	5.3	15.9	26.4	33.0	9.3
5 PW-03	LSUU02	U 4 3	U 5.8	4.1	U 3.4	6.8	U 3	U 2.7	2.7	5.5	9.6	15.0	8.2
5 PW 04	LSUU03	12.1	U 5.8	22.9	U 3.4	4.0	U 3	U 2.7	4.0	12.1	25.6	35.0	16.2

STATION#		benzo(a) anthra- cene	benzo(a) pyrene	total benzo- fluor- anthenes	indeno- (1,2, 3-cd) pyrene	dibenzo- (a,h)an- thracene	benzo- (ghi) perylene	dimethyl phtha- late	diethyl phtha- late	di-n- butyl phtha- late	di-n- octyl phtha- late	total PCBs	4,4'- DDE
5 AP-01	LSKR04	13.0	24.7	48.1	U32.8	U34.4	6.5	U 3.7	5.2	46.8	U 7.5	18	L0.65
5 AP-02	LSKR05	U 18	U 12.5	U12.4	U32.8	U34.4	U31.7	U 3.7	2.7	51.8	14.6	19	L0.66
5 AP-03	LSKR06	U 18	U 12.5	2.6	U32.8	U34.4	U31.7	U 3.7	U 3.6	69.7	U 7.5	29	L0.66
5 AP-04	LSJR02	74.2	100.0	U12.4	1.6	3.2	33.9	U 3.7	4.8	48.4	4.8	34	1.61
5 AP-05	LSLR02	26.4	21.3	57.7	18.8	2.5	13.8	U 3.7	21.3	82.8	U 7.5	14	L0.63
5 AP-06	LSLP02	10.4	10.4	33.8	9.1	U34.4	10.4	U 3.7	6.5	63.7	2.6	6.6	L0.65
5 AP-07	LSKN02	11.9	13.2	60.7	U32.8	U34.4	10.6	U 3.7	5.2	71.2	U 7.5	11	L0.66
5 PW-01	LSUV01	2.6	U 12.5	U12.4	U32.8	U34.4	U31.7	U 3.7	U 3.6	29.6	U 7.5	13	L0.64
5 PW-02	LSUU01	5.3	13.2	33.1	U32.8	U34.4	4.0	U 3.7	6.6	44.0	U 7.5	8.6	U0.07
5 PW 03	LSUU02	5 5	4.1	27.3	U32.8	U34.4	6.8	U 3.7	6.8	61.5	U 7.5	5.6	L0.68
5 PW 04	LSUU03	6.7	21.6	51.3	U32.8	U34.4	9.4	1.4	4.0	31.0	U 7.5	25.2	L0.67

STATION#		4,4'- DDD	4,4'- DDT	tetra- chloro- ethane	ethyl- benzene	1,2-di- chloro- benzene	1,3-di- chloro- benzene	hexa- chloro- buta- diene	butyl- benzyl phtha- late	2,4,6- tri- chloro- phenol	penta- chloro- phenol	2,6-di- nitro toluene	1,2,4- tri- chloro- benzene
5 AP-01	LSKR04	U 0.08	U 0.10	U 5	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-02	LSKR05	U 0.08	U 0.10	0.04	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-03	LSKR06	U 0.08	U 0.10	0.01	0.04	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-04	LSJR02	U 0.08	U 0.10	0.03	0.05	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-05	LSLR02	U 0.08	U 0.10	U 5	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-06	LSLP02	U 0.08	U 0.10	U 5	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 AP-07	LSKN02	U 0.08	U 0.10	0.03	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 PW 01	LSUV01	U 0.08	U 0.10	U 5	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 PW 02	LSUU01	U 0.08	U 0.10	U 5	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 PW 03	LSUU02	U 0.08	U 0 10	0.06	0 03	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10
5 PW 04	LSUU03	U 0.08	U 0 10	0.01	U 5	U 3.5	U 4	U0.31	U 7.5	U 23	U 209	U 230	U 10

STATION#		hexa chloro benzene	hexa chlor ethane	hexa chlor cyclo penta diene	bis(2 ethyl hexyl) phtha late	2,4 di methyl phenol	N-ni troso diphenyl amine	arsenic	silver	cadmium	chromium	copper
5 AP 01	LSKR04	U 20	U 12	U 110	U 10	U 5	U 4.8	4.9	0.35	LO.23	23	3.8
5 AP 02	LSKR05	U 20	U 12	U 110	U 10	U 5	U 4.8	9.3	0.26	LO.21	24	4.2
5 AP 03	LSKR06	U 20	U 12	U 110	U 10	U 5	U 4.8	4.7	0.28	LO.18	20	4.3
5 AP 04	LSJR02	U 20	U 12	U 110	U 10	U 5	U 4.8	11	0.48	LO.32	31	11
5 AP 05	LSLR02	U 20	U 12	U 110	U 10	U 5	U 4.8	14	LO.21	LO.21	28	9.9
5 AP-06	LSLP02	U 20	U 12	U 110	U 10	U 5	U 4.8	31	LO.23	LO.23	31	11.6
5 AP 07	LSKN02	U 20	U 12	U 110	U 10	U 5	U 4.8	15	LO.20	LO.20	44	18.4
5 PW 01	LSUV01	U 20	U 12	U 110	U 10	U 5	U 4.8	2.0	0.33	LO.22	23	3.6
5 PW 02	LSUU01	U 20	U 12	U 110	U 10	U 5	U 4.8	19	LO.17	LO.17	26	11
5 PW 03	LSUU02	U 20	U 12	U 110	U 10	U 5	U 4.8		0.34	LO.19	27	13
5 PW 04	LSUU03	U 20	U 12	U 110	U 10	U 5	U 4.8	20	0.29	LO.16	31	16

STATION#		mercury	nickel	lead	antimony	zinc	depth (m)	% total volatile solids	% total organic carbon[d]	% fines[e]	BENTHIC CODE	TOX CODE	MICRO CODE
5 AP-01	LSKR04	0.022	18	4.7	LO.05	22	22	1	0.57	0.54	1	0	0
5 AP-02	LSKR05	LO.012	17	5.8	LO.05	21	22	1	0.57	0.60	1	0	0
5 AP 03	LSKR06	0.020	17	5.8	LO.04	21	22	1	0.57	0.60	1	0	0
5 AP-04	LSJR02	0.05	23	16	LO.08	37	49	2	0.74	4.1	1	0	0
5 AP-05	LSLR02	0.056	23	14	LO.05	43	98	4	1.07	5.4	1	0	0
5 AP 06	LSLP02	0.053	27	10	LO.05	44	112	2	0.74	3.8	1	0	0
5 AP-07	LSKN02	0.053	22	13	LO.04	49	22	4	1.07	1.9	1	0	0
5 PW 01	LSUV01	LO.023	15	5	LO.05	21	22	1	0.57	0.89	1	0	0
5 PW-02	LSUU01	0.053	23	20	LO.04	38	47	2	0.74	2.1	1	0	0
5 PW-03	LSUU02	0.051	23	11	LO.04	40	96	2	0.74	3.0	1	0	0
5 PW-04	LSUU03	0 055	23	13	LO.04	44	110	2	0.74	2.4	1	0	0

a. References:
Osborn, J.G., D.E. Weitkamp, and T.H. Schadt. 1985. Alki wastewater treatment plant outfall improvements predesign study. Technical Report No. 6.0, Marine Biology. Municipality of Metropolitan Seattle. 50 pp.

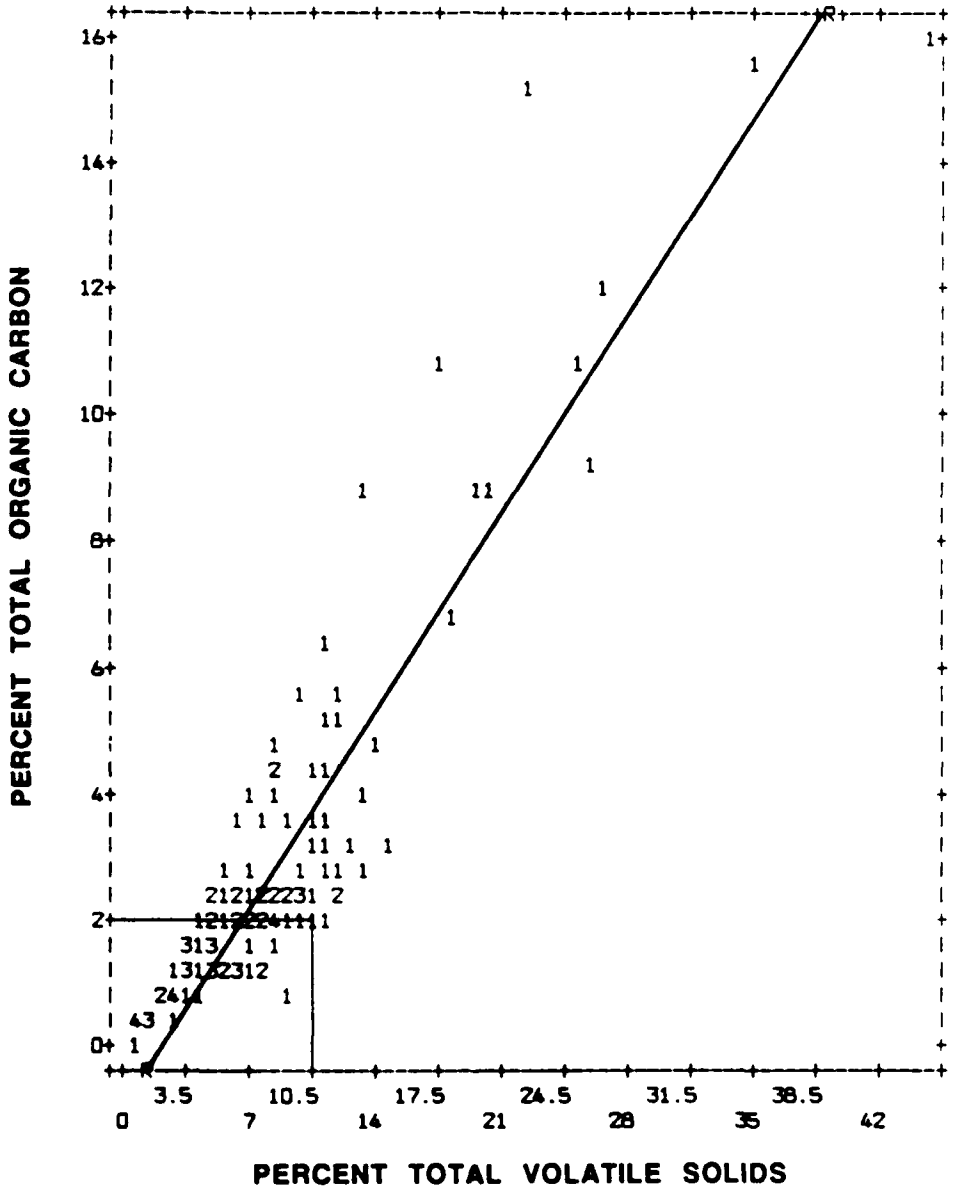
Trial, W., and J. Michaud. 1985. Alki wastewater treatment plant outfall improvements predesign study. Technical Report No. 8.3, Water Quality. Municipality of Metropolitan Seattle. 89 pp.

b. U = Undetected at detection limit shown. Detection limits are from:
Romberg, G.P., S.P. Pavlou, and E.A. Crecelius. 1984. Presence, distribution, and fate of toxicants in Puget Sound and Lake Washington. METRO Toxicant Program Report No. 6A. Toxicant Pretreatment Planning Study Technical Report C1. Municipality of Metropolitan Seattle, Seattle, WA. 231 pp.

c. L = Less than the value shown. For purposes of this report, these were considered undetected.

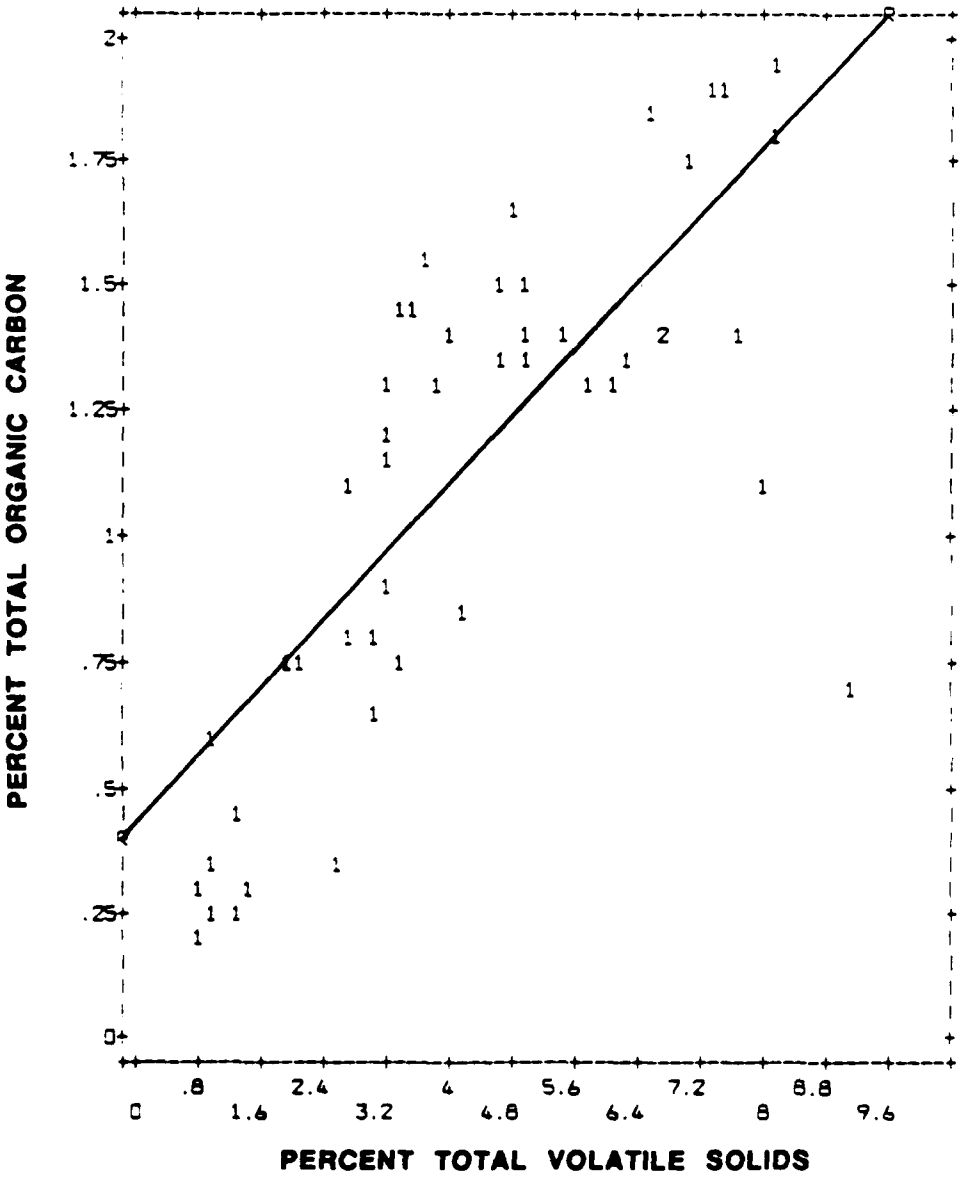
d. Total organic carbon values were estimated from a regression plot of total volatile solids with total organic carbon. See Figures A-13and A-14. The regression in figure A-13was used for the estimate and includes only data in the range of volatile solids found in the Alki Study (i.e., <10%).

e. Grain size data were unavailable for station AP-03. Because or its proximity to AP-02, an estimated value of 0.6% fine grained material was assigned for use in calculations .



119 cases plotted. Regression statistics of TOC on VSOLIDS:
Correlation .90784 R Squared .82417 S.E. of Est 1.28046 Sig. .0000
Intercept(S.E.) -.56853(.19400) Slope(S.E.) .42116(.01798)

Figure A-13. Plot of total organic carbon with total volatile solids.



47 cases plotted. Regression statistics of TOC on VSOLIDS:
Correlation .75506 R Squared .57011 S.E. of Est .33882 Sig. .0000
Intercept(S.E.) .40340(.10455) Slope(S.E.) .16684(.02160)

Figure A-14. Regression of total organic carbon on total volatile solids for total volatile solids <10%.

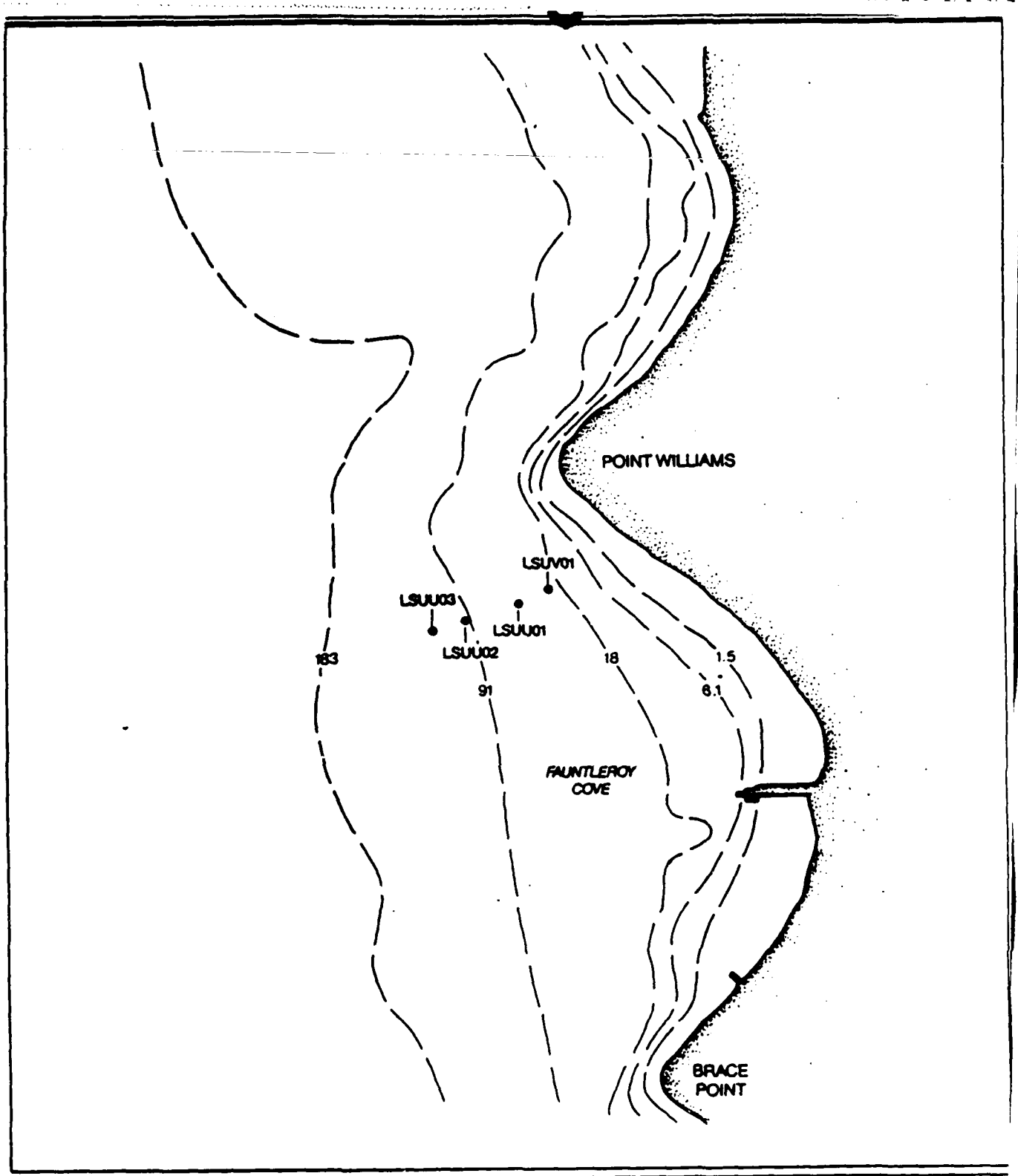


Figure A-15.
Sediment collection stations offshore of Point Williams, sampled May 26, 1984.
Reference: Osborn et al. 1985.

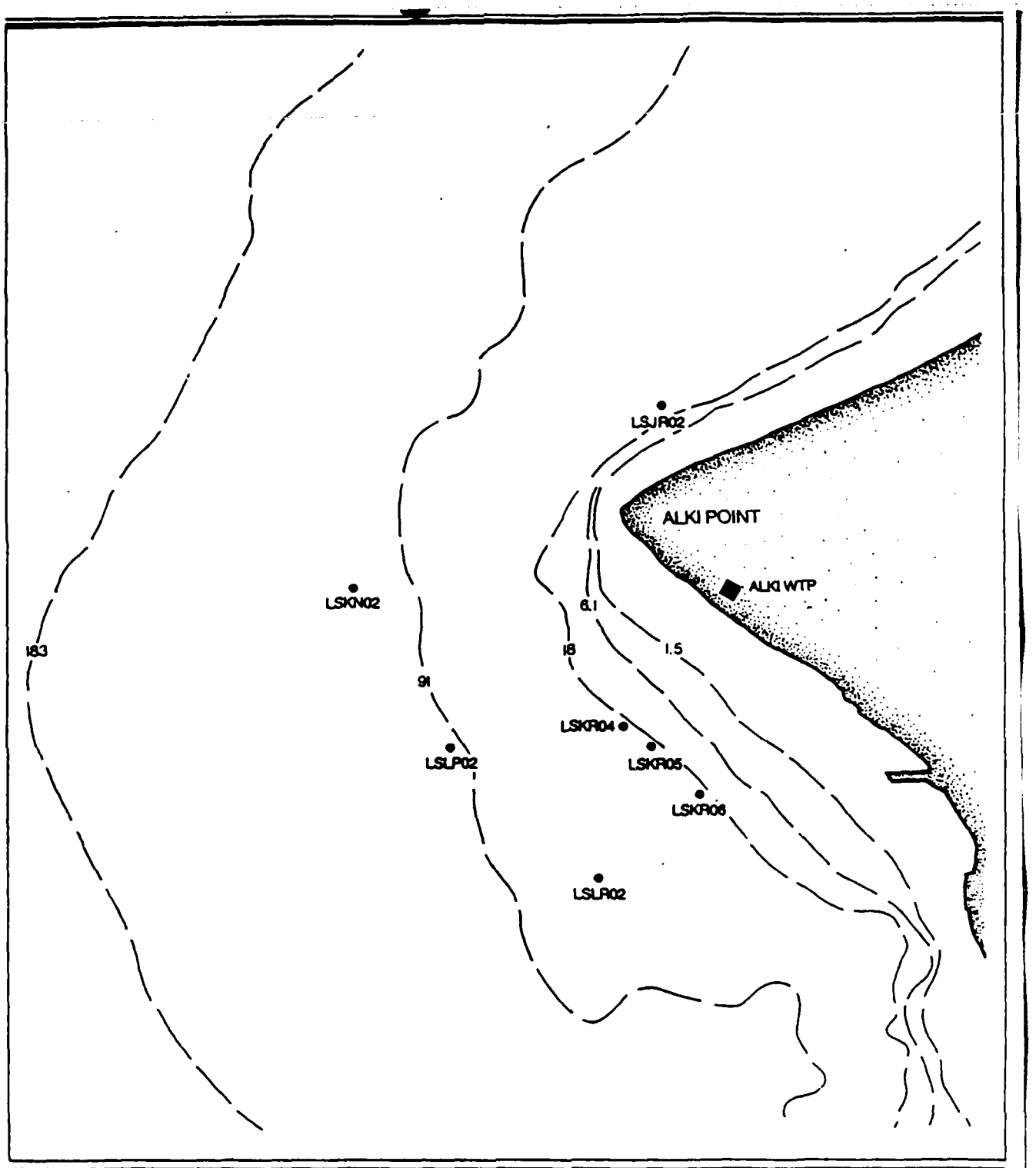


Figure A-16.
Sediment collection stations offshore of Alki Point, sampled May 25-26, 1984.
Reference: Osborn et al. 1985.

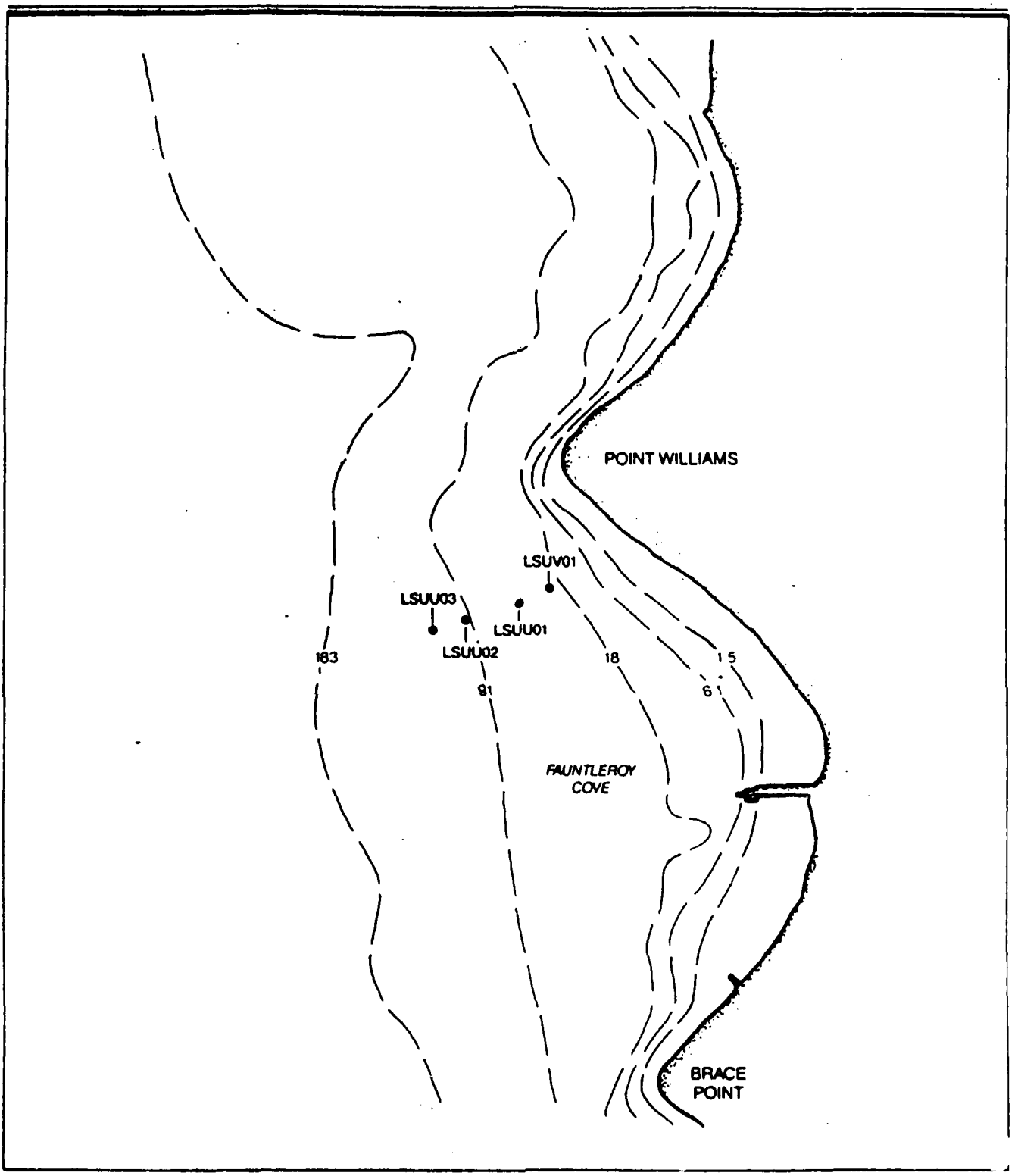


Figure A-17.
Point Williams benthos reference sampling station locations.
Reference: Osborn et al. 1985.

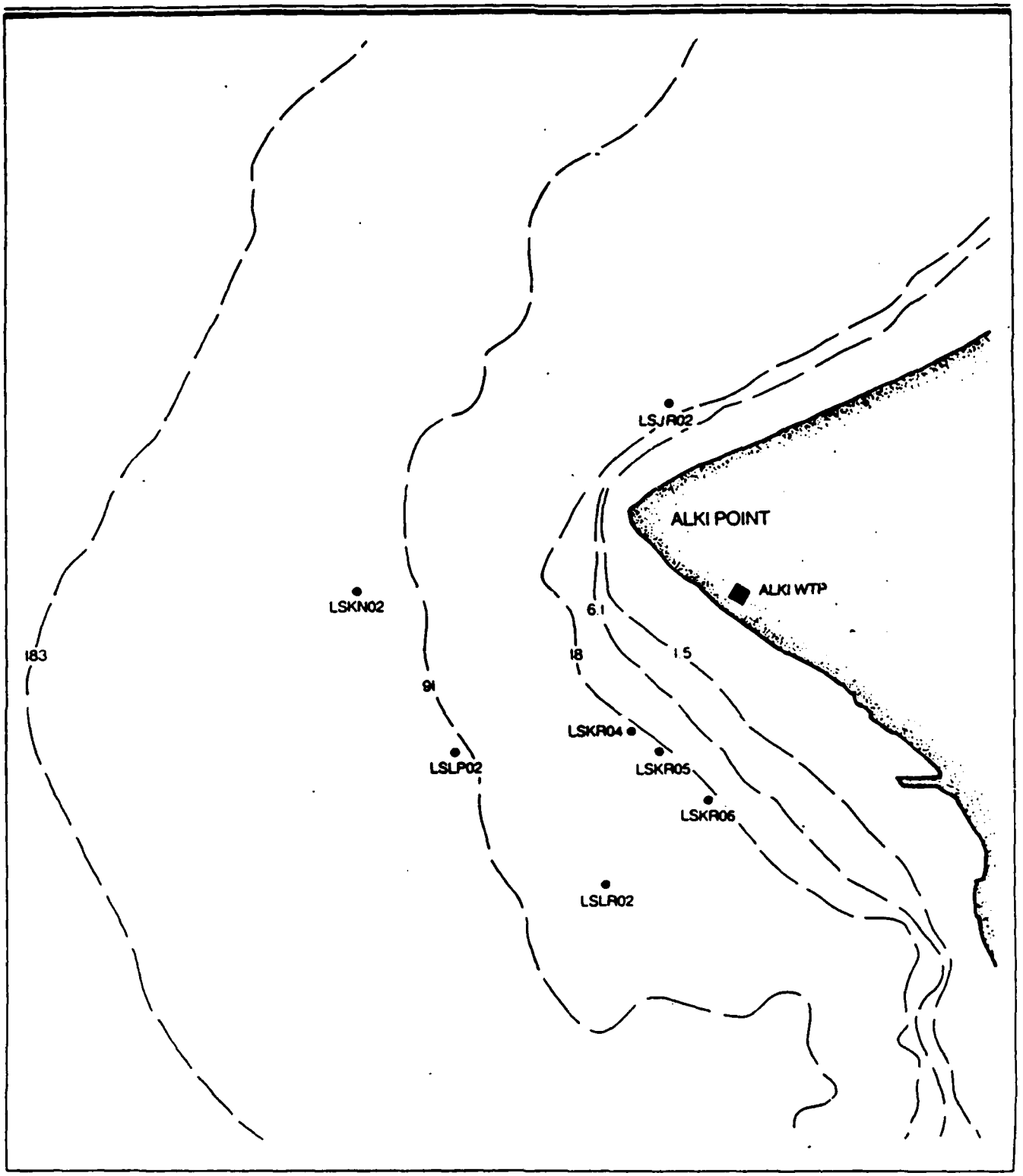


Figure A-18.
Alki Point benthos sampling station locations.
Reference: Osborn et al. 1985.

TABLE A-6. TPPS PHASE 3 A & B[a]

	STATION #			phenol	2,4-dimethylphenol	1,2 diphenylhydrazine	n-nitrosodiphenylamine	acenaphthene	acenaphthylene	anthracene	fluorene	naphthalene	phenanthrene
*	6 EB-30	401230	1824	L[c] 52	U 5	U 5.8	U 4.8	L 37	L 34	79	220	241	241
*	7 EB-30	401230	2081	U[b] 4.3	U 5	U 5.8	U 4.8	25	U 2.7	86	38	93	303
*	6 EB-31	401630	1818	U 4.3	L 24	U 5.8	U 4.8	L 68	L 63	149	418	444	313
*	7 EB-31	401630	2078	U 4.3	U 5	U 5.8	L 7	L 34	25	64	29	172	184
*	6 EB-32	401830	1825	U 4.3	L 30	U 5.8	U 4.8	U 3	U 2.7	174	124	275	367
*	7 EB-32	401830	2077	U 4.3	U 5	U 5.8	L 30	L 61	L 56	82	L 70	152	220
	6 EB-33	401406	1779	U 4.3	U 5	U 5.8	L 132	L 460	L 431	L 49	L 276	L 316	316
	7 EB-33	401406	2080	U 4.3	U 5	U 5.8	U 4.8	U 3	U 2.7	L 65	U 3.4	L 108	203
*	6 EB-34	401512	1780	U 4.3	U 5	U 5.8	U 4.8	L 694	U 2.7	53	L 429	U 1.6	220
*	7 EB-34	401512	2071	U 4.3	U 5	U 5.8	L 46	81	L 46	217	115	133	681
	6 EB-35	401603	1775	U 4.3	U 5	U 5.8	U 4.8	L 304	U 2.7	3936	2683	L 215	4293
	7 EB-35	401603	2079	U 4.3	U 5	U 5.8	276	U 3	L 42	1636	118	U 1.6	2574
	6 EB-36	401606	1776	U 4.3	U 5	U 5.8	L 54	U 3	4013	67	U 3.4	U 1.6	157
	7 EB-36	401606	2072	L 236	U 5	U 5.8	L 308	U 3	U 2.7	U 2.9	L 97	128	U 2.9
*	6 EB-37	401612	1777	U 4.3	U 5	U 5.8	U 4.8	L 78	L 75	98	490	L 52	261
*	7 EB-37	401612	2073	U 4.3	U 5	U 5.8	191	L 57	L 3	1274	86	236	3822
	6 EB-38	401706	1778	U 4.3	U 5	U 5.8	L 61	L 293	L 276	L 67	L 173	U 1.6	232
	7 EB-38	401706	2074	U 4.3	U 5	U 5.8	L 18	85	42	871	218	184	2970
*	6 EB-39	401810	1814	L 40	U 5	U 5.8	U 4.8	804	U 2.7	1080	704	578	1683
*	7 EB-39	401810	2075	U 4.3	U 5	U 5.8	U 4.8	L 43	U 2.7	U 2.9	U 3.4	498	U 2.9
*	6 WP-01	400330	1806	U 4.3	U 5	U 5.8	U 4.8	177	L 31	L 136	150	129	477
	7 WP-01	400330	2088	U 4.3	U 5	U 5.8	U 4.8	L 3	12	16	4	U 1.6	61
*	6 WP-02	400430	1807	U 4.3	U 5	U 5.8	U 4.8	142	247	277	324	308	1032
	7 WP-02	400430	2089	U 4.3	U 5	U 5.8	U 4.8	L 29	50	360	79	139	1166
*	6 WP-03	400510	1788	U 4.3	U 5	U 5.8	U 4.8	U 3	U 2.7	U 2.9	U 3.4	U 1.6	U 2.9
	7 WP-03	400510	2090	U 4.3	U 5	U 5.8	U 4.8	U 3	L 4	4	U 3.4	U 1.6	14
*	6 WP-04	400530	1809	U 4.3	U 5	U 5.8	U 4.8	U 3	U 2.7	124	L 106	U 1.6	187
	7 WP-04	400530	2091	29	U 5	U 5.8	U 4.8	L 10	23	106	14	33	259
*	6 WP-05	400621	1810	U 4.3	U 5	U 5.8	486	U 3	U 2.7	U 2.9	U 3.4	U 1.6	U 2.9
	7 WP-05	400621	2092	U 4.3	U 5	U 5.8	U 4.8	U 3	L 35	63	L 44	U 1.6	298
*	6 WP-06	400712	1811	U 4.3	U 5	U 5.8	L 542	L 64	L 60	203	L 38	L 42	285
	7 WP-06	400712	2084	U 4.3	U 5	U 5.8	U 4.8	4	67	34	15	27	343
*	6 WP-07	400730	1812	U 4.3	U 5	U 5.8	U 4.8	U 3	L 48	78	L 48	U 1.6	397
	7 WP-07	400730	2093	U 4.3	U 5	U 5.8	U 4.8	12	57	189	31	65	392
*	6 WP-08	400810	1813	U 4.3	U 5	U 5.8	U 4.8	L 104	L 91	L 26	L 65	L 65	104
	7 WP-08	400810	2083	U 4.3	U 5	U 5.8	L 3	L 37	L 33	22	45	U 1.6	61
*	6 WP-09	400830	1815	U 4.3	U 5	U 5.8	U 4.8	L 488	L 460	L 21	L 293	U 1.6	84
	7 WP-09	400830	2082	U 4.3	U 5	U 5.8	U 4.8	U 3	U 2.7	L 4	10	U 1.6	135
*	6 WP-10	400210	1787	U 4.3	U 5	U 5.8	L 14	L 35	L 32	517	L 21	U 1.6	401
	7 WP-10	400210	2076	U 4.3	U 5	U 5.8	U 4.8	L 12	51	126	63	U 1.6	383
*	6 WP-11	400310	1789	U 4.3	U 5	U 5.8	L 196	1335	2278	9964	4804	2669	33630
	7 WP-11	400310	2087	U 4.3	U 5	U 5.8	U 4.8	102	643	1273	643	328	3150
	6 WP-12	400275	1786	U 4.3	U 5	U 5.8	L 75	U 3	U 2.7	L 29	L 29	U 1.6	56
	7 WP-12	400275	2069	U 4.3	U 5	U 5.8	L 22	U 3	L 14	U 2.9	U 3.4	U 1.6	U 2.9
	6 WP-13	400375	1784	U 4.3	U 5	U 5.8	U 4.8	U 3	U 2.7	U 2.9	L 222	U 1.6	U 2.9
	7 WP-13	400375	2070	U 4.3	U 5	U 5.8	18	U 3	U 2.7	26	L 24	U 1.6	132
	6 WP-14	400575	1785										
	7 WP-14	400575	2085	U 4.3	U 5	U 5.8	63	L 106	L 95	32	475	U 1.6	124
	6 WP-15	400775	1817	U 4.3	U 5	U 5.8	U 4.8	L 68	U 2.7	74	417	L 45	298
	7 WP-15	400775	2094	U 4.3	U 5	U 5.8	U 4.8	14	20	115	32	126	489
	6 WP-16	400875	1816	U 4.3	U 5	U 5.8	U 4.8	L 3	U 2.7	L 47	L 50	U 1.6	503
	7 WP-16	400875	2086	U 4.3	U 5	U 5.8	U 4.8	L 4	L 17	23	L 24	41	88

	STATION #			dibenzo (a,h)an thracene	benzo(a) anthra- cene	benzo(a)- pyrene	total benzo fluor- anthenes	chrysene	fluor- anthene	indeno (1,2,3-cd) pyrene	pyrene	benzo (ghi) perylene	1,2 di chloro benzene
*	6 EB 30	401230	1824	U 34.4	289	814	1759	1050	446	341	551	656	U 3.5
*	7 EB 30	401230	2081	U 34.4	556	758	3283	631	732	303	707	455	U 3.5
*	6 EB 31	401630	1818	392	339	1305	2794	1201	522	522	653	1071	U 3.5
*	7 EB 31	401630	2078	U 34.4	123	245	270	179	294	64	319	L 54	U 3.5
*	6 EB-32	401830	1825	U 34.4	U 18	U 12.5	U 12.4	U 18	528	U 32.8	688	U 31.7	U 3.5
*	7 EB-32	401830	2077	U 34.4	257	173	185	350	374	68	397	65	U 3.5
	6 EB-33	401406	1779	4023	862	9770	17529	1121	1178	2874	1494	8046	U 3.5
	7 EB-33	401406	2080	U 34.4	U 18	U 12.5	U 12.4	U 18	1703	U 32.8	1189	U 31.7	U 3.5
*	6 EB-34	401512	1780	U 34.4	L 122	9959	18041	L 445	1306	U 32.8	1878	U 31.7	U 3.5
*	7 EB-34	401512	2071	U 34.4	805	1022	1084	1362	1022	341	1424	341	L 8978
	6 EB-35	401603	1775	U 34.4	9481	U 12.5	U 12.4	10376	5367	U 32.8	6440	U 31.7	U 3.5
	7 EB-35	401603	2079	1048	3125	5882	11213	5147	5882	4412	6250	5147	L 18
	6 EB-36	401606	1776	U 34.4	535	903	2475	1605	468	U 32.8	1137	U 31.7	U 3.5
	7 EB-36	401606	2072	U 34.4	138	154	338	277	369	308	718	174	U 3.5
*	6 EB-37	401612	1777	850	621	2092	3791	2255	65	U 32.8	95	1699	U 3.5
*	7 EB-37	401612	2073	U 34.4	5414	2930	4140	7962	11147	L 105	11147	L 115	L 51
	6 EB-38	401706	1778	471	573	976	3570	1552	606	U 32.8	774	808	U 3.5
	7 EB-38	401706	2074	U 34.4	851	990	2574	1802	1624	257	U 7.6	192	U 3.5
*	6 EB-39	401810	1814	U 34.4	905	1432	3266	804	3518	U 32.8	4774	U 31.7	U 3.5
*	7 EB-39	401810	2075	U 34.4	844	1450	3463	1385	1450	2165	2078	2597	U 3.5
*	6 WP 01	400330	1806	L 10	341	490	1294	886	858	150	913	163	U 3.5
	7 WP-01	400330	2088	U 34.4	81	120	110	96	116	41	146	32	U 3.5
*	6 WP-02	400430	1807	U 34.4	740	1002	2640	1171	1572	143	2712	200	U 3.5
	7 WP-02	400430	2089	172	1715	3602	4117	2058	2744	1012	3774	1235	U 3.5
*	6 WP-03	400510	1788	U 34.4	U 18	U 12.5	U 12.4	U 18	U 7.6	U 32.8	U 7.6	U 31.7	U 3.5
	7 WP-03	400510	2090	U 34.4	U 18	65	83	82	76	U 32.8	136	U 31.7	U 3.5
*	6 WP 04	400530	1809	U 34.4	U 18	642	160	227	428	U 32.8	521	U 31.7	U 3.5
	7 WP-04	400530	2091	U 34.4	273	177	273	532	614	191	846	150	U 3.5
*	6 WP-05	400621	1810	U 34.4	U 18	U 12.5	U 12.4	U 18	U 7.6	U 32.8	U 7.6	U 31.7	U 3.5
	7 WP-05	400621	2092	U 34.4	194	323	310	220	401	142	466	142	U 3.5
*	6 WP-06	400712	1811	U 34.4	L 46	L 339	2534	L 33	488	L 136	705	L 271	U 3.5
	7 WP-06	400712	2084	U 34.4	313	194	463	522	746	313	955	284	U 3.5
*	6 WP-07	400730	1812	780	265	1852	3452	1455	622	U 32.8	661	1587	U 3.5
	7 WP 07	400730	2093	U 34.4	1757	1622	1757	2297	1757	2432	2838	2568	U 3.5
*	6 WP-08	400810	1813	U 34.4	298	L 95	1712	L 106	311	389	441	765	U 3.5
	7 WP-08	400810	2083	U 34.4	95	109	136	115	123	L 7	176	10	U 3.5
*	6 WP-09	400830	1815	U 34.4	209	572	1032	725	167	U 32.8	321	L 46	U 3.5
	7 WP-09	400830	2082	U 34.4	162	471	412	250	412	U 32.8	588	U 31.7	U 3.5
*	6 WP 10	400210	1787	L 26	1151	349	1294	4140	1203	362	1811	310	U 3.5
	7 WP-10	400210	2076	71	344	816	855	383	689	523	829	944	U 3.5
*	6 WP-11	400310	1789	L 203	14947	22598	129359	35409	71352	9093	62811	10658	U 3.5
	7 WP-11	400310	2087	1155	4462	6824	8005	6693	6299	5249	7349	5381	U 3.5
	6 WP-12	400275	1786	U 34.4	643	1877	3405	231	260	U 32.8	402	U 31.7	U 3.5
	7 WP-12	400275	2069	U 34.4	235	447	782	279	U 7.6	92	U 7.6	109	U 3.5
	6 WP-13	400375	1784	U 34.4	U 18	L 1263	L 2274	U 18	U 7.6	U 32.8	U 7.6	U 31.7	U 3.5
	7 WP 13	400375	2070	U 34.4	289	500	737	368	342	95	421	129	U 3.5
	6 WP-14	400575	1785										
	7 WP-14	400575	2085	U 34.4	174	L 74	L 113	206	2375	L 185	290	L 201	U 3.5
	6 WP-15	400775	1817	U 34.4	685	2173	3928	2440	714	893	1042	1756	U 3.5
	7 WP 15	400775	2094	U 34.4	402	402	1322	575	833	316	1379	270	U 3.5
	6 WP-16	400875	1816	U 34.4	U 18	651	3077	U 18	1302	U 32.8	1509	U 31.7	U 3.5
	7 WP 16	400875	2086	U 34.4	110	121	161	144	203	L 25	243	L 25	U 3.5

	STATION #			1,3 dichlorobenzene	1,4-dichlorobenzene	hexachlorobutadiene	benzyl butyl phthalate	diethyl phthalate	di n butyl phtha late	dimethyl phthalate	di-n-octyl phthalate	4,4'-DDD	4,4'-DDE
*	6 EB 30	401230	1824	U 4	U 3	U 0.31	160	L 11	108	L 5	244	8	2
*	7 EB 30	401230	2081	U 4	U 3	13	U 7.5	U 3.6	328	U 3.7	L 40	U 0.08	3
*	6 EB 31	401630	1818	U 4	U 3	U 0.31	217	U 3.6	L 13	U 3.7	14386	3	3
*	7 EB 31	401630	2078	U 4	U 3	7	54	51	515	L 10	539	U 0.08	4
*	6 EB-32	401830	1825	U 4	U 3	U 0.31	L 32	L 25	L 32	U 3.7	482	U 0.08	1
*	7 EB-32	401830	2077	U 4	U 3	7	L 58	42	888	L 30	678	U 0.08	5
	6 EB-33	401406	1779	U 4	U 3	U 0.31	1724	U 3.6	L 106	U 3.7	2615	U 0.08	11
	7 EB-33	401406	2080	U 4	U 3	11	U 7.5	U 3.6	405	U 3.7	3243	30	30
*	6 EB-34	401512	1780	U 4	U 3	U 0.31	U 7.5	L 90	531	U 3.7	L 2082	U 0.08	6
*	7 EB-34	401512	2071	U 4	L 7740	22	124	43	310	L 15	1269	U 0.08	22
	6 EB-35	401603	1775	U 4	U 3	U 0.31	U 7.5	U 3.6	2147	U 3.7	9481	175	47
	7 EB-35	401603	2079	U 4	U 3	U 0.31	1820	L 83	2941	L 88	37668	U 0.08	U 0.07
	6 EB-36	401606	1776	U 4	U 3	U 0.31	334	L 23	211	U 3.7	27759	U 0.08	37
	7 EB-36	401606	2072	U 4	U 3	15	67	318	4103	U 3.7	303	U 0.08	10
*	6 EB-37	401612	1777	U 4	U 3	U 0.31	U 7.5	L 29	281	U 3.7	948	U 0.08	9
*	7 EB-37	401612	2073	U 4	L 45	6	178	45	860	U 3.7	13376	U 0.08	14
	6 EB-38	401706	1778	U 4	U 3	U 0.31	U 7.5	L 88	175	U 3.7	1717	U 0.08	7
	7 EB-38	401706	2074	U 4	U 3	2	812	20	832	18	4158	U 0.08	4
*	6 EB-39	401810	1814	U 4	U 3	U 0.31	L 578	L 45	578	U 3.7	6784	U 0.08	8
*	7 EB-39	401810	2075	U 4	U 3	6	U 7.5	U 3.6	L 193	U 3.7	U 7.5	U 0.08	6
*	6 WP-01	400330	1806	U 4	U 3	U 0.31	U 7.5	U 3.6	L 25	U 3.7	U 7.5	U 0.08	5
	7 WP-01	400330	2088	U 4	U 3	1	11	9	112	L 20	173	U 0.08	L 0.3
*	6 WP-02	400430	1807	U 4	U 3	U 0.31	L 20	U 3.6	200	L 17	431	U 0.08	1
	7 WP-02	400430	2089	U 4	U 3	2	L 34	L 17	103	L 31	L 5	U 0.08	L 3
*	6 WP-03	400510	1788	U 4	U 3	U 0.31	U 7.5	U 3.6	L 14	U 3.7	L 352	U 0.08	0.1
	7 WP-03	400510	2090	U 4	U 3	U 0.31	12	11	423	U 3.7	423	U 0.08	L 0.4
*	6 WP-04	400530	1809	U 4	U 3	U 0.31	U 7.5	U 3.6	L 28	U 3.7	414	U 0.08	0.1
	7 WP-04	400530	2091	U 4	U 3	11	U 7.5	97	164	U 3.7	205	L 0.3	1
*	6 WP-05	400621	1810	U 4	U 3	U 0.31	U 7.5	U 3.6	187	U 3.7	461	U 0.08	U 0.07
	7 WP-05	400621	2092	U 4	U 3	4	U 7.5	L 23	1423	U 3.7	246	U 0.08	U 0.07
*	6 WP-06	400712	1811	U 4	U 3	U 0.31	U 7.5	L 50	L 45	U 3.7	1165	U 0.08	1
	7 WP-06	400712	2084	U 4	U 3	3	U 7.5	22	194	U 3.7	254	L 0.5	1
*	6 WP-07	400730	1812	U 4	U 3	U 0.31	L 11	L 11	198	U 3.7	489	U 0.08	2
	7 WP-07	400730	2093	U 4	U 3	7	U 7.5	L 8	1622	U 3.7	500	U 0.08	1
*	6 WP-08	400810	1813	U 4	U 3	U 0.31	L 17	L 10	101	U 3.7	L 259	U 0.08	1
	7 WP-08	400810	2083	U 4	U 3	5	26	47	2035	U 3.7	258	L 1	3
*	6 WP-09	400830	1815	U 4	U 3	U 0.31	L 11	L 8	73	L 4	181	10	3
	7 WP-09	400830	2082	U 4	U 3	U 0.31	U 7.5	12	162	U 3.7	235	L 0.4	2
*	6 WP-10	400210	1787	U 4	U 3	U 0.31	U 7.5	U 3.6	L 43	L 23	2329	U 0.08	1
	7 WP-10	400210	2076	U 4	U 3	U 0.31	23	17	94	U 3.7	3571	U 0.08	L 0.1
*	6 WP-11	400310	1789	U 4	U 3	U 0.31	U 7.5	U 3.6	U 2.4	U 3.7	1423	12	3
	7 WP-11	400310	2087	U 4	U 3	L 0.3	U 7.5	L 9	262	U 3.7	U 7.5	2	1
	6 WP-12	400275	1786	U 4	U 3	U 0.31	U 7.5	U 3.6	U 2.4	U 3.7	6166	U 0.08	2
	7 WP-12	400275	2069	U 4	U 3	6	307	50	475	U 3.7	249	U 0.08	U 0.07
	6 WP-13	400375	1784	U 4	U 3	U 0.31	U 7.5	U 3.6	U 2.4	U 3.7	L 530	U 0.08	9
	7 WP-13	400375	2070	U 4	U 3	5	L 26	18	4474	U 3.7	2605	U 0.08	L 5
	6 WP 14	400575	1785										
	7 WP 14	400575	2085	U 4	U 3	U 0.31	259	U 3.6	844	L 18	68602	L 1	L 2
	6 WP 15	400775	1817	U 4	U 3	U 0.31	U 7.5	L 27	247	U 3.7	625	U 0.08	1
	7 WP 15	400775	2094	U 4	U 3	U 11	287	57	402	L 9	1264	U 0.08	3
	6 WP 16	400875	1816	U 4	U 3	U 0.31	U 7.5	U 3.6	L 89	U 3.7	1331	12	5
	7 WP 16	400875	2086	U 4	U 3	6	28	51	339	L 11	367	L 0.3	1

	STATION #			4,4' DDT	total PCBs[d]	2,4,6-trichlorophenol	pentachlorophenol	2,6-dinitrotoluene	1,2,4-trichlorobenzene	hexachlorobenzene	hexachloroethane	hexachlorocyclopentadiene	bis(2-ethylhexyl)phthalate
*	6 EB 30	401230	1824	U 0.10	404	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB 30	401230	2081	U 0.10	230	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 EB 31	401630	1818	U 0.10	454	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB 31	401630	2078	U 0.10	255	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 EB-32	401830	1825	U 0.10	117	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB-32	401830	2077	14	327	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 EB 33	401406	1779	U 0.10	1060	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 EB-33	401406	2080	L 1	2280	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 EB-34	401512	1780	U 0.10	955	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB-34	401512	2071	77	2070	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 EB-35	401603	1775	U 0.10	3940	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 EB-35	401603	2079	U 0.10	965	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 EB-36	401606	1776	U 0.10	3970	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 EB-36	401606	2072	15	487	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 EB-37	401612	1777	U 0.10	915	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB-37	401612	2073	67	1130	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 EB-38	401706	1778	U 0.10	730	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 EB-38	401706	2074	28	315	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 EB-39	401810	1814	U 0.10	925	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	7 EB-39	401810	2075	48	468	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-01	400330	1806	U 0.10	109	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-01	400330	2088	1	15	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-02	400430	1807	U 0.10	79	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-02	400430	2089	U 0.10	149	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-03	400510	1788	U 0.10	18	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP 03	400510	2090	U 0.10	25	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-04	400530	1809	1	123	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-04	400530	2091	2	68	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP 05	400621	1810	U 0.10	11	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-05	400621	2092	U 0.10	U 0.5	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-06	400712	1811	U 0.10	49	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-06	400712	2084	U 0.10	70	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-07	400730	1812	U 0.10	151	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP 07	400730	2093	10	130	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-08	400810	1813	U 0.10	77	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-08	400810	2083	U 0.10	161	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-09	400830	1815	U 0.10	251	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-09	400830	2082	L 1	130	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-10	400210	1787	U 0.10	53	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-10	400210	2076	U 0.10	41	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
*	6 WP-11	400310	1789	U 0.10	1080	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP 11	400310	2087	U 0.10	131	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 WP 12	400275	1786	U 0.10	102	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-12	400275	2069	U 0.10	106	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 WP 13	400375	1784	U 0.10	480	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP-13	400375	2070	U 0.10	87	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 WP-14	400575	1785										
	7 WP 14	400575	2085	U 0 10	145	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 WP 15	400775	1817	U 0.10	146	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP 15	400775	2094	11	221	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	6 WP 16	400875	1816	U 0 10	275	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10
	7 WP 16	400875	2086	U 0.10	76	U 23	U 209	U 230	U 10	U 20	U 12	U 110	U 10

	STATION #			antimony	arsenic	beryllium	cadmium	chromium	copper	lead	mercury	nickel	selenium
*	6 EB-30	401230	1824	0.50	13	0.36	0.25	54	62	55	0.43	32	L 0.20
*	7 EB-30	401230	2081	0.67	14	0.40	0.46	47	50	81	0.29	38	0.30
*	6 EB-31	401630	1818	0.80	12	0.45	0.23	37	55	68	0.63	27	L 0.33
*	7 EB-31	401630	2078	0.53	8.0	0.070	0.050	11	13	30	0.060	13	L 0.20
*	6 EB-32	401830	1825	1.0	10	0.44	0.30	47	50	62	0.53	31	0.20
*	7 EB-32	401830	2077	0.67	11	0.24	0.14	47	46	72	0.34	43	0.34
	6 EB-33	401406	1779	3.2	8.8	0.33	0.99	60	130	89	0.98	44	0.48
	7 EB-33	401406	2080	1.5	15	0.35	2.1	61	87	210	1.0	44	L 0.20
*	6 EB-34	401512	1780	2.3	12	0.30	0.32	48	52	54	1.6	40	0.56
*	7 EB-34	401512	2071	0.67	13	0.37	0.39	57	55	94	0.34	51	L 0.20
	6 EB-35	401603	1775	3.3	15	0.21	0.46	63	120	670	1.6	41	L 0.20
	7 EB-35	401603	2079	2.4	16	0.24	2.2	57	120	430	1 3	49	L 0.20
	6 EB-36	401606	1776	1.3	12	0.41	0.15	63	57	88	0.77	56	0.40
	7 EB 36	401606	2072	0.46	9.1	0.16	0.34	45	34	49	0.22	50	L 0.20
*	6 EB 37	401612	1777	3.7	16	0.30	0.70	60	62	90	0.72	48	0.78
*	7 EB-37	401612	2073	1.0	14	0.11	0.36	59	54	98	3.6	50	L 0.20
	6 EB-38	401706	1778	3.2	15	0.40	0.86	59	61	95	0.62	49	0.48
	7 EB-38	401706	2074	0.60	12	0.20	0.63	53	54	100	0.72	58	L 0.20
*	6 EB-39	401810	1814	1.0	12	0.37	0.47	54	82	82	0.65	39	L 0.20
*	7 EB-39	401810	2075	0.94	11	0.18	0.33	49	58	120	0.61	45	L 0.20
*	6 WP-01	400330	1806	0.80	9.2	0.26	0.33	36	32	51	0.20	36	L 0.20
	7 WP-01	400330	2086	L 0.30	6.1	0.32	0.10	45	15	22	0.17	24	0.37
*	6 WP-02	400430	1807	0.30	7.2	0.51	0.43	38	37	43	0.58	31	L 0.20
	7 WP-02	400430	2089	0.33	8.4	0.26	0.10	48	25	27	0.22	34	0.70
*	6 WP-03	400510	1788	1.3	4.0	0.12	0.080	8.9	13	13	0.14	21	L 0.20
	7 WP-03	400510	2090	L 0.30	1.9	0.16	0.080	20	7.6	10	L 0.050	23	L 0.20
*	6 WP-04	400530	1809	0.80	3.2	0.19	0.060	13	17	18	0.11	18	L 0.20
	7 WP-04	400530	2091	0.33	4.5	0.24	0.070	26	14	28	0.080	24	0.30
*	6 WP-05	400621	1810	L 0.30	15	0.11	0.070	24	12	14	L 0.050	23	L 0.20
	7 WP-05	400621	2092	0.60	4.2	0.16	L 0.010	18	6.3	13	L 0.050	19	L 0.20
*	6 WP-06	400712	1811	0.40	1.4	0.23	0.14	21	34	42	0.13	18	L 0.20
	7 WP-06	400712	2084	0.40	6.8	0.24	0.080	33	14	24	0.11	28	L 0.20
*	6 WP-07	400730	1812	0.30	4.7	0.41	0.23	16	20	12	0.22	23	L 0.20
	7 WP-07	400730	2093	0.33	5.3	0.34	0.030	23	13	23	0.090	26	L 0.20
*	6 WP-08	400810	1813	0.70	13	0.22	0.10	24	33	17	0.15	8.3	L 0.20
	7 WP-08	400810	2083	0.33	3.8	0.21	0.030	21	10	13	0.47	19	L 0.20
*	6 WP-09	400830	1815	L 0.30	29	0.28	0.18	62	28	19	L 0.050	47	L 0.20
	7 WP-09	400830	2082	0.33	6.8	0.33	0.14	42	21	21	0.11	40	L 0.20
*	6 WP-10	400210	1787	0.60	5.2	0.15	0.070	17	29	19	0.15	17	L 0.20
	7 WP-10	400210	2076	0.33	3.0	0.090	0.15	19	7.2	13	L 0.050	25	L 0.20
*	6 WP 11	400310	1789	1.3	6.8	0.20	0.40	37	27	31	0.37	31	L 0.20
	7 WP-11	400310	2087	0.33	3.8	0.21	0.10	29	11	17	0.27	32	L 0.20
	6 WP-12	400275	1786	0.40	11	0.47	0.35	40	36	35	0.36	27	0.78
	7 WP-12	400275	2069	0.33	10	0.49	0.20	50	35	39	0.11	39	0.80
	6 WP-13	400375	1784	3 0	12	0.49	0.31	43	39	33	0.34	30	0 78
	7 WP 13	400375	2070	0 40	9.5	0.34	0.40	45	34	40	0.11	42	0.59
	6 WP 14	400575	1785	1 9	12	0.50	0.33	48	41	42	0.39	33	63
	7 WP-14	400575	2085	0 33	11	0.36	0.11	53	40	44	0 88	40	0 90
	6 WP 15	400775	1817	0 80	8.9	0 47	0 34	39	46	35	0.33	30	0 56
	7 WP 15	400775	2094	0 33	9.9	0 47	0 11	52	40	43	0.20	36	1 7
	6 WP 16	400875	1816	0 50	9 4	0 42	0 47	63	74	290	0 33	44	0 56
	7 WP 16	400875	2086	L 0 30	12	0.40	0.10	51	38	38	0 13	40	0 43

	STATION #			silver	thallium	zinc	iron	manganese	% total organic carbon	% silt	% clay	TOX CODE	BENTHIC CODE	MICRO CODE
*	6 EB 30	401230	1824	3.9	L 0.10	100	35000	420	1.0	81.5	0	0	0	0
*	7 EB 30	401230	2081	0.24	L 0.10	100	30000	380	0.40	82.7	0	0	0	0
*	6 EB 31	401630	1818	3.6	L 0.10	120	31000	380	1.7	95.9	0	0	0	0
*	7 EB 31	401630	2078	0.050	L 0.10	50	14000	130	0.04	93.3	0	0	0	0
*	6 EB 32	401830	1825	2.3	L 0.10	110	32000	340	1.2	90.6	0	0	0	0
*	7 EB 32	401830	2077	0.74	L 0.10	100	30000	330	0.40	83.1	0	0	0	0
	6 EB 33	401406	1779	4.6	L 0.10	140	31000	300	0.90	82.1	0	0	3	0
	7 EB 33	401406	2080	1.1	L 0.10	170	30000	310	0.60	80.6	0	0	3	0
*	6 EB 34	401512	1780	3.4	L 0.10	100	25000	300	0.67	93.6	0	0	0	0
*27	EB-34	401512	2071	2.1	L 0.10	110	25000	280	0.50	89.8	0	0	0	0
	6 EB 35	401603	1775	4.1	L 0.10	300	19000	220	0.77	31.9	0	0	2	0
	7 EB 35	401603	2079	0.94	L 0.10	260	19000	200	0.44	38.8	0	0	2	0
	6 EB 36	401606	1776	5.4	L 0.10	150	31000	400	0.60	86.6	0	0	2	0
	7 EB 36	401606	2072	1.3	L 0.10	86	19000	210	0.62	80.0	0	0	3	0
*	6 EB 37	401612	1777	3.9	L 0.10	120	32000	330	1.3	72.2	0	0	0	0
*	7 EB 37	401612	2073	1.5	L 0.10	110	25000	300	0.50	80.3	0	0	0	0
	6 EB 38	401706	1778	5.2	L 0.10	130	37000	420	1.3	86.6	0	0	1	0
	7 EB 38	401706	2074	2.2	L 0.10	110	26000	310	1.2	62.1	0	0	3	0
*	6 EB-39	401810	1814	2.1	L 0.10	120	28000	580	0.92	78.7	0	0	0	0
*	7 EB-39	401810	2075	2.4	L 0.10	120	24000	300	0.14	69.6	0	0	0	0
*	6 WP 01	400330	1806	2.8	L 0.10	72	29000	390	0.53	18.9	0	0	0	0
	7 WP-01	400330	2088	0.24	L 0.10	52	23000	440	0.14	16.3	0	0	1	0
*	6 WP-02	400430	1807	4.2	L 0.10	120	32000	520	0.80	29.4	0	0	0	0
	7 WP-02	400430	2089	0.45	L 0.10	68	18000	380	0.27	24.0	0	0	1	0
*	6 WP 03	400510	1788	1.0	L 0.10	45	16000	200	0.42	10.5	0	0	0	0
	7 WP-03	400510	2090	0.030	L 0.10	29	10000	160	0.18	4.7	0	0	2	0
*	6 WP 04	400530	1809	1.0	L 0.10	59	22000	580	1.2	16.4	0	0	0	0
	7 WP-04	400530	2091	0.21	L 0.10	45	15000	340	0.16	9.0	0	0	1	0
*	6 WP-05	400621	1810	0.050	0.10	57	11000	500	0.31	7.1	0	0	0	0
	7 WP-05	400621	2092	L 0.020	L 0.10	26	12000	420	0.15	2.4	0	0	1	0
*	6 WP-06	400712	1811	1.3	L 0.10	78	21000	570	1.4	14.1	0	0	0	0
	7 WP-06	400712	2084	0.20	L 0.10	54	17000	520	0.28	9.7	0	0	1	0
*	6 WP-07	400730	1812	2.9	L 0.10	81	39000	420	0.18	10.5	0	0	0	0
	7 WP-07	400730	2093	0.060	L 0.10	38	16000	460	0.27	5.1	0	0	1	0
*	6 WP-08	400810	1813	1.1	L 0.10	51	16000	380	0.50	8.8	0	0	0	0
	7 WP-08	400810	2083	0.030	L 0.10	32	13000	630	0.06	5.9	0	0	1	0
*	6 WP-09	400830	1815	0.21	L 0.10	86	28000	650	0.48	41.5	0	0	0	0
	7 WP-09	400830	2082	0.28	L 0.10	71	26000	1000	0.20	18.6	0	0	1	0
*	6 WP 10	400210	1787	1.0	L 0.10	46	20000	340	0.38	12.6	0	0	0	0
	7 WP-10	400210	2076	0.030	L 0.10	38	12000	360	0.08	4.8	0	0	1	0
*	6 WP 11	400310	1789	1.6	L 0.10	83	19000	280	0.60	23.4	0	0	0	0
	7 WP-11	400310	2087	0.24	L 0.10	42	13000	190	0.10	6.7	0	0	1	0
	6 WP-12	400275	1786	3.7	L 0.10	120	32000	580	0.95	91.2	0	0	1	0
	7 WP-12	400275	2069	0.51	L 0.10	100	32000	460	0.70	96.6	0	0	1	0
	6 WP-13	400375	1784	3.7	L 0.10	110	36000	520	0.90	91.8	0	0	1	0
	7 WP-13	400375	2070	0.56	L 0.10	100	29000	380	0.26	88.5	0	0	1	0
	6 WP 14	400575	1785	3.7	L 0.10	120	34000	630	0.75	96.2		0	1	0
	7 WP 14	400575	2085	0.61	L 0.10	140	30000	380	0.59	91.1	0	0	1	0
	6 WP 15	400775	1817	3.3	L 0.10	120	28000	430	0.76	97.0	0	0	1	0
	7 WP 15	400775	2094	0.58	L 0.10	98	30000	450	0.45	92.9	0	0	1	0
	6 WP 16	400875	1816	5.0	L 0.10	130	27000	410	1.3	95.9	0	0	2	0
	7 WP 16	400875	2086	0.58	L 0.10	110	30000	500	0.75	93.2	0	0	1	0

* These stations were not used for developing sediment quality values as appropriate biological reference stations were not available.

a. Reference:
Romberg, G.P., S.P. Pavlou, and E.A. Crecelius. 1984. Presence, distribution, and fate of toxicants in Puget Sound and Lake Washington. METRO Toxicant Program Report No. 6A. Toxicant Pretreatment Planning Study Technical Report C1. Municipality of Metropolitan Seattle, Seattle, WA. 231 pp.

b. U = Undetected at detection limit shown. Detection limits are from Romberg et al. 1984.

c. L = Less than the value shown. For purposes of this report, these were considered undetected.

d. Total PCBs are the sum of detected Aroclors.

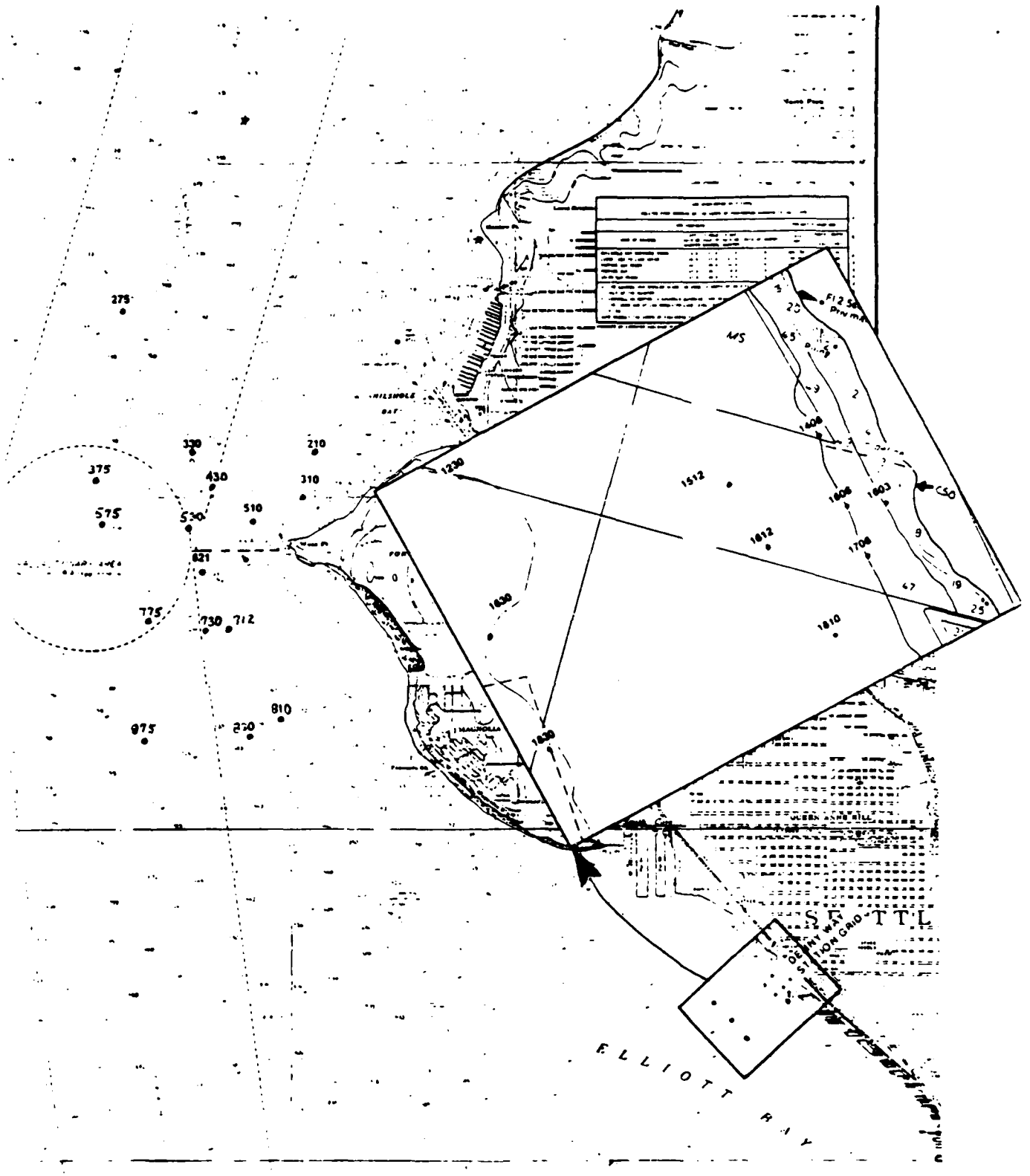


Figure A-19. MAP SHOWING THE 26 STATIONS IN THE CENTRAL BASIN OF PUGET SOUND AND ELLIOTT BAY SAMPLED DURING PHASE III OF THE TPPS PROGRAM.
Note: These are "corrected" station locations based on a miniranger survey and some may vary from those illustrated in subsequent figures. The corresponding station numbers listed in Table A-6 have 40 or 400 preceeding the station numbers shown on this map.

Reference: Romberg et al. 1984.

TABLE A 7 EVERETT HARBOR[a]

STATION #		naphtha lene	1,1' biphenyl	acenaph- thylene	acenaph- thene	fluorene	dibenzo- thio- phene	phenan- threne	anthra- cene	1-methyl phenan threne	fluor- anthene	pyrene
8 EV-20	EEW-1	1045	44	U 6	558	315	150	779	168	68	838	562
8 EV-21	EEW-2	1762	8	U 6	64	33	9	94	12	9	74	110
8 EV-22	EEW-3	94	11	18	35	41	44	192	80	77	272	299
8 EV-23	EEW-4	17	U[b] 6	6	9	16	22	92	26	62	154	464
8 EV 24	EEW 5	76	16	25	25	12	U 6	229	61	U 6	246	1029
8 EV-25	EEW 6	345	18	43	40	61	39	222	90	96	348	447

STATION #		benzo(a) anthra- cene	chrysene	total benzo- fluor- anthenes	benzo(a) pyrene	indeno- (1,2 3-cd) pyrene	dibenzo- (a,h)an- thracene	benzo- (ghi) perylene	% silt	% clay	% total organic carbon	% total volatile solids
8 EV-20	EEW-1	371	306	274	170	U 6	U 6	U 6	50.0	20.1	0.78	3.06
8 EV-21	EEW-2	15	U 6	9	12	U 6	U 6	U 6	35.3	10.1	0.88	3.14
8 EV-22	EEW-3	117	134	395	609	U 6	U 6	U 6	50.3	15.5	1.39	4.89
8 EV-23	EEW-4	124	141	111	103	U 6	U 6	U 6	51.3	11.3	0.77	3.30
8 EV-24	EEW-5	205	210	818	1030	U 6	U 6	U 6	48.7	14.0	1.36	4.67
8 EV-25	EEW 6	320	252	546	829	U 6	U 6	U 6	30.3	12.5	1.37	4.90

STATION #		mercury	cadmium	copper	zinc	lead	arsenic	DEPTH (m)	TOX CODE	BENTHIC CODE	MICRO CODE
8 EV-20	EEW-1	0.08	0.30	41.6	80.5	14.6	7.9	11.7	1	0	0
8 EV-21	EEW-2	0.06	0.26	39.9	72.5	14.7	8.6	9.5	1	0	0
8 EV-22	EEW-3	0.09	0.42	47.2	81.0	14.9	12.5	10.2	1	0	0
8 EV-23	EEW-4	0.06	0.37	37.2	71.2	16.1	10.0	9.1	1	0	0
8 EV-24	EEW-5	0.10	0.46	59.6	80.2	21.5	9.1	10.1	1	0	0
8 EV-25	EEW-6	0.08	0.36	36.0	69.4	18.8	9.2	9.7	1	0	0

a. Reference:
U.S. Department of the Navy. 1985. Final environmental impact statement. Carrier Battle Group Puget Sound region ship homeporting project. Technical Appendix. Vol. 2. Prepared for U.S. Department of the Navy, Western Division, Naval Facilities Engineering Command, San Bruno, CA.

b. U = Undetected at detection limit shown. Detection limits are estimates based on concentrations of detected chemicals. No detection limits are provided in the Navy report.

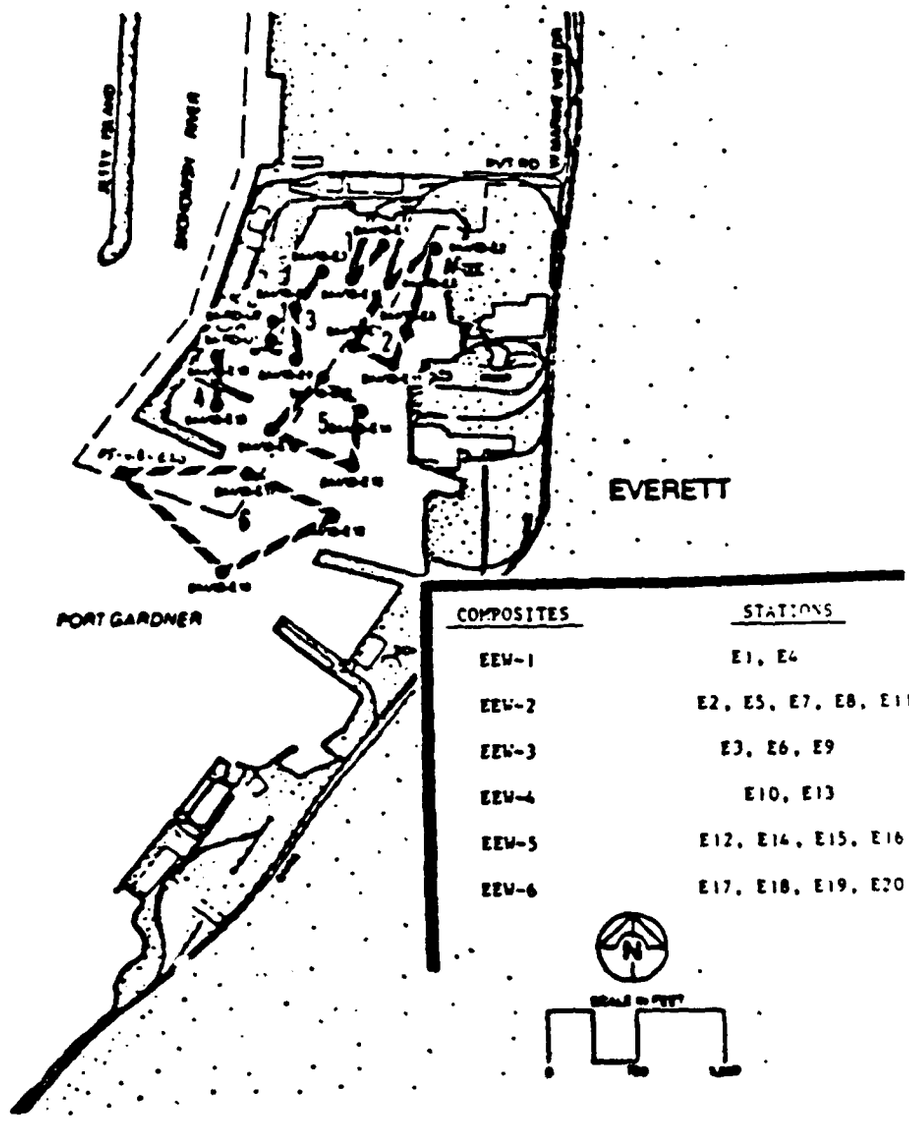


Figure A-20. Sediment sampling locations in the East Waterway.

Reference: U.S. Navy 1985.

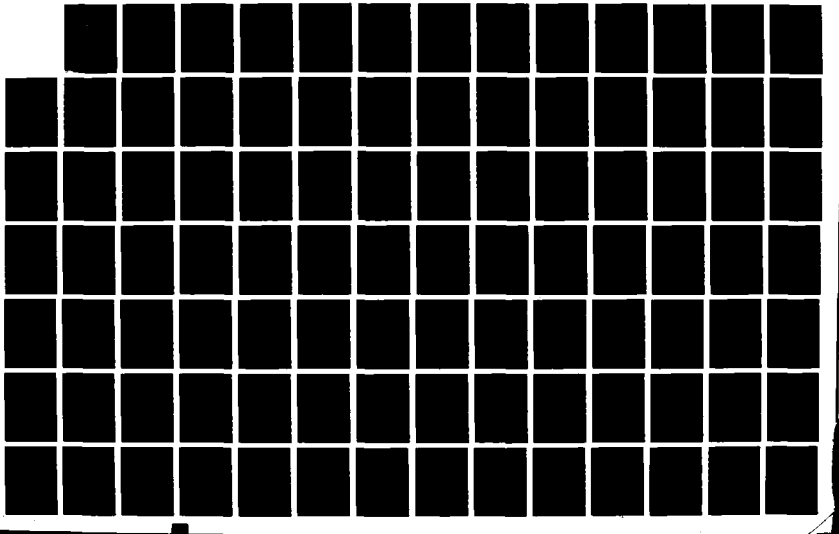
TABLE A H DUWAMISH RIVER II[a]

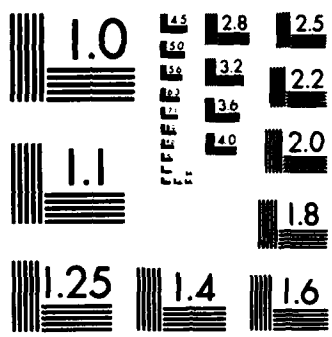
STATION #		total PCBs	naphthalene	2 methyl naphthalene	1,1' biphenyl	acenaphthene	fluorene	phenanthrene	anthracene	1 methyl phenanthrene	fluoranthene
9 DR-10	CA1	5400	1400	390	11	71	98	970	170	70	1400
9 DR-11	CA2	530	200	49	8.9	60	60	300	130	32	620
9 DR-12	CA3	24	7.4	6.1	2.8	7.7	6.8	32	2.0	1.9	9.2
9 DR-13	CB1	M[b] 215	M 201	M 73.4	MU16.5	M 32	M 26.4	M 128	M 61	M 7.4	M 125
9 DR-14	CB2	150	660	200	78	480	480	1500	170	68	850
9 DR-15	CB3	15	5.7	U 2.9	U 2.5	U 2.5	U 2.2	11	2.8	2.0	13
9 DR-16	CB4	19	U[c] 3.5	U 3.7	U 3.1	U 3.1	U 2.7	2.6	U 2.2	2.3	U 2.0
9 DR-17	CB5	M 14.9	MU 3.1	MU 3.2	MU 2.7	MU2.7	MU 2.4	M 6.1	MU 2.5	MU 1.9	MU 2.3
9 DR-18	CC1	74	69	45	6.5	18	26	160	50	37	210
9 DR-19	CC2	330	520	120	29	140	120	310	120	14	460
9 DR-20	CC3	15	U 2.8	U 2.8	U 2.5	U 2.5	U 2.2	12	U 1.9	U 1.7	22
9 DR 21	CC4	22	32	17	U 2.4	U 2.4	U 2.1	17	U 1.8	U 1.7	36
9 DR-22	CC5	180	58	18	U 1.3	19	12	88	30	7.7	150
9 DR-23	CD1	1800	120	41	U 4.1	67	26	330	95	14	61
9 DR-24	CD2	16	9.5	U 3.9	U 3.3	U 3.3	U 2.9	15	3.7	U 2.3	21
9 DR-25	CE1	790	190	77	11	150	150	810	140	51	960
9 DR-26	CE2	170	160	69	9.0	79	75	290	53	24	270
9 DR-27	CE3	40	75	25	U 4.5	40	32	190	25	13	160
9 DR-28	CF1	2500	360	190	54	400	320	1000	280	82	1900
9 DR-29	CF2	2200	80	39	6.4	47	29	240	100	72	680
9 DR-30	CF3	650	180	130	23	26	27	130	53	33	200
9 DR-31	CF4	560	130	51	7.4	41	33	220	76	33	380
9 DR-32	CF5	88	8.9	6.0	U 2.7	U 2.7	U 2.4	21	5.9	U 1.8	38
9 DR-33	CG1	1200	46	27	U 1.6	25	17	170	66	26	430
9 DR-34	CG2	1300	46	32	5.0	29	15	200	79	28	440
9 DR-35	CG3	620	44	23	6.1	34	22	100	32	18	190
9 DR-36	CG4	1500	100	41	U 2.0	45	30	170	73	24	290
9 DR 37	CG5	8.7	U 1.7	U 1.7	U 1.4	U 1.3	U 1.2	U 1.0	U 0.99	U 0.93	U 0.89
9 DR-38	CH1	1400	40	26	5.2	34	17	160	90	29	380
9 DR-39	CW/A1	M 124	M 75	M 15	MU 3.7	M 35	M 36	M 355	M 84	M 42	M 540
9 SQ-21	SEQUIM	37	7.0	16	U 2.8	U 2.8	3.9	48	2.0	U 1.9	63

STATION #		pyrene	benzo(a) anthracene	chrysene	benzo(a) pyrene	dibenzo (a,h)anthracene	hexa chloro-benzene	4,4'-DDE	4,4'-DDD	4,4' DDT
9 DR-10	CA1	1700	590	1000	390	46	0.66	41	38	U 1.2
9 DR 11	CA2	790	280	480	170	51	U 0.15	4.1	7.8	U 0.53
9 DR-12	CA3	4.6	3.2	2.5	U 2.1	U 2.0	0.66	U 0.071	U 0.14	U 0.15
9 DR 13	CB1	M 350	M 177	M 355	M 280	M 38	M 0.26	M 0.93	M 3.6	MU0.19
9 DR-14	CB2	780	220	330	160	14	0.21	0.61	6.1	U 0.21
9 DR-15	CB3	38	4.2	4.7	3.1	U 2.6	U 0.087	U 0.082	U 0.14	U 0.31
9 DR-16	CB4	U 2.0	U 1.9	U 2.0	U 2.0	U 1.8	0.54	U 0.083	U 0.16	U 0.17
9 DR-17	CB5	MU 1.8	MU2.8	MU 3.1	MU2.8	MU7.3	MU0.092	MU0.087	MU0.14	MU0.56
9 DR-18	CC1	770	92	180	110	11	0.15	0.26	1.9	U 0.32
9 DR-19	CC2	830	190	370	150	19	U 0.14	1.4	4.3	U 0.33
9 DR-20	CC3	40	U 2.8	U 3.1	U 2.9	U 3.3	U 0.089	U 0.081	U 0.15	U 0.12
9 DR-21	CC4	36	2.0	3.0	U 1.9	U 2.2	U 0.084	U 0.075	U 0.14	U 0.12
9 DR-22	CC5	250	180	200	54	U 2.6	U 0.16	0.94	2.4	U 0.21
9 DR-23	CD1	1200	500	810	470	97	1.2	11	29	0.44
9 DR-24	CD2	60	5.7	8.1	5.8	U 3.4	U 0.10	U 0.095	0.22	U 0.14
9 DR-25	CE1	870	250	510	150	23	0.27	4.0	14	U 0.41
9 DR-26	CE2	280	87	200	54	17	U 0.12	1.1	2.3	U 0.30
9 DR-27	CE3	100	25	20	3.7	U 3.8	0.24	2.3	3.4	U 0.21
9 DR-28	CF1	1700	920	860	320	50	0.77	15	43	0.96
9 DR-29	CF2	880	450	700	240	22	0.65	15	35	0.69
9 DR-30	CF3	340	120	230	69	11	U 0.14	3.3	9.2	U 0.85
9 DR-31	CF4	600	240	550	150	21	U 0.14	3.6	24	0.49
9 DR-32	CF5	56	12	15	8.2	U 3.2	U 0.092	0.30	0.32	U 0.14
9 DR-33	CG1	580	340	530	230	20	0.24	10	14	U 0.23
9 DR-34	CG2	580	230	420	210	29	0.40	7.2	16	U 0.35
9 DR-35	CG3	310	320	260	69	U 5.5	0.24	5.6	15	2.4
9 DR-36	CG4	830	170	460	160	U 3.2	U 0.25	9.9	25	U 0.33
9 DR-37	CG5	U 0.87	U 1.0	U 1.1	U 1.1	U 1.3	U 0.15	U 0.12	U 0.25	U 0.20
9 DR-38	CH1	470	850	440	130	33	0.38	0.83	14	U 0.38
9 DR-39	CW/A1	M 830	M 250	M 410	M 370	M 67	MU0.094	M 0.72	M 2.3	M 0.67
9 SQ 21	SEQUIM	45	7.2	7.9	4.1	U 3.0	U 0.28	0.26	0.52	U 0.38

AD-A184 867 DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND 4/6
VOLUME 1(U) TETRA TECH INC BELLEVUE WA SEP 86
TC3090-02-VOL-1 DACW67-85-D-0029

UNCLASSIFIED F/G 24/3 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

	STATION #		arsenic	cadmium	copper	lead	mercury	zinc	total volatile solids	total organic carbon	% silt	TOX CODE	BENTHIC CODE	MICRO CODE
9	DR-10	CA1	2.9	2.4	83	130	0.83	202	4.67	1.42	50.27	3	0	0
9	DR-11	CA2	7.2	0.97	45	82	0.29	78.2	3.94	0.99	68.00	3	0	0
9	DR-12	CA3	1.2	U 0.05	8.7	5.5	0.08	18.4	1.41	0.59	4.63	1	0	0
9	DR-13	CB1	4.3	0.18	28	86	0.42	58.4	1.49	0.55	12.94	1	0	0
9	DR-14	CB2	3.6	0.13	39	700	0.37	83.9	3.83	0.83	21.15	1	0	0
9	DR-15	CB3	M 3.1	M 0.07	M 17	M 18	M 0.06	M 30.7	M 1.53	M 0.35	M 19.66	1	0	0
9	DR-16	CB4	3.5	U 0.05	20	4.4	0.14	34.2	1.71	0.35	37.88	3	0	0
9	DR-17	CB5	2.7	0.05	18	6.0	0.04	26	1.81	0.34	48.07	1	0	0
9	DR-18	CC1	3.0	0.09	19	14	0.07	30.7	1.50	0.38	15.61	1	0	0
9	DR-19	CC2	4.6	0.30	38	50	0.23	66.1	2.12	2.10	15.25	1	0	0
9	DR-20	CC3	1.7	0.11	13	22	0.08	24.6	2.50	0.39	26.25	1	0	0
9	DR-21	CC4	2.5	U 0.05	15	15	0.05	27.8	M 1.71	M 0.45	13.68	1	0	0
9	DR-22	CC5	3.1	U 0.05	15	6.0	0.02	21.3	2.26	0.61	31.84	1	0	0
9	DR-23	CD1	24	1.36	115	103	0.68	188	6.20	1.36	65.42	1	0	0
9	DR-24	CD2	1.7	U 0.05	16	19	0.05	22.5	1.86	M 0.45	14.20	1	0	0
9	DR-25	CE1	29	1.73	76	131	0.33	523	4.97	0.72	51.59	3	0	0
9	DR-26	CE2	M 47	M 2.64	M 63	M 128	M 0.15	M 1211	M 3.74	M 0.57	36.58	3	0	0
9	DR-27	CE3	57.	10.4	66	128	2.3	2600	3.87	0.52	31.66	3	0	0
9	DR-28	CF1	19	1.68	74	94	0.23	203	5.04	2.00	58.23	1	0	0
9	DR-29	CF2	16	1.79	96	130	0.46	336	6.26	1.66	79.64	1	0	0
9	DR-30	CF3	3.3	0.36	37	62	0.27	74.8	3.90	1.06	22.01	1	0	0
9	DR-31	CF4	7.4	0.61	63	77	0.33	126	M 5.16	M 1.34	75.62	1	0	0
9	DR-32	CF5	2.9	0.15	18	26	0.08	39	2.03	0.70	39.23	1	0	0
9	DR-33	CG1	13	0.58	96	95	0.23	167	6.28	1.25	68.2	1	0	0
9	DR-34	CG2	9.3	0.4	79	87	0.28	141	5.97	1.20	79.85	1	0	0
9	DR-35	CG3	M 10	M 0.31	M 48	M 56	M 0.58	M 86.4	M 5.08	M 1.20	M 61.04	1	0	0
9	DR-36	CG4	7.9	0.35	59	71	1.1	116	5.64	1.36	69.49	1	0	0
9	DR-37	CG5	7.1	0.12	32	39	0.11	56.7	3.64	M 1.04	55.6	1	0	0
9	DR-38	CH1	8.8	1.16	65	91	0.11	130	M 7.50	1.62	78.74	1	0	0
9	DR-39	CW/A1	13	2.05	55	50	0.85	110	2.18	1.11	17.77	1	0	0
9	SQ-21	SEQUIM										1	0	0

a. Reference:
Chan, S.-L., M.H. Schiewe, D.W. Brown. 1985. Analyses of sediment samples for U.S. Army Corps of Engineers East, West and Duwamish Waterway navigation improvement project operations and maintenance sampling and testing of Duwamish River sediments. Unpublished data.

b. M = mean of replicate measurements.

c. U = undetected at detection limit shown.

APPENDIX B

STATION LISTINGS OF CHEMICALS EXCEEDING SEDIMENT QUALITY VALUES

APPENDIX B. STATION LISTINGS OF CHEMICALS EXCEEDING SEDIMENT QUALITY VALUES

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STATION LISTINGS OF CHEMICALS EXCEEDING SEDIMENT QUALITY VALUES

The dry weight values are those found in the original data reports (see Appendix A). Organic carbon and fines normalized values are calculated and not adjusted for the proper number of significant figures (i.e., typically 2).

Toxicity, benthic, and microtox codes are indicated for all stations. The toxicity code is defined as:

0 = No data available

1 = No significant[a] oyster larvae abnormality or amphipod mortality

2 = Significant[a] oyster larvae abnormality

3 = Significant[a] amphipod mortality

4 = Both significant[a] oyster larvae abmnormality and amphipod mortality.

The benthic code is defined as:

0 = No data available

1 = No significant[a] depressions in benthic infaunal abundances

2 = Significant[a] depressions in benthic infaunal abundances of one major taxonomic group

3 = Significant[a] depressions in benthic infaunal abundances of more than one major taxonomic group.

The microtox code is defined as:

0 = No data available

1 = No significant[a] decrease in bacterial luminescence

2 = Significant[a] decrease in bacterial luminescence.

[a] Significance implies statistically significant difference ($P>0.05$) from reference conditions.

TABLE B-1. STATION LISTING OF ORGANIC CARBON NORMALIZED CHEMICALS EXCEEDING EQUILIBRIUM PARTITIONING SEDIMENT QUALITY VALUES

Organics expressed as ppb organic carbon, metals ppm organic carbon

Group: 1 Station: HY-22
Toxicity code: 4 Benthic code: 3 Microtox code 2

	Concentration OC
total PCBs	45045.0

Group: 1 Station: HY-23
Toxicity code: 4 Benthic code: 3 Microtox code 2

	Concentration OC
total PCBs	39682.5

Group: 1 Station: HY-37
Toxicity code: 1 Benthic code: 2 Microtox code 2

	Concentration OC
total PCBs	16935.5

Group: 1 Station: HY-42
Toxicity code: 3 Benthic code: 1 Microtox code 2

	Concentration OC
total PCBs	46025.1

Group: 2 Station: B04
Toxicity code: 1 Benthic code: 1 Microtox code 0

	Concentration OC
4,4'-DDT	234

Group: 2 Station: B15
Toxicity code: 3 Benthic code: 1 Microtox code 0

	Concentration OC
4,4'-DDT	391.89

Group: 3 Station: EB-09
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	18644.1

Group: 3 Station: EB-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	33645.8

Group: 3 Station: EB-20
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	46043.2

Group: 3 Station: EB-22
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	35595.9

Group: 3 Station: EB-23
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	13333.3

Group: 3 Station: SC-06
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	42764.5

Group: 3 Station: SC-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	27735.8

Group: 3 Station: SC-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	22508.7

Group: 3 Station: SC-14
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	55000.0

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
4,4'-DDT	1222.22

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	177272.7

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

	Concentration OC
total PCBs	117777.8

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

	Concentration OC
fluoranthene	697013.0
total PCBs	511688.3

Group: 6 Station: EB-36
Toxicity code: 0 Benthic code: 2 Microtox code 0

	Concentration OC
total PCBs	661666.7

Group: 6 Station: EB-38
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	56153.8

Group: 6 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	53333.3

Group: 6 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	19210.5

Group: 6 Station: WP-16
Toxicity code: 0 Benthic code: 2 Microtox code 0

	Concentration OC
total PCBs	21153.8

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

	Concentration OC
total PCBs	380000.0

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

	Concentration OC
fluoranthene	1336818
total PCBs	219318.2

Group: 7 Station: EB-36
Toxicity code: 0 Benthic code: 3 Microtox code 0

	Concentration OC
diethyl phthalate	51290.3
total PCBs	78548.4
4,4'-DDT	2419.35

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

	Concentration OC
total PCBs	26250.0
4,4'-DDT	2333.33

Group: 7 Station: WP-01
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
4,4'-DDT	714.29

Group: 7 Station: WP-02
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
fluoranthene	1016296
total PCBs	55185.2

Group: 7 Station: WP-03
Toxicity code: 0 Benthic code: 2 Microtox code 0

	Concentration OC
total PCBs	13888.9

Group: 7 Station: WP-04
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
diethyl phthalate	60625.0
total PCBs	42500.0
4,4'-DDT	1250.00

Group: 7 Station: WP-06
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	25000.0

Group: 7 Station: WP-07
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
fluoranthene	650740
total PCBs	48148.1
4,4'-DDT	3703.70

Group: 7 Station: WP-08
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
diethyl phthalate	78333.3
total PCBs	268333.3

Group: 7 Station: WP-09
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	65000.0
4,4'-DDT	500.00

Group: 7 Station: WP-10
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
fluoranthene	861250.0
total PCBs	51250.0

Group: 7 Station: WP-11
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
phenanthrene	3150000
fluoranthene	6299000
total PCBs	131000.0

Group: 7 Station: WP-12
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	15142.9

Group: 7 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	33461.5

Group: 7 Station: WP-14
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	24576.3

Group: 7 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

	Concentration OC
total PCBs	49111.1
4,4'-DDT	2444.44

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	380281.7

Group: 9 Station: DR-11
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	53535.4

Group: 9 Station: DR-13
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	39090.9

Group: 9 Station: DR-14
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	18072.3

Group: 9 Station: DR-18
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	19473.7

Group: 9 Station: DR-19
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	15714.3

Group: 9 Station: DR-22
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	29508.2

Group: 9 Station: DR-23
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	132352.9

Group: 9 Station: DR-25
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	109722.2

Group: 9 Station: DR-26
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	29824.6

Group: 9 Station: DR-27
Toxicity code: 3 Benthic code: 0 Microtox code 0

	Concentration OC
dieldrin	577
heptachlor	904
lindane	692

Group: 9 Station: DR-28
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	125000.0

Group: 9 Station: DR-29
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	132530.1

Group: 9 Station: DR-30
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	61320.8

Group: 9 Station: DR-31
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	41791.0

Group: 9 Station: DR-32
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	12571.4

Group: 9 Station: DR-33
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	96000.0

Group: 9 Station: DR-34
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	108333.3

Group: 9 Station: DR-35
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	51666.7

Group: 9 Station: DR-36
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	110294.1

Group: 9 Station: DR-38
Toxicity code: 1 Benthic code: 0 Microtox code 0

	Concentration OC
total PCBs	86419.8

TABLE B-2. STATION LISTING OF CHEMICALS EXCEEDING DRY WEIGHT NORMALIZED AET

Organics expressed as ppb dry weight, metals ppm dry weight

Group: 1 Station: BL-13
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
butyl benzyl phthalate	83.0

Group: 1 Station: CI-11
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration DW
phenol	1100
benzo(ghi)perylene	780.0
1,4-dichlorobenzene	290.0
benzyl alcohol	140
lead	725

Oyster	Concentration DW
phenol	1100
phenanthrene	1800
benzo(ghi)perylene	780.0
1,4-dichlorobenzene	290.0
benzyl alcohol	140
lead	725
nickel	40.0

Benthic	Concentration DW
1,4-dichlorobenzene	290.0
benzyl alcohol	140
lead	725
zinc	325.0

Microtox	Concentration DW
phenanthrene	1800
fluoranthene	2400
chrysene	1600.0
benzo(ghi)perylene	780.0
1,2-dichlorobenzene	37.0
1,4-dichlorobenzene	290.0
benzyl alcohol	140
lead	725
mercury	.53
High molecular wt. PAH	13090.0
Chlorinated benzenes	327.0

Group: 1 Station: CI-13
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration DW
bis(2-ethylhexyl)phthalate	3100.0
benzoic acid	690
mercury	1.10
Total phthalates	3548.0

Benthic	Concentration DW
bis(2-ethylhexyl)phthalate	3100.0
benzoic acid	690
cadmium	6.70
lead	450
mercury	1.10

Microtox	Concentration DW
bis(2-ethylhexyl)phthalate	3100.0
butyl benzyl phthalate	210.0
total PCBs	140.0
benzoic acid	690
mercury	1.10
Total phthalates	3548.0

Group: 1 Station: CI-16
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration DW
N-nitrosodiphenylamine	220.0
1,2-dichlorobenzene	350.0
1,4-dichlorobenzene	260.0
di-n-butyl phthalate	1600.0
4-methylphenol	1200
Chlorinated benzenes	667.0

Benthic	Concentration DW
2,4-dimethylphenol	50.0
N-nitrosodiphenylamine	220.0
1,2-dichlorobenzene	350.0
1,4-dichlorobenzene	260.0
4-methylphenol	1200
Chlorinated benzenes	667.0

Microtox	Concentration DW
N-nitrosodiphenylamine	220.0
1,2-dichlorobenzene	350.0
1,4-dichlorobenzene	260.0
di-n-butyl phthalate	1600.0
4-methylphenol	1200
Chlorinated benzenes	667.0

Group: 1 Station: CI-17
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
fluoranthene	1900
1,4-dichlorobenzene	119.0

Group: 1 Station: CI-20
Toxicity code: 4 Benthic code: 1 Microtox code 1

Amphipod	Concentration DW
phenol	1200
1,1'-biphenyl	270.0
dibenzothiophene	250.0

Oyster	Concentration DW
phenol	1200
1,1'-biphenyl	270.0
dibenzothiophene	250.0

Group: 1 Station: HY-12
Toxicity code: 2 Benthic code: 1 Microtox code 2

Oyster	Concentration DW
phenol	500
benzo(ghi)perylene	740.0
dibenzo(a,h)anthracene	260.0
di-n-butyl phthalate	5100.0
Total phthalates	5100.0

Microtox	Concentration DW
chrysene	1800.0
benzo(ghi)perylene	740.0
di-n-butyl phthalate	5100.0
mercury	.46
Total phthalates	5100.0

Group: 1 Station: HY-14
Toxicity code: 1 Benthic code: 2 Microtox code 2

Microtox	Concentration DW
fluoranthene	2500
chrysene	2800.0
benzo(ghi)perylene	720.0
High molecular wt. PAH	16650.0

Group: 1 Station: HY-17
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration DW
benzo(a)pyrene	2400.0
Total benzofluoranthenes	3700
pyrene	4300
tetrachloroethene	210
ethylbenzene	50
total xylenes	160
High molecular wt. PAH	18402.0

Benthic	Concentration DW
tetrachloroethene	210
ethylbenzene	50
total xylenes	160
arsenic	86.0
zinc	268.0

Microtox	Concentration DW
fluoranthene	3900
benzo(a)pyrene	2400.0
chrysene	2700.0
ethylbenzene	50
total PCBs	170.0
total xylenes	160
High molecular wt. PAH	18402.0

Group: 1 Station: HY-22
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration DW
benzo(a)anthracene	2300.0
benzo(a)pyrene	6100.0
Total benzofluoranthenes	8500
dibenzo(a,h)anthracene	1500
indeno(1,2,3-cd)pyrene	2700.0
1,2,4-trichlorobenzene	260.0
hexachlorobenzene	730.0
hexachlorobutadiene	730.0
dibenzothiophene	320.0
1-methylphenanthrene	530.0
High molecular wt. PAH	30000.0
Chlorinated benzenes	1328.0

Oyster	Concentration DW
phenol	530
benzo(a)anthracene	2300.0
benzo(a)pyrene	6100.0
Total benzofluoranthenes	8500
dibenzo(a,h)anthracene	1500
indeno(1,2,3-cd)pyrene	2700.0
1,2,4-trichlorobenzene	260.0
1,2-dichlorobenzene	73.0
1,4-dichlorobenzene	180.0
hexachlorobutadiene	730.0
bis(2-ethylhexyl)phthalate	3000.0
total PCBs	2000.0
nickel	52.0
dibenzothiophene	320.0
1-methylphenanthrene	530.0
High molecular wt. PAH	30000.0
Total phthalates	3560.0
Chlorinated benzenes	1328.0

Benthic	Concentration DW
Total benzofluoranthenes	8500
dibenzo(a,h)anthracene	1500
1,2,4-trichlorobenzene	260.0
hexachlorobenzene	730.0
1,2-dichlorobenzene	73.0
1,4-dichlorobenzene	180.0
hexachlorobutadiene	730.0
bis(2-ethylhexyl)phthalate	3000.0
total PCBs	2000.0
arsenic	90.0
dibenzothiophene	320.0
1-methylphenanthrene	530.0
Chlorinated benzenes	1328.0

Microtox	Concentration DW
fluoranthene	3600
benzo(a)pyrene	6100.0
chrysene	2700.0
1,2,4-trichlorobenzene	260.0
hexachlorobenzene	730.0
1,2-dichlorobenzene	73.0
1,4-dichlorobenzene	180.0
hexachlorobutadiene	730.0
bis(2-ethylhexyl)phthalate	3000.0
total PCBs	2000.0
mercury	.50
dibenzothiophene	320.0
1-methylphenanthrene	530.0
High molecular wt. PAH	30000.0
Total phthalates	3560.0
Chlorinated benzenes	1328.0

Group: 1 Station: HY-23
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration DW
phenanthrene	2300
benzo(ghi)perylene	1100.0
dibenzo(a,h)anthracene	440.0
dimethyl phthalate	350.0

Oyster	Concentration DW
phenanthrene	2300
benzo(a)pyrene	2000.0
benzo(ghi)perylene	1100.0
dibenzo(a,h)anthracene	440.0
dimethyl phthalate	350.0
tetrachloroethene	170
total PCBs	1500.0
nickel	56.0

Benthic	Concentration DW
dimethyl phthalate	350.0
tetrachloroethene	170
total PCBs	1500.0

Microtox	Concentration DW
phenanthrene	2300
fluoranthene	2500
benzo(a)pyrene	2000.0
chrysene	2300.0
benzo(ghi)perylene	1100.0
hexachlorobutadiene	170.0
butyl benzyl phthalate	110.0
dimethyl phthalate	350.0
total PCBs	1500.0
total xylenes	110
High molecular wt. PAH	13790.0

Group: 1 Station: HY-24
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
chrysene	2300.0
hexachlorobutadiene	140.0
butyl benzyl phthalate	470.0
dimethyl phthalate	120.0
total PCBs	250.0
mercury	.49

Group: 1 Station: HY-37
Toxicity code: 1 Benthic code: 2 Microtox code 2

Microtox	Concentration DW
1,2,4-trichlorobenzene	34.0
hexachlorobenzene	96.0
hexachlorobutadiene	130.0
total PCBs	420.0
Chlorinated benzenes	203.0

Group: 1 Station: HY-42
Toxicity code: 3 Benthic code: 1 Microtox code 2

Amphipod	Concentration DW
1,2,4-trichlorobenzene	64.0
hexachlorobenzene	230.0

Microtox	Concentration DW
chrysene	1800.0
1,2,4-trichlorobenzene	64.0
hexachlorobenzene	230.0
hexachlorobutadiene	270.0
total PCBs	1100.0
Chlorinated benzenes	395.0

Group: 1 Station: HY-43
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
1,2,4-trichlorobenzene	51.0
hexachlorobenzene	130.0
hexachlorobutadiene	180.0
ethylbenzene	37
total xylenes	120
Chlorinated benzenes	274.2

Group: 1 Station: HY-47
Toxicity code: 2 Benthic code: 2 Microtox code 2

Oyster	Concentration DW
1,4-dichlorobenzene	120.0
hexachlorobutadiene	290.0
di-n-butyl phthalate	1500.0

Benthic	Concentration DW
1,4-dichlorobenzene	120.0
hexachlorobutadiene	290.0

Microtox	Concentration DW
1,2,4-trichlorobenzene	51.0
hexachlorobenzene	100.0
1,4-dichlorobenzene	120.0
hexachlorobutadiene	290.0
di-n-butyl phthalate	1500.0
Chlorinated benzenes	312.0

Group: 1 Station: HY-50
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
benzyl alcohol	73

Group: 1 Station: MI-13
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
dimethyl phthalate	110.0
FINES	.89

Group: 1 Station: RS-13
Toxicity code: 4 Benthic code: 1 Microtox code 1

Amphipod	Concentration DW
2-methylphenol	72

Oyster	Concentration DW
2-methylphenol	72

Group: 1 Station: RS-18
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration DW
N-nitrosodiphenylamine	610.0
acenaphthene	2500.0
anthracene	1400.0
phenanthrene	11000
fluorene	3100.0
fluoranthene	8100
benzo(a)anthracene	3200.0
benzo(a)pyrene	4000.0
Total benzofluoranthenes	4200
chrysene	4700.0
dibenzo(a,h)anthracene	320.0
indeno(1,2,3-cd)pyrene	770.0
pyrene	5600
2-methylphenol	71
dibenzofuran	2000
2-methylnaphthalene	1200
antimony	420.0
arsenic	9700.0
cadmium	184.00
copper	11400
iron	52900
lead	6250
manganes	748
thallium	3.20
zinc	3320.0
mercury	52.00
1,1'-biphenyl	1100.0
dibenzothiophene	1100.0
1-methylphenanthrene	1300.0
Low molecular wt. PAH	20190.0
High molecular wt. PAH	30890.0

Oyster	Concentration DW
N-nitrosodiphenylamine	610.0
acenaphthene	2500.0
anthracene	1400.0
phenanthrene	11000
fluorene	3100.0
benzo(a)anthracene	3200.0
benzo(a)pyrene	4000.0
Total benzofluoranthenes	4200
chrysene	4700.0
dibenzo(a,h)anthracene	320.0
indeno(1,2,3-cd)pyrene	770.0
pyrene	5600
1,4-dichlorobenzene	250.0
2-methylphenol	71
dibenzofuran	2000
2-methylnaphthalene	1200
antimony	420.0
arsenic	9700.0
cadmium	184.00
copper	11400
iron	52900
lead	6250
manganes	748
nickel	93.0
thallium	3.20
zinc	3320.0
mercury	52.00
1,1'-biphenyl	1100.0
dibenzothiophene	1100.0
1-methylphenanthrene	1300.0
Low molecular wt. PAH	20190.0
High molecular wt. PAH	30890.0

Benthic	Concentration DW
N-nitrosodiphenylamine	610.0
acenaphthene	2500.0
anthracene	1400.0
phenanthrene	11000
fluorene	3100.0
fluoranthene	8100
1,4-dichlorobenzene	250.0
dibenzofuran	2000
2-methylnaphthalene	1200
antimony	420.0
arsenic	9700.0
cadmium	184.00
copper	11400
iron	52900
lead	6250
thallium	3.20
zinc	3320.0
mercury	52.00
1,1'-biphenyl	1100.0
dibenzothiophene	1100.0
1-methylphenanthrene	1300.0
Low molecular wt. PAH	20190.0

Microtox	Concentration DW
N-nitrosodiphenylamine	610.0
acenaphthene	2500.0
anthracene	1400.0
phenanthrene	11000
fluorene	3100.0
fluoranthene	8100
benzo(a)pyrene	4000.0
chrysene	4700.0
1,4-dichlorobenzene	250.0
dibenzofuran	2000
2-methylnaphthalene	1200
antimony	420.0
arsenic	9700.0
cadmium	184.00
copper	11400
iron	52900
lead	6250
manganes	748
thallium	3.20
zinc	3320.0
mercury	52.00
1,1'-biphenyl	1100.0
dibenzothiophene	1100.0
1-methylphenanthrene	1300.0
Low molecular wt. PAH	20190.0
High molecular wt. PAH	30890.0
Chlorinated benzenes	268.0

Group: 1 Station: RS-19
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration DW
antimony	36.00
arsenic	1550.0
cadmium	16.00
copper	2240
lead	1020
thallium	.46
zinc	906.0
mercury	3.20

Oyster	Concentration DW
di-n-butyl phthalate	1600.0
antimony	36.00
arsenic	1550.0
cadmium	16.00
copper	2240
lead	1020
thallium	.46
mercury	3.20

Benthic	Concentration DW
arsenic	1550.0
cadmium	16.00
copper	2240
lead	1020
thallium	.46
zinc	906.0
mercury	3.20

Microtox	Concentration DW
di-n-butyl phthalate	1600.0
antimony	36.00
arsenic	1550.0
cadmium	16.00
copper	2240
lead	1020
thallium	.46
mercury	3.20

Group: 1 Station: RS-20
Toxicity code: 1 Benthic code: 2 Microtox code 2

Benthic	Concentration DW
arsenic	90.0

Microtox	Concentration DW
mercury	.59

Group: 1 Station: RS-24
Toxicity code: 3 Benthic code: 0 Microtox code 1

Amphipod	Concentration DW
antimony	26.00
arsenic	700.0
cadmium	9.60
iron	37100
manganes	484
zinc	1620.0

Group: 1 Station: SI-11
Toxicity code: 1 Benthic code: 2 Microtox code 2

Benthic	Concentration DW
arsenic	93.0
lead	661
zinc	491.0

Microtox	Concentration DW
lead	661

Group: 1 Station: SI-12
Toxicity code: 3 Benthic code: 2 Microtox code 2

Benthic	Concentration DW
N-nitrosodiphenylamine	130.0
lead	496
zinc	337.0

Microtox	Concentration DW
N-nitrosodiphenylamine	130.0

Group: 1 Station: SI-15
Toxicity code: 3 Benthic code: 1 Microtox code 1

Amphipod	Concentration DW
1-methylphenanthrene	370.0

Group: 1 Station: SP-12
Toxicity code: 2 Benthic code: 1 Microtox code 2

Microtox	Concentration DW
benzyl alcohol	61

Group: 1 Station: SP-14
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration DW
phenol	1700
naphthalene	4400.0
4-methylphenol	96000
2-methylnaphthalene	810
manganes	556
total volatile solids	44.70
total organic carbon	16.00
1,1'-biphenyl	310.0
Low molecular wt. PAH	6065.0

Oyster	Concentration DW
phenol	1700
naphthalene	4400.0
4-methylphenol	96000
2-methylnaphthalene	810
manganes	556
nickel	40.0
total volatile solids	44.70
total organic carbon	16.00
1,1'-biphenyl	310.0
Low molecular wt. PAH	6065.0

Benthic	Concentration DW
phenol	1700
naphthalene	4400.0
4-methylphenol	96000
2-methylnaphthalene	810
total volatile solids	44.70
total organic carbon	16.00
1,1'-biphenyl	310.0

Microtox	Concentration DW
phenol	1700
naphthalene	4400.0
4-methylphenol	96000
2-methylnaphthalene	810
manganes	556
total volatile solids	44.70
total organic carbon	16.00
1,1'-biphenyl	310.0
Low molecular wt. PAH	6065.0

Group: 1 Station: SP-15
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration DW
4-methylphenol	2600

Oyster	Concentration DW
4-methylphenol	2600

Benthic	Concentration DW
4-methylphenol	2600

Microtox	Concentration DW
4-methylphenol	2600

Group: 1 Station: SP-16
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration DW
benzyl alcohol	130

Oyster	Concentration DW
4-methylphenol	890
benzyl alcohol	130

Benthic	Concentration DW
4-methylphenol	890
benzyl alcohol	130

Microtox	Concentration DW
4-methylphenol	890
benzyl alcohol	130

Group: 2 Station: B15
Toxicity code: 3 Benthic code: 1 Microtox code 0

Amphipod	Concentration DW
4,4'-DDT	5.8

Group: 3 Station: EV-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
fluoranthene	4800
thallium	.50

Group: 3 Station: EV-04
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenol	1400
acenaphthene	3300.0
naphthalene	5900.0
acenaphthylene	770.0
phenanthrene	4700
fluorene	2100.0
fluoranthene	4100
zinc	1074.0
total volatile solids	35.06
total organic carbon	15.42
Low molecular wt. PAH	17180.0

Group: 3 Station: SC-20
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenanthrene	8900
fluorene	980.0
fluoranthene	5200
benzo(a)anthracene	1900.0
benzo(ghi)perylene	1000.0
pyrene	6400
Low molecular wt. PAH	11080.0
High molecular wt. PAH	20140.0

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
4,4'-DDT	22.0

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
acenaphthylene	2400
total PCBs	3900.0
4,4'-DDD	71.00

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW
N-nitrosodiphenylamine	132.0
benzo(a)pyrene	9770.0
Total benzofluoranthenes	17529
benzo(ghi)perylene	8046.0
dibenzo(a,h)anthracene	4023
butyl benzyl phthalate	1724
mercury	.98
4,4'-DDE	11.00

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW
anthracene	3936.0
phenanthrene	4293
fluorene	2683.0
benzo(a)anthracene	9481.0
chrysene	10376
total PCBs	3940.0
lead	670
zinc	300.0
mercury	1.60
4,4'-DDE	47.00
4,4'-DDD	175.00
Low molecular wt. PAH	11431.0

Group: 6 Station: EB-36
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW
acenaphthylene	4013
total PCBs	3970.0
silver	5.40
4,4'-DDE	37.00

Group: 6 Station: WP-16
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW
4,4'-DDD	12.00

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW
total PCBs	2280.0
mercury	1.00
4,4'-DDE	30.00
4,4'-DDD	30.00

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW
N-nitrosodiphenylamine	276.0
anthracene	1636.0
Total benzofluoranthenes	11213
butyl benzyl phthalate	1820
lead	430
zinc	260.0
mercury	1.30

Group: 7 Station: EB-36
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW
N-nitrosodiphenylamine	308.0
diethyl phthalate	318.0
4,4'-DDT	15.0
4,4'-DDE	10.00

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW
butyl benzyl phthalate	812.0
4,4'-DDT	28.0

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	5400.0
4,4'-DDE	41.00

Group: 9 Station: DR-26
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
zinc	1211.0

Group: 9 Station: DR-27
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
cadmium	10.40
zinc	2600.0
mercury	2.30

TABLE B-3. STATION LISTING OF CHEMICALS EXCEEDING ORGANIC CARBON NORMALIZED AET

Organics expressed as ppb organic carbon, metals ppm organic carbon

Group: 1 Station: BL-31
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration OC
phenol	38532.1

Group: 1 Station: CI-11
Toxicity code: 4 Benthic code: 2 Microtox code 2

Oyster	Concentration OC
1,4-dichlorobenzene	3273.1

Group: 1 Station: CI-13
Toxicity code: 2 Benthic code: 3 Microtox code 2

Microtox	Concentration OC
bis(2-ethylhexyl)phthalate	47692.3

Group: 1 Station: CI-16
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration OC
1,2-dichlorobenzene	3211.0

Benthic	Concentration OC
1,2-dichlorobenzene	3211.0

Microtox	Concentration OC
1,2-dichlorobenzene	3211.0

Group: 1 Station: HY-22
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration OC
benzo(a)pyrene	137387.4
dibenzo(a,h)anthracene	33783.8
indeno(1,2,3-cd)pyrene	60810.8
hexachlorobenzene	16441.4
hexachlorobutadiene	16441.4
Chlorinated benzenes	29909.9

Oyster	Concentration OC
benzo(a)pyrene	137387.4
dibenzo(a,h)anthracene	33783.8
indeno(1,2,3-cd)pyrene	60810.8
1,2,4-trichlorobenzene	5855.9
hexachlorobenzene	16441.4
1,4-dichlorobenzene	4054.1
hexachlorobutadiene	16441.4
bis(2-ethylhexyl)phthalate	67567.6
Chlorinated benzenes	29909.9

Benthic	Concentration OC
hexachlorobutadiene	16441.4
bis(2-ethylhexyl)phthalate	67567.6
Chlorinated benzenes	29909.9
1,2,4-trichlorobenzene	5855.9
hexachlorobenzene	16441.4

Microtox	Concentration OC
dibenzo(a,h)anthracene	33783.8
1,2,4-trichlorobenzene	5855.9
hexachlorobenzene	16441.4
hexachlorobutadiene	16441.4
bis(2-ethylhexyl)phthalate	67567.6
total PCBs	45045.0
Chlorinated benzenes	29909.9

Group: 1 Station: HY-23
Toxicity code: 4 Benthic code: 3 Microtox code 2

Microtox	Concentration OC
hexachlorobutadiene	4497.4
total PCBs	39682.5

Group: 1 Station: HY-24
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration OC
butyl benzyl phthalate	9179.7

Group: 1 Station: HY-37
Toxicity code: 1 Benthic code: 2 Microtox code 2

Microtox	Concentration OC
1,2,4-trichlorobenzene	1371.0
hexachlorobenzene	3871.0
hexachlorobutadiene	5241.9
total PCBs	16935.5

Group: 1 Station: HY-42
Toxicity code: 3 Benthic code: 1 Microtox code 2

Amphipod	Concentration OC
hexachlorobenzene	9623.4

Microtox	Concentration OC
1,2,4-trichlorobenzene	2677.8
hexachlorobenzene	9623.4
hexachlorobutadiene	11297.1
total PCBs	46025.1

Group: 1 Station: HY-43
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration OC
1,2,4-trichlorobenzene	1764.7
hexachlorobenzene	4498.3
hexachlorobutadiene	6228.4

Group: 1 Station: HY-47
Toxicity code: 2 Benthic code: 2 Microtox code 2

Oyster	Concentration OC
1,2,4-trichlorobenzene	2771.7
1,4-dichlorobenzene	6521.7
hexachlorobutadiene	15760.9

Benthic	Concentration OC
hexachlorobutadiene	15760.9
1,2,4-trichlorobenzene	2771.7

Microtox	Concentration OC
1,2,4-trichlorobenzene	2771.7
hexachlorobenzene	5434.8
hexachlorobutadiene	15760.9

Group: 1 Station: MI-13
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration OC
2,4-dimethylphenol	1336.4

Group: 1 Station: RS-13
Toxicity code: 4 Benthic code: 1 Microtox code 1

Amphipod	Concentration OC
fluorene	71014.5
fluoranthene	188405.8
benzo(a)anthracene	159420.3
benzo(a)pyrene	142029.0
Total benzofluoranthenes	434782.6
chrysene	202898.6
dibenzo(a,h)anthracene	33333.3
indeno(1,2,3-cd)pyrene	86956.5
1,4-dichlorobenzene	15942.0
2-methylphenol	10434.8
4-methylphenol	81159.4
dibenzofuran	57971.0
2-methylnaphthalene	63768.1
Low molecular wt. PAH	528985.5
High molecular wt. PAH	1488406
1,1'-biphenyl	11594.2
1-methylphenanthrene	28985.5

Oyster	Concentration OC
acenaphthene	56521.7
naphthalene	173913.0
phenanthrene	159420.3
fluorene	71014.5
fluoranthene	188405.8
benzo(a)anthracene	159420.3
benzo(a)pyrene	142029.0
Total benzofluoranthenes	434782.6
chrysene	202898.6
benzo(ghi)perylene	66666.7
dibenzo(a,h)anthracene	33333.3
indeno(1,2,3-cd)pyrene	86956.5
1,2-dichlorobenzene	2318.8
1,4-dichlorobenzene	15942.0
2-methylphenol	10434.8
4-methylphenol	81159.4
dibenzofuran	57971.0
2-methylnaphthalene	63768.1
Low molecular wt. PAH	528985.5
High molecular wt. PAH	1488406
1,1'-biphenyl	11594.2
dibenzothiophene	14202.9
1-methylphenanthrene	28985.5

Group: 1 Station: RS-18
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration OC
dibenzofuran	22650.1
antimony	4756.5
arsenic	109852.8
cadmium	2083.8
copper	129105.3
selenium	271.8
mercury	588.9
1,1'-biphenyl	12457.5

Oyster	Concentration OC
acenaphthene	28312.6
phenanthrene	124575.3
fluorene	35107.6
dibenzofuran	22650.1
antimony	4756.5
arsenic	109852.8
cadmium	2083.8
copper	129105.3
lead	70781.4
mercury	588.9
1,1'-biphenyl	12457.5
dibenzothiophene	12457.5

Benthic	Concentration OC
antimony	4756.5
arsenic	109852.8
cadmium	2083.8
copper	129105.3
lead	70781.4
1,1'-biphenyl	12457.5

Microtox	Concentration OC
antimony	4756.5
arsenic	109852.8
cadmium	2083.8
copper	129105.3
lead	70781.4
mercury	588.9
1,1'-biphenyl	12457.5

Group: 1 Station: RS-19
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration OC
di-n-butyl phthalate	275862.1
dibenzofuran	18965.5
antimony	6206.9
arsenic	267241.4
cadmium	2758.6
copper	386206.9
lead	175862.1
selenium	241.4
zinc	156206.9
mercury	551.7
1-methylphenanthrene	24137.9

Oyster	Concentration OC
fluorene	24137.9
di-n-butyl phthalate	275862.1
dibenzofuran	18965.5
antimony	6206.9
arsenic	267241.4
cadmium	2758.6
copper	386206.9
lead	175862.1
mercury	551.7
dibenzothiophene	16724.1
1-methylphenanthrene	24137.9

Benthic	Concentration OC
antimony	6206.9
arsenic	267241.4
cadmium	2758.6
copper	386206.9
lead	175862.1
zinc	156206.9
dibenzothiophene	16724.1

Microtox	Concentration OC
di-n-butyl phthalate	275862.1
antimony	6206.9
arsenic	267241.4
cadmium	2758.6
copper	386206.9
lead	175862.1
mercury	551.7
Total phthalates	275862.1
dibenzothiophene	16724.1

Group: 1 Station: RS-20
Toxicity code: 1 Benthic code: 2 Microtox code 2

Benthic	Concentration OC
antimony	642.9
arsenic	32142.9
cadmium	1071.4
copper	48928.6
lead	27857.1

Microtox	Concentration OC
di-n-butyl phthalate	264285.7
copper	48928.6
iron	5678571
manganese	82857.1
nickel	6785.7
mercury	210.7
Total phthalates	264285.7

Group: 1 Station: RS-24
Toxicity code: 3 Benthic code: 0 Microtox code 1

Amphipod	Concentration OC
antimony	3250.0
arsenic	87500.0
cadmium	1200.0
zinc	202500.0

Group: 1 Station: SI-11
Toxicity code: 1 Benthic code: 2 Microtox code 2

Benthic	Concentration OC
lead	31476.2

Group: 1 Station: SI-12
Toxicity code: 3 Benthic code: 2 Microtox code 2

Benthic	Concentration OC
lead	31794.9

Group: 1 Station: SP-14
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration OC
4-methylphenol	600000.0

Oyster	Concentration OC
4-methylphenol	600000.0

Benthic	Concentration OC
4-methylphenol	600000.0

Microtox	Concentration OC
4-methylphenol	600000.0

Group: 1 Station: SP-15
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration OC
4-methylphenol	126213.6

Oyster	Concentration OC
4-methylphenol	126213.6

Benthic	Concentration OC
4-methylphenol	126213.6

Microtox	Concentration OC
4-methylphenol	126213.6

Group: 1 Station: SP-16
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration OC
4-methylphenol	60544.2
benzyl alcohol	8843.5

Oyster	Concentration OC
4-methylphenol	60544.2
benzyl alcohol	8843.5

Benthic	Concentration OC
benzyl alcohol	8843.5

Microtox	Concentration OC
benzyl alcohol	8843.5

Group: 3 Station: SC-20
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
phenanthrene	271341.5

Group: 3 Station: SM-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
bis(2-ethylhexyl)phthalate	212121.2

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
4,4'-DDT	1222.22 *

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
acenaphthylene	109090.9
bis(2-ethylhexyl)phthalate	127272.7
total PCBs	177272.7
4,4'-DDD	3227.27

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration OC
N-nitrosodiphenylamine	14666.7
butyl benzyl phthalate	191555.6
silver	511.1

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration OC
total PCBs	511688.3
lead	87013.0
silver	532.5
4,4'-DDD	22727.27

Group: 6 Station: EB-36
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration OC
acenaphthylene	668833.3
total PCBs	661666.7
silver	900.0

Group: 6 Station: WP-16
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration OC
lead	22307.7

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration OC
total PCBs	380000.0
lead	35000.0
4,4'-DDD	5000.00

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration OC
N-nitrosodiphenylamine	62727.3
1,2-dichlorobenzene	4090.9
butyl benzyl phthalate	413636.4
copper	27272.7
lead	97727.3
zinc	59090.9

Group: 7 Station: EB-36
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration OC
N-nitrosodiphenylamine	49677.4

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration OC
butyl benzyl phthalate	67666.7

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
total PCBs	380281.7
4,4'-DDD	2676.06
4,4'-DDE	2887.32

Group: 9 Station: DR-25
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
zinc	72638.9

Group: 9 Station: DR-26
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
zinc	212456.1

Group: 9 Station: DR-27
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration OC
cadmium	2000.0
zinc	500000.0
mercury	442.3

TABLE B-4. STATION LISTING OF CHEMICALS EXCEEDING FINES NORMALIZED AET

Organics expressed as ppb fine grained material, metals ppm fine grained material

Group: 1 Station: CI-11
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration Fines
benzo(ghi)perylene	1981.7
indeno(1,2,3-cd)pyrene	1600.6
1,4-dichlorobenzene	736.8
benzyl alcohol	355.7
dibenzothiophene	482.7

Oyster	Concentration Fines
acenaphthene	1168.7
benzo(ghi)perylene	1981.7
indeno(1,2,3-cd)pyrene	1600.6
1,2-dichlorobenzene	94.0
1,4-dichlorobenzene	736.8
benzyl alcohol	355.7
Chlorinated benzenes	830.8
dibenzothiophene	482.7

Benthic	Concentration Fines
benzyl alcohol	355.7
lead	1842.0

Microtox	Concentration Fines
benzyl alcohol	355.7

Group: 1 Station: CI-13
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration Fines
bis(2-ethylhexyl)phthalate	3959.1

Benthic	Concentration Fines
bis(2-ethylhexyl)phthalate	3959.1

Microtox	Concentration Fines
bis(2-ethylhexyl)phthalate	3959.1
butyl benzyl phthalate	268.2

Group: 1 Station: CI-16
Toxicity code: 2 Benthic code: 3 Microtox code 2

Oyster	Concentration Fines
2,4-dimethylphenol	67.9
1,2-dichlorobenzene	475.2
1,4-dichlorobenzene	353.0
4-methylphenol	1629.3
Chlorinated benzenes	905.6

Benthic	Concentration Fines
2,4-dimethylphenol	67.9
1,2-dichlorobenzene	475.2

Microtox	Concentration Fines
2,4-dimethylphenol	67.9
1,2-dichlorobenzene	475.2

Group: 1 Station: CI-20
Toxicity code: 4 Benthic code: 1 Microtox code 1

Oyster	Concentration Fines
2,4-dimethylphenol	36.4

Group: 1 Station: HY-17
Toxicity code: 2 Benthic code: 3 Microtox code 2

Microtox	Concentration Fines
total PCBs	254.0

Group: 1 Station: HY-22
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration Fines
benzo(a)pyrene	8077.3
Total benzofluoranthenes	11255.3
dibenzo(a,h)anthracene	1986.2
indeno(1,2,3-cd)pyrene	3575.2
1,2,4-trichlorobenzene	344.3
hexachlorobenzene	966.6
hexachlorobutadiene	966.6
bis(2-ethylhexyl)phthalate	3972.5
Chlorinated benzenes	1758.5

Oyster	Concentration Fines
benzo(a)pyrene	8077.3
Total benzofluoranthenes	11255.3
dibenzo(a,h)anthracene	1986.2
indeno(1,2,3-cd)pyrene	3575.2
1,2,4-trichlorobenzene	344.3
hexachlorobenzene	966.6
1,2-dichlorobenzene	96.7
1,4-dichlorobenzene	238.3
hexachlorobutadiene	966.6
bis(2-ethylhexyl)phthalate	3972.5
total PCBs	2648.3
Chlorinated benzenes	1758.5

Benthic	Concentration Fines
1,2,4-trichlorobenzene	344.3
hexachlorobenzene	966.6
hexachlorobutadiene	966.6
bis(2-ethylhexyl)phthalate	3972.5

Microtox	Concentration Fines
benzo(a)pyrene	8077.3
dibenzo(a,h)anthracene	1986.2
1,2,4-trichlorobenzene	344.3
hexachlorobenzene	966.6
hexachlorobutadiene	966.6
bis(2-ethylhexyl)phthalate	3972.5
total PCBs	2648.3
Chlorinated benzenes	1758.5

Group: 1 Station: HY-23
Toxicity code: 4 Benthic code: 3 Microtox code 2

Oyster	Concentration Fines
total PCBs	1735.1

Microtox	Concentration Fines
hexachlorobutadiene	196.6
butyl benzyl phthalate	127.2
total PCBs	1735.1

Group: 1 Station: HY-24
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration Fines
butyl benzyl phthalate	576.6
total PCBs	306.7

Group: 1 Station: HY-37
Toxicity code: 1 Benthic code: 2 Microtox code 2

Microtox	Concentration Fines
hexachlorobenzene	123.9
total PCBs	542.0

Group: 1 Station: HY-42
Toxicity code: 3 Benthic code: 1 Microtox code 2

Amphipod	Concentration Fines
hexachlorobenzene	294.6

Microtox	Concentration Fines
1,2,4-trichlorobenzene	82.0
hexachlorobenzene	294.6
hexachlorobutadiene	345.8
total PCBs	1409.0

Group: 1 Station: HY-43
Toxicity code: 1 Benthic code: 1 Microtox code 2

Microtox	Concentration Fines
1,2,4-trichlorobenzene	89.2
hexachlorobenzene	227.4
hexachlorobutadiene	314.9

Group: 1 Station: HY-47
Toxicity code: 2 Benthic code: 2 Microtox code 2

Oyster	Concentration Fines
hexachlorobutadiene	370.4

Benthic	Concentration Fines
hexachlorobutadiene	370.4

Microtox	Concentration Fines
1,2,4-trichlorobenzene	65.1
hexachlorobenzene	127.7
hexachlorobutadiene	370.4

Group: 1 Station: RS-13
Toxicity code: 4 Benthic code: 1 Microtox code 1

Amphipod	Concentration Fines
acenaphthene	3102.6
phenanthrene	8751.0
fluorene	3898.2
fluoranthene	10342.1
benzo(a)anthracene	8751.0
benzo(a)pyrene	7796.3
Total benzofluoranthenes	23866.3
chrysene	11137.6
benzo(ghi)perylene	3659.5
dibenzo(a,h)anthracene	1829.8
indeno(1,2,3-cd)pyrene	4773.3
pyrene	9546.5
naphthalene	9546.5
1,4-dichlorobenzene	875.1
2-methylphenol	572.8
4-methylphenol	4455.1
dibenzofuran	3182.2
benzyl alcohol	167.1
2-methylnaphthalene	3500.4
Low molecular wt. PAH	29037.4
High molecular wt. PAH	81702.5
Chlorinated benzenes	1002.4
1,1'-biphenyl	636.4
dibenzothiophene	779.6
1-methylphenanthrene	1591.1

Oyster	Concentration Fines
acenaphthene	3102.6
phenanthrene	8751.0
fluorene	3898.2
fluoranthene	10342.1
benzo(a)anthracene	8751.0
benzo(a)pyrene	7796.3
Total benzofluoranthenes	23866.3
chrysene	11137.6
benzo(ghi)perylene	3659.5
dibenzo(a,h)anthracene	1829.8
indeno(1,2,3-cd)pyrene	4773.3
pyrene	9546.5
naphthalene	9546.5
1,2-dichlorobenzene	127.3
1,4-dichlorobenzene	875.1
2-methylphenol	572.8
4-methylphenol	4455.1
dibenzofuran	3182.2
benzyl alcohol	167.1
2-methylnaphthalene	3500.4
Low molecular wt. PAH	29037.4
High molecular wt. PAH	81702.5
Chlorinated benzenes	1002.4
1,1'-biphenyl	636.4
dibenzothiophene	779.6
1-methylphenanthrene	1591.1

Group: 1 Station: RS-18
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration Fines
N-nitrosodiphenylamine	1829.6
acenaphthene	7498.5
anthracene	4199.2
phenanthrene	32993.4
fluorene	9298.1
fluoranthene	24295.1
benzo(a)anthracene	9598.1
benzo(a)pyrene	11997.6
Total benzofluoranthenes	12597.5
chrysene	14097.2
dibenzo(a,h)anthracene	959.8
indeno(1,2,3-cd)pyrene	2309.5
pyrene	16796.6
naphthalene	5698.9
1,4-dichlorobenzene	749.9
2-methylphenol	213.0
dibenzofuran	5998.8
2-methylnaphthalene	3599.3
antimony	1259.75
arsenic	29094.2
cadmium	551.9
copper	34193.2
lead	18746.3
selenium	71.99
thallium	9.60
mercury	156.0
Low molecular wt. PAH	60557.9
High molecular wt. PAH	92651.5
1,1'-biphenyl	3299.3
dibenzothiophene	3299.3
1-methylphenanthrene	3899.2

Oyster	Concentration Fines
N-nitrosodiphenylamine	1829.6
acenaphthene	7498.5
anthracene	4199.2
phenanthrene	32993.4
fluorene	9298.1
fluoranthene	24295.1
benzo(a)anthracene	9598.1
benzo(a)pyrene	11997.6
Total benzofluoranthenes	12597.5
chrysene	14097.2
dibenzo(a,h)anthracene	959.8
indeno(1,2,3-cd)pyrene	2309.5
pyrene	16796.6
naphthalene	5698.9
1,4-dichlorobenzene	749.9
2-methylphenol	213.0
dibenzofuran	5998.8
2-methylnaphthalene	3599.3
antimony	1259.75
arsenic	29094.2
cadmium	551.9
copper	34193.2
lead	18746.3
selenium	71.99
thallium	9.60
mercury	156.0
Low molecular wt. PAH	60557.9
High molecular wt. PAH	92651.5
Chlorinated benzenes	803.8
1,1'-biphenyl	3299.3
dibenzothiophene	3299.3
1-methylphenanthrene	3899.2

Benthic	Concentration Fines
N-nitrosodiphenylamine	1829.6
acenaphthene	7498.5
dibenzofuran	5998.8
2-methylnaphthalene	3599.3
antimony	1259.75
arsenic	29094.2
cadmium	551.9
copper	34193.2
lead	18746.3
selenium	71.99
thallium	9.60
zinc	9958.0
mercury	156.0
1,1'-biphenyl	3299.3
dibenzothiophene	3299.3
1-methylphenanthrene	3899.2

Microtox	Concentration Fines
N-nitrosodiphenylamine	1829.6
acenaphthene	7498.5
anthracene	4199.2
phenanthrene	32993.4
fluorene	9298.1
fluoranthene	24295.1
benzo(a)anthracene	9598.1
benzo(a)pyrene	11997.6
chrysene	14097.2
pyrene	16796.6
dibenzofuran	5998.8
2-methylnaphthalene	3599.3
antimony	1259.75
arsenic	29094.2
cadmium	551.9
copper	34193.2
lead	18746.3
thallium	9.60
mercury	156.0
Low molecular wt. PAH	60557.9
High molecular wt. PAH	92651.5
1,1'-biphenyl	3299.3
dibenzothiophene	3299.3
1-methylphenanthrene	3899.2

Group: 1 Station: RS-19
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration Fines
anthracene	12539.2
phenanthrene	17868.3
fluorene	4388.7
fluoranthene	26645.8
benzo(a)anthracene	10971.8
benzo(a)pyrene	8463.9
Total benzofluoranthenes	12539.2
chrysene	12539.2
benzo(ghi)perylene	2382.4
dibenzo(a,h)anthracene	658.3
indeno(1,2,3-cd)pyrene	2821.3
pyrene	21316.6
naphthalene	4702.2
di-n-butyl phthalate	50156.7
dibenzofuran	3448.3
2-methylnaphthalene	1912.2
antimony	1128.53
arsenic	48589.3
cadmium	501.6
copper	70219.4
lead	31974.9
selenium	43.89
thallium	14.42
zinc	28401.3
mercury	100.3
Low molecular wt. PAH	40188.1
High molecular wt. PAH	98338.6
Total phthalates	50156.7
1,1'-biphenyl	721.0
dibenzothiophene	3040.8
1-methylphenanthrene	4388.7

Oyster	Concentration Fines
anthracene	12539.2
phenanthrene	17868.3
fluorene	4388.7
fluoranthene	26645.8
benzo(a)anthracene	10971.8
benzo(a)pyrene	8463.9
Total benzofluoranthenes	12539.2
chrysene	12539.2
benzo(ghi)perylene	2382.4
dibenzo(a,h)anthracene	658.3
indeno(1,2,3-cd)pyrene	2821.3
pyrene	21316.6
naphthalene	4702.2
1,4-dichlorobenzene	313.5
di-n-butyl phthalate	50156.7
dibenzofuran	3448.3
2-methylnaphthalene	1912.2
antimony	1128.53
arsenic	48589.3
cadmium	501.6
copper	70219.4
lead	31974.9
selenium	43.89
thallium	14.42
zinc	28401.3
mercury	100.3
Low molecular wt. PAH	40188.1
High molecular wt. PAH	98338.6
Total phthalates	50156.7
1,1'-biphenyl	721.0
dibenzothiophene	3040.8
1-methylphenanthrene	4388.7

Benthic	Concentration Fines
dibenzofuran	3448.3
antimony	1128.53
arsenic	48589.3
cadmium	501.6
copper	70219.4
iron	752351.1
lead	31974.9
thallium	14.42
zinc	28401.3
mercury	100.3
1,1'-biphenyl	721.0
dibenzothiophene	3040.8
1-methylphenanthrene	4388.7

Microtox	Concentration Fines
anthracene	12539.2
phenanthrene	17868.3
fluorene	4388.7
fluoranthene	26645.8
benzo(a)anthracene	10971.8
benzo(a)pyrene	8463.9
chrysene	12539.2
pyrene	21316.6
di-n-butyl phthalate	50156.7
total PCBs	438.9
dibenzofuran	3448.3
antimony	1128.53
arsenic	48589.3
cadmium	501.6
copper	70219.4
lead	31974.9
thallium	14.42
mercury	100.3
Low molecular wt. PAH	40188.1
High molecular wt. PAH	98338.6
Total phthalates	50156.7
1,1'-biphenyl	721.0
dibenzothiophene	3040.8
1-methylphenanthrene	4388.7

Group: 1 Station: RS-20
Toxicity code: 1 Benthic code: 2 Microtox code 2

Benthic	Concentration Fines
antimony	30.98
cadmium	51.6
copper	2358.0
lead	1342.5
mercury	10.2

Group: 1 Station: SP-12
Toxicity code: 2 Benthic code: 1 Microtox code 2

Oyster	Concentration Fines
benzyl alcohol	123.6

Group: 1 Station: SP-14
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration Fines
naphthalene	6606.6
4-methylphenol	144144.1
1,1'-biphenyl	465.5

Oyster	Concentration Fines
naphthalene	6606.6
4-methylphenol	144144.1
1,1'-biphenyl	465.5

Benthic	Concentration Fines
4-methylphenol	144144.1

Microtox	Concentration Fines
4-methylphenol	144144.1

Group: 1 Station: SP-15
Toxicity code: 4 Benthic code: 3 Microtox code 2

Amphipod	Concentration Fines
4-methylphenol	10038.6

Oyster	Concentration Fines
4-methylphenol	10038.6

Benthic	Concentration Fines
4-methylphenol	10038.6

Microtox	Concentration Fines
4-methylphenol	10038.6

Group: 1 Station: SP-16
Toxicity code: 4 Benthic code: 2 Microtox code 2

Amphipod	Concentration Fines
benzyl alcohol	237.0

Oyster	Concentration Fines
4-methylphenol	1622.6
benzyl alcohol	237.0

Benthic	Concentration Fines
benzyl alcohol	237.0

Microtox	Concentration Fines
benzyl alcohol	237.0

Group: 2 Station: B15
Toxicity code: 3 Benthic code: 1 Microtox code 0

Amphipod	Concentration Fines
4,4'-DDT	8.17

Group: 3 Station: EV-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
fluoranthene	7633.6

Group: 3 Station: EV-04
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
acenaphthene	6131.5
acenaphthylene	1430.7
phenanthrene	8732.8
fluorene	3901.9
fluoranthene	7618.0
naphthalene	10962.5
Low molecular wt. PAH	31921.2

Group: 3 Station: SC-20
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
phenanthrene	12981.3
fluoranthene	7584.6
pyrene	9334.9
Low molecular wt. PAH	16161.0

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
4,4'-DDT	40.89

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
acenaphthylene	2739.7
total PCBs	4452.1
4,4'-DDD	81.05

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration Fines
butyl benzyl phthalate	2099.9

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration Fines
total PCBs	12351.1
lead	2100.3
4,4'-DDD	548.6
4,4'-DDE	147.3

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration Fines
4,4'-DDD	37.22

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration Fines
N-nitrosodiphenylamine	711.3
butyl benzyl phthalate	4690.7
di-n-octyl phthalate	97597.9
lead	1108.2
Total phthalates	110309.3

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration Fines
butyl benzyl phthalate	1307.6

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration Fines
total PCBs	10742.0
4,4'-DDD	75.59
4,4'-DDE	81.56

TABLE B-5. STATION LISTING OF CHEMICALS EXCEEDING LOWEST DRY WEIGHT NORMALIZED AET

Organics expressed as ppb dry weight, metals ppm dry weight

Group: 1 Station: BL-13
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
butyl benzyl phthalate	83.0

Group: 1 Station: CI-11
Toxicity code: 4 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
phenol	1100
phenanthrene	1800
fluoranthene	2400
chrysene	1600.0
benzo(ghi)perylene	780.0
1,2-dichlorobenzene	37.0
1,4-dichlorobenzene	290.0
benzyl alcohol	140
lead	725
nickel	40.0
zinc	325.0
mercury	.53
High molecular wt. PAH	13090.0
Chlorinated benzenes	327.0

Group: 1 Station: CI-13
Toxicity code: 2 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
bis(2-ethylhexyl)phthalate	3100.0
butyl benzyl phthalate	210.0
total PCBs	140.0
benzoic acid	690
cadmium	6.70
lead	450
mercury	1.10
Total phthalates	3548.0

Group: 1 Station: CI-16
Toxicity code: 2 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
2,4-dimethylphenol	50.0
N-nitrosodiphenylamine	220.0
1,2-dichlorobenzene	350.0
1,4-dichlorobenzene	260.0
di-n-butyl phthalate	1600.0
4-methylphenol	1200
Chlorinated benzenes	667.0

Group: 1 Station: CI-17
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
fluoranthene	1900
1,4-dichlorobenzene	119.0

Group: 1 Station: CI-20
Toxicity code: 4 Benthic code: 1 Microtox code 1

Lowest AET	Concentration DW
phenol	1200
1,1'-biphenyl	270.0
dibenzothiophene	250.0

Group: 1 Station: HY-12
Toxicity code: 2 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
phenol	500
chrysene	1800.0
benzo(ghi)perylene	740.0
dibenzo(a,h)anthracene	260.0
di-n-butyl phthalate	5100.0
mercury	.46
Total phthalates	5100.0

Group: 1 Station: HY-14
Toxicity code: 1 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
fluoranthene	2500
chrysene	2800.0
benzo(ghi)perylene	720.0
High molecular wt. PAH	16650.0

Group: 1 Station: HY-17
Toxicity code: 2 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
fluoranthene	3900
benzo(a)pyrene	2400.0
Total benzofluoranthenes	3700
chrysene	2700.0
pyrene	4300
tetrachloroethene	210
ethylbenzene	50
total PCBs	170.0
total xylenes	160
arsenic	86.0
zinc	268.0
High molecular wt. PAH	18402.0

Group: 1 Station: HY-22
Toxicity code: 4 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
phenol	530
fluoranthene	3600
benzo(a)anthracene	2300.0
benzo(a)pyrene	6100.0
Total benzofluoranthenes	8500
chrysene	2700.0
dibenzo(a,h)anthracene	1500
indeno(1,2,3-cd)pyrene	2700.0
1,2,4-trichlorobenzene	260.0
hexachlorobenzene	730.0
1,2-dichlorobenzene	73.0
1,4-dichlorobenzene	180.0
hexachlorobutadiene	730.0
bis(2-ethylhexyl)phthalate	3000.0
total PCBs	2000.0
arsenic	90.0
nickel	52.0
mercury	.50
dibenzothiophene	320.0
1-methylphenanthrene	530.0
High molecular wt. PAH	30000.0
Total phthalates	3560.0
Chlorinated benzenes	1328.0

Group: 1 Station: HY-23
Toxicity code: 4 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
phenanthrene	2300
fluoranthene	2500
benzo(a)pyrene	2000.0
chrysene	2300.0
benzo(ghi)perylene	1100.0
dibenzo(a,h)anthracene	440.0
hexachlorobutadiene	170.0
butyl benzyl phthalate	110.0
dimethyl phthalate	350.0
tetrachloroethene	170
total PCBs	1500.0
total xylenes	110
nickel	56.0
High molecular wt. PAH	13790.0

Group: 1 Station: HY-24
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
chrysene	2300.0
hexachlorobutadiene	140.0
butyl benzyl phthalate	470.0
dimethyl phthalate	120.0
total PCBs	250.0
mercury	.49

Group: 1 Station: HY-37
Toxicity code: 1 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
1,2,4-trichlorobenzene	34.0
hexachlorobenzene	96.0
hexachlorobutadiene	130.0
total PCBs	420.0
Chlorinated benzenes	203.0

Group: 1 Station: HY-42
Toxicity code: 3 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
chrysene	1800.0
1,2,4-trichlorobenzene	64.0
hexachlorobenzene	230.0
hexachlorobutadiene	270.0
total PCBs	1100.0
Chlorinated benzenes	395.0

Group: 1 Station: HY-43
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
1,2,4-trichlorobenzene	51.0
hexachlorobenzene	130.0
hexachlorobutadiene	180.0
ethylbenzene	37
total xylenes	120
Chlorinated benzenes	274.2

Group: 1 Station: HY-47
Toxicity code: 2 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
1,2,4-trichlorobenzene	51.0
hexachlorobenzene	100.0
1,4-dichlorobenzene	120.0
hexachlorobutadiene	290.0
di-n-butyl phthalate	1500.0
Chlorinated benzenes	312.0

Group: 1 Station: HY-50
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
benzyl alcohol	73

Group: 1 Station: MI-13
Toxicity code: 1 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
dimethyl phthalate	110.0
FINES	.89

Group: 1 Station: RS-13
Toxicity code: 4 Benthic code: 1 Microtox code 1

Lowest AET	Concentration DW
2-methylphenol	72

Group: 1 Station: RS-18
Toxicity code: 4 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
N-nitrosodiphenylamine	610.0
acenaphthene	2500.0
anthracene	1400.0
phenanthrene	11000
fluorene	3100.0
fluoranthene	8100
benzo(a)anthracene	3200.0
benzo(a)pyrene	4000.0
Total benzofluoranthenes	4200
chrysene	4700.0
dibenzo(a,h)anthracene	320.0
indeno(1,2,3-cd)pyrene	770.0
pyrene	5600
1,4-dichlorobenzene	250.0
2-methylphenol	71
dibenzofuran	2000
2-methylnaphthalene	1200
antimony	420.0
arsenic	9700.0
cadmium	184.00
copper	11400
iron	52900
lead	6250
manganes	748
nickel	93.0
thallium	3.20
zinc	3320.0
mercury	52.00
1,1'-biphenyl	1100.0
dibenzothiophene	1100.0
1-methylphenanthrene	1300.0
Low molecular wt. PAH	20190.0
High molecular wt. PAH	30890.0
Chlorinated benzenes	268.0

Group: 1 Station: RS-19
Toxicity code: 4 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
di-n-butyl phthalate	1600.0
antimony	36.00
arsenic	1550.0
cadmium	16.00
copper	2240
lead	1020
thallium	.46
zinc	906.0
mercury	3.20

Group: 1 Station: RS-20
Toxicity code: 1 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
arsenic	90.0
mercury	.59

Group: 1 Station: RS-24
Toxicity code: 3 Benthic code: 0 Microtox code 1

Lowest AET	Concentration DW
antimony	26.00
arsenic	700.0
cadmium	9.60
copper	385
iron	37100
lead	531
manganes	484
zinc	1620.0

Group: 1 Station: SI-11
Toxicity code: 1 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
arsenic	93.0
lead	661
zinc	491.0

Group: 1 Station: SI-12
Toxicity code: 3 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
N-nitrosodiphenylamine	130.0
lead	496
zinc	337.0

Group: 1 Station: SI-15
Toxicity code: 3 Benthic code: 1 Microtox code 1

Lowest AET	Concentration DW
1-methylphenanthrene	370.0

Group: 1 Station: SP-12
Toxicity code: 2 Benthic code: 1 Microtox code 2

Lowest AET	Concentration DW
benzyl alcohol	61

Group: 1 Station: SP-14
Toxicity code: 4 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
phenol	1700
naphthalene	4400.0
4-methylphenol	96000
2-methylnaphthalene	810
manganes	556
nickel	40.0
total volatile solids	44.70
total organic carbon	16.00
1,1'-biphenyl	310.0
Low molecular wt. PAH	6065.0

Group: 1 Station: SP-15
Toxicity code: 4 Benthic code: 3 Microtox code 2

Lowest AET	Concentration DW
4-methylphenol	2600

Group: 1 Station: SP-16
Toxicity code: 4 Benthic code: 2 Microtox code 2

Lowest AET	Concentration DW
4-methylphenol	890
benzyl alcohol	130

Group: 2 Station: B03
Toxicity code: 1 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
1,2-dichlorobenzene	50.0

Group: 2 Station: B04
Toxicity code: 1 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	2140
butyl benzyl phthalate	125.0
mercury	.52

Group: 2 Station: B09
Toxicity code: 1 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
dimethyl phthalate	160.0

Group: 2 Station: B15
Toxicity code: 3 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
4,4'-DDT	5.8

Group: 3 Station: BH-03
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
copper	400
nickel	73.5
mercury	1.35
total volatile solids	26.93

Group: 3 Station: BH-04
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	89.6
mercury	1.69

Group: 3 Station: BH-05
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	111.0
mercury	.81
FINES	.97

Group: 3 Station: BH-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	105.0
mercury	.97
FINES	.92

Group: 3 Station: BH-11
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	118.0
mercury	.54
FINES	.98

Group: 3 Station: BH-12
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	72.0
mercury	.64

Group: 3 Station: BH-23
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	102.0
mercury	.54
FINES	.95

Group: 3 Station: BH-24
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	117.0
mercury	.59
FINES	.97

Group: 3 Station: CS-01
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
phenol	560
silver	.57
FINES	.89

Group: 3 Station: DB-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
silver	.78

Group: 3 Station: DB-15
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	46.0
FINES	.90

Group: 3 Station: EB-09
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	330.0
silver	.74
zinc	434.0
mercury	1.69

Group: 3 Station: EB-10
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
acenaphthene	630.0
phenanthrene	2100
fluoranthene	2300
chrysene	1500.0
pyrene	3400
total PCBs	279.0
lead	607
silver	.65
zinc	687.0
mercury	1.08
High molecular wt. PAH	12200.0

Group: 3 Station: EB-12
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
silver	.68
FINES	.89

Group: 3 Station: EB-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	646.0
silver	.65
mercury	.58

Group: 3 Station: EB-20
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	640.0
silver	.60
zinc	460.0
mercury	.78

Group: 3 Station: EB-22
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	687.0
silver	.67
mercury	.51

Group: 3 Station: EB-23
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	148.0

Group: 3 Station: EV-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
phenanthrene	1900
fluoranthene	4800
total PCBs	445.0
nickel	44.0
thallium	.50
zinc	313.0

Group: 3 Station: EV-02
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	48.0

Group: 3 Station: EV-03
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	516.0
nickel	43.0
total volatile solids	25.44

Group: 3 Station: EV-04
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
phenol	1400
acenaphthene	3300.0
naphthalene	5900.0
acenaphthylene	770.0
phenanthrene	4700
fluorene	2100.0
fluoranthene	4100
butyl benzyl phthalate	440.0
total PCBs	965.0
nickel	45.0
thallium	.30
zinc	1074.0
total volatile solids	35.06
total organic carbon	15.42
Low molecular wt. PAH	17180.0

Group: 3 Station: EV-05
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	1800
total PCBs	394.0
nickel	51.0
thallium	.50
total volatile solids	25.99

Group: 3 Station: EV-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
phenanthrene	1600
total PCBs	155.0
nickel	50.0
thallium	.40

Group: 3 Station: EV-11
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	171.0
nickel	46.0

Group: 3 Station: SC-06
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1253.0
nickel	44.0
silver	3.70
zinc	330.0
mercury	1.38

Group: 3 Station: SC-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	588.0
copper	807
silver	2.30
zinc	873.0
mercury	1.28

Group: 3 Station: SC-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	646.0
nickel	45.0
silver	2.29
zinc	311.0
mercury	1.21
FINES	.90

Group: 3 Station: SC-14
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1672.0
nickel	43.0
silver	2.32
zinc	272.0
mercury	1.57
FINES	.92

Group: 3 Station: SC-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	231.0
nickel	43.0
silver	1.29
zinc	328.0
mercury	.70

Group: 3 Station: SC-18
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	229.0
silver	1.56
mercury	.72

Group: 3 Station: SC-19
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
lead	360
nickel	45.0
silver	1.36
zinc	343.0
mercury	2.07

Group: 3 Station: SC-20
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
phenanthrene	8900
fluorene	980.0
fluoranthene	5200
benzo(a)anthracene	1900.0
chrysene	2000.0
benzo(ghi)perylene	1000.0
pyrene	6400
total PCBs	384.0
nickel	44.0
silver	2.67
mercury	1.64
Low molecular wt. PAH	11080.0
High molecular wt. PAH	20140.0

Group: 3 Station: SM-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
bis(2-ethylhexyl)phthalate	2800.0

Group: 3 Station: SQ-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
nickel	41.0

Group: 4 Station: DR-03
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
4,4'-DDD	3.90

Lowest AET	Concentration DW
4,4'-DDD	2.60

Group: 4 Station: DR-06
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
4,4'-DDD	3.20

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
4,4'-DDT	22.0
4,4'-DDD	5.60

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
acenaphthylene	2400
bis(2-ethylhexyl)phthalate	2800.0
total PCBs	3900.0
zinc	270.0
mercury	.42
4,4'-DDD	71.00

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	132.0
benzo(a)pyrene	9770.0
Total benzofluoranthenes	17529
benzo(ghi)perylene	8046.0
dibenzo(a,h)anthracene	4023
indeno(1,2,3-cd)pyrene	2874.0
butyl benzyl phthalate	1724
total PCBs	1060.0
iron	31000
manganes	300
nickel	44.0
silver	4.60
mercury	.98
4,4'-DDE	11.00
High molecular wt. PAH	46897.0
Total phthalates	4445.0

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Lowest AET	Concentration DW
anthracene	3936.0
phenanthrene	4293
fluorene	2683.0
fluoranthene	5367
benzo(a)anthracene	9481.0
chrysene	10376
pyrene	6440
di-n-butyl phthalate	2147.0
total PCBs	3940.0
lead	670
nickel	41.0
silver	4.10
zinc	300.0
mercury	1.60
4,4'-DDE	47.00
4,4'-DDD	175.00
Low molecular wt. PAH	11431.0
High molecular wt. PAH	31664.0
Total phthalates	11628.0

Group: 6 Station: EB-36
Toxicity code: 0 Benthic code: 2 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	54.0
acenaphthylene	4013
chrysene	1605.0
butyl benzyl phthalate	334.0
total PCBs	3970.0
iron	31000
manganes	400
nickel	56.0
silver	5.40
mercury	.77
4,4'-DDE	37.00
Total phthalates	28327.0

Group: 6 Station: EB-38
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	61.0
chrysene	1552.0
benzo(ghi)perylene	808.0
dibenzo(a,h)anthracene	471.0
total PCBs	730.0
iron	37000
manganes	420
nickel	49.0
silver	5.20
mercury	.62

Group: 6 Station: WP-12
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	75.0
benzo(a)pyrene	1877.0
iron	32000
manganes	580
silver	3.70
Total phthalates	6166.0
FINES	.91

Group: 6 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
total PCBs	480.0
iron	36000
manganes	520
silver	3.70
FINES	.92

Group: 6 Station: WP-14
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
iron	34000
manganes	630
silver	3.70
FINES	.96

Group: 6 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
benzo(a)pyrene	2173.0
Total benzofluoranthenes	3928
chrysene	2440.0
benzo(ghi)perylene	1756.0
indeno(1,2,3-cd)pyrene	893.0
total PCBs	146.0
iron	28000
manganes	430
silver	3.30
High molecular wt. PAH	13631.0
FINES	.97

Group: 6 Station: WP-16
Toxicity code: 0 Benthic code: 2 Microtox code 0

Lowest AET	Concentration DW
total PCBs	275.0
iron	27000
manganes	410
nickel	44.0
silver	5.00
4,4'-DDD	12.00
FINES	.96

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	1703
total PCBs	2280.0
iron	30000
manganes	310
nickel	44.0
silver	1.10
mercury	1.00
4,4'-DDE	30.00
4,4'-DDD	30.00
Total phthalates	3648.0

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	276.0
anthracene	1636.0
phenanthrene	2574
fluoranthene	5882
benzo(a)anthracene	3125.0
benzo(a)pyrene	5882.0
Total benzofluoranthenes	11213
chrysene	5147.0
benzo(ghi)perylene	5147.0
dibenzo(a,h)anthracene	1048
indeno(1,2,3-cd)pyrene	4412.0
pyrene	6250
butyl benzyl phthalate	1820
di-n-butyl phthalate	2941.0
dimethyl phthalate	88.0
total PCBs	965.0
lead	430
nickel	49.0
silver	.94
zinc	260.0
mercury	1.30
High molecular wt. PAH	48106.0
Total phthalates	42800.0

Group: 7 Station: EB-36
Toxicity code: 0 Benthic code: 3 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	308.0
butyl benzyl phthalate	67.0
di-n-butyl phthalate	4103.0
diethyl phthalate	318.0
4,4'-DDT	15.0
total PCBs	487.0
nickel	50.0
silver	1.30
4,4'-DDE	10.00
Total phthalates	4791.0

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

Lowest AET	Concentration DW
phenanthrene	2970
chrysene	1802.0
butyl benzyl phthalate	812.0
4,4'-DDT	28.0
total PCBs	315.0
manganes	310
nickel	58.0
silver	2.20
mercury	.72
Total phthalates	5840.0

Group: 7 Station: WP-01
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
manganes	440

Group: 7 Station: WP-02
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	2744
benzo(a)anthracene	1715.0
benzo(a)pyrene	3602.0
Total benzofluoranthenes	4117
chrysene	2058.0
benzo(ghi)perylene	1235.0
indeno(1,2,3-cd)pyrene	1012.0
pyrene	3774
total PCBs	149.0
manganes	380
High molecular wt. PAH	20429.0

Lowest AET	Concentration DW
manganes	340

Group: 7 Station: WP-05
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
di-n-butyl phthalate	1423.0
manganes	420

Group: 7 Station: WP-06
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
manganes	520

Group: 7 Station: WP-07
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	1757
benzo(a)anthracene	1757.0
benzo(a)pyrene	1622.0
chrysene	2297.0
benzo(ghi)perylene	2568.0
indeno(1,2,3-cd)pyrene	2432.0
di-n-butyl phthalate	1622.0
4,4'-DDT	10.0
manganes	460
High molecular wt. PAH	17028.0

Group: 7 Station: WP-08
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
di-n-butyl phthalate	2035.0
total PCBs	161.0
manganes	630
mercury	.47

Group: 7 Station: WP-09
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
manganes	1000
nickel	40.0

Group: 7 Station: WP-10
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
benzo(ghi)perylene	944.0
manganes	360
Total phthalates	3705.0

Group: 7 Station: WP-11
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
acenaphthylene	643.0
anthracene	1273.0
phenanthrene	3150
fluorene	643.0
fluoranthene	6299
benzo(a)anthracene	4462.0
benzo(a)pyrene	6824.0
Total benzofluoranthenes	8005
chrysene	6693.0
benzo(ghi)perylene	5381.0
dibenzo(a,h)anthracene	1155
indeno(1,2,3-cd)pyrene	5249.0
pyrene	7349
total PCBs	131.0
Low molecular wt. PAH	6139.0
High molecular wt. PAH	51417.0

Group: 7 Station: WP-12
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
butyl benzyl phthalate	307.0
iron	32000
manganes	460
FINES	.97

Group: 7 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
di-n-butyl phthalate	4474.0
iron	29000
manganes	380
nickel	42.0
Total phthalates	7123.0
FINES	.89

Group: 7 Station: WP-14
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
N-nitrosodiphenylamine	63.0
fluoranthene	2375
butyl benzyl phthalate	259.0
total PCBs	145.0
iron	30000
manganes	380
nickel	40.0
silver	.61
mercury	.88
Total phthalates	69723.0
FINES	.91

Group: 7 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
butyl benzyl phthalate	287.0
4,4'-DDT	11.0
total PCBs	221.0
iron	30000
manganes	450
silver	.58
FINES	.93

Group: 7 Station: WP-16
Toxicity code: 0 Benthic code: 1 Microtox code 0

Lowest AET	Concentration DW
iron	30000
manganes	500
nickel	40.0
silver	.58
FINES	.93

Group: 8 Station: EV-20
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
acenaphthene	558.0

AD-A184 867 DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND 5/6
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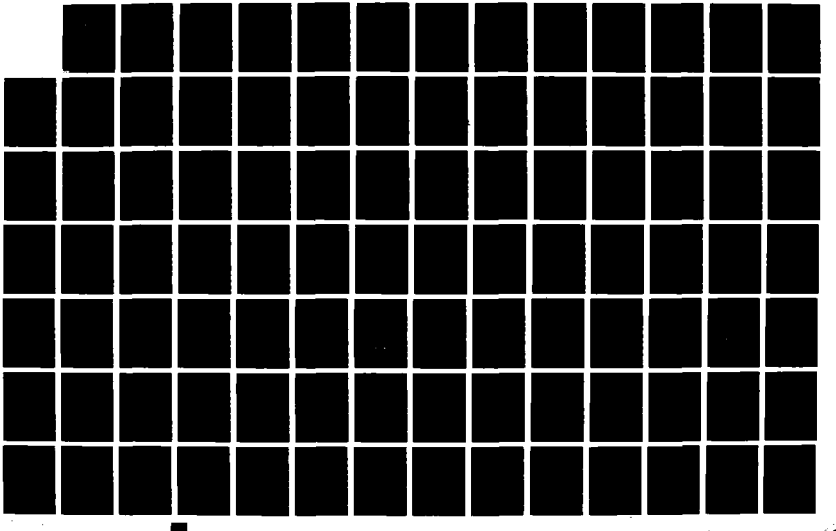

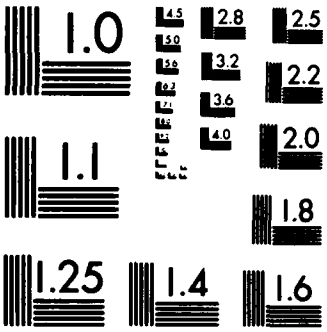

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	5400.0
mercury	.83
4,4'-DDE	41.00
4,4'-DDD	38.00

Group: 9 Station: DR-11
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	530.0
4,4'-DDD	7.80

Group: 9 Station: DR-13
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	215.0
mercury	.42
4,4'-DDD	3.60

Group: 9 Station: DR-14
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	150.0
lead	700
4,4'-DDD	6.10

Group: 9 Station: DR-19
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	330.0
4,4'-DDD	4.30

Group: 9 Station: DR-22
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	180.0
4,4'-DDD	2.40

Group: 9 Station: DR-23
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1800.0
mercury	.68
4,4'-DDE	11.00
4,4'-DDD	29.00

Group: 9 Station: DR-25
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	790.0
zinc	523.0
4,4'-DDD	14.00

Group: 9 Station: DR-26
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	170.0
zinc	1211.0
4,4'-DDD	2.30

Group: 9 Station: DR-27
Toxicity code: 3 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
cadmium	10.40
zinc	2600.0
mercury	2.30
4,4'-DDD	3.40

Group: 9 Station: DR-28
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
fluoranthene	1900
total PCBs	2500.0
4,4'-DDE	15.00
4,4'-DDD	43.00

Group: 9 Station: DR-29
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	2200.0
zinc	336.0
mercury	.46
4,4'-DDE	15.00
4,4'-DDD	35.00

Group: 9 Station: DR-30
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	650.0
4,4'-DDD	9.20

Group: 9 Station: DR-31
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	560.0
4,4'-DDD	24.00

Group: 9 Station: DR-33
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1200.0
4,4'-DDE	10.00
4,4'-DDD	14.00

Group: 9 Station: DR-34
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1300.0
4,4'-DDD	16.00

Group: 9 Station: DR-35
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	620.0
mercury	.58
4,4'-DDD	15.00

Group: 9 Station: DR-36
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1500.0
mercury	1.10
4,4'-DDE	9.90
4,4'-DDD	25.00

Group: 9 Station: DR-38
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
total PCBs	1400.0
4,4'-DDD	14.00

Group: 9 Station: DR-39
Toxicity code: 1 Benthic code: 0 Microtox code 0

Lowest AET	Concentration DW
mercury	.85
4,4'-DDD	2.30

TABLE B-6. STATION LISTING OF CHEMICALS EXCEEDING COMMENCEMENT BAY DRY WEIGHT NORMALIZED AET (NON-COMMENCEMENT BAY STATIONS)

Organic compounds expressed as ppb dry weight, metals as ppm dry weight

Group: 3 Station: BH-03
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
copper	400
nickel	73.5
mercury	1.35
total volatile solids	26.93

Group: 3 Station: BH-04
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	89.6
mercury	1.69

Group: 3 Station: BH-05
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	111.0

Group: 3 Station: BH-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	105.0

Group: 3 Station: BH-11
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	118.0

Group: 3 Station: BH-12
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	72.0

Group: 3 Station: BH-23
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	102.0

Group: 3 Station: BH-24
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	117.0

Group: 3 Station: CS-01
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenol	560

Group: 3 Station: DB-15
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	46.0

Group: 3 Station: EB-09
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
mercury	1.69

Group: 3 Station: EB-10
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
acenaphthene	630.0
phenanthrene	2100
zinc	687.0

Group: 3 Station: EB-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	646.0

Group: 3 Station: EB-20
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	640.0

Group: 3 Station: EB-22
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	687.0

Group: 3 Station: EV-01
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenanthrene	1900
fluoranthene	4800
total PCBs	445.0
nickel	44.0
thallium	.50

Group: 3 Station: EV-02
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	48.0

Group: 3 Station: EV-03
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	516.0
nickel	43.0
total volatile solids	25.44

Group: 3 Station: EV-04
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenol	1400
acenaphthene	3300.0
naphthalene	5900.0
phenanthrene	4700
fluorene	2100.0
fluoranthene	4100
total PCBs	965.0
nickel	45.0
thallium	.30
zinc	1074.0
total volatile solids	35.06
total organic carbon	15.42
Low molecular wt. PAH	17180.0

Group: 3 Station: EV-05
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	51.0
thallium	.50
total volatile solids	25.99

Group: 3 Station: EV-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenanthrene	1600
nickel	50.0
thallium	.40

Group: 3 Station: EV-11
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	46.0

Group: 3 Station: SC-06
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1253.0
nickel	44.0
mercury	1.38

Group: 3 Station: SC-07
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	588.0
copper	807
zinc	873.0
mercury	1.28

Group: 3 Station: SC-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	646.0
nickel	45.0
mercury	1.21

Group: 3 Station: SC-14
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1672.0
nickel	43.0
mercury	1.57

Group: 3 Station: SC-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	43.0

Group: 3 Station: SC-19
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	45.0
mercury	2.07

Group: 3 Station: SC-20
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
phenanthrene	8900
fluorene	980.0
fluoranthene	5200
benzo(a)anthracene	1900.0
benzo(ghi)perylene	1000.0
pyrene	6400
nickel	44.0
mercury	1.64
Low molecular wt. PAH	11080.0
High molecular wt. PAH	20140.0

Group: 3 Station: SQ-17
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
nickel	41.0

Group: 4 Station: DR-07
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
4,4'-DDT	22.0

Group: 4 Station: DR-08
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	3900.0

Group: 6 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	132.0	
benzo(a)pyrene	9770.0	
Total benzofluoranthenes	17529	
benzo(ghi)perylene	8046.0	
dibenzo(a,h)anthracene	4023	
indeno(1,2,3-cd)pyrene	2874.0	
butyl benzyl phthalate	1724	
di-n-octyl phthalate	2615	
antimony	3.20	
iron	31000	
manganes	300	
nickel	44.0	*
mercury	.98	
High molecular wt. PAH	46897.0	

Group: 6 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW	
anthracene	3936.0	
phenanthrene	4293	
fluorene	2683.0	
fluoranthene	5367	
benzo(a)anthracene	9481.0	
chrysene	10376	
pyrene	6440	
di-n-octyl phthalate	9481	
total PCBs	3940.0	
antimony	3.30	
lead	670	
manganes	220	
nickel	41.0	*
zinc	300.0	
mercury	1.60	
Low molecular wt. PAH	11431.0	
High molecular wt. PAH	31664.0	
Total phthalates	11628.0	

Group: 6 Station: EB-36
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	54.0	
di-n-octyl phthalate	27759	
total PCBs	3970.0	
iron	31000	
manganes	400	
nickel	56.0	*
mercury	.77	
Total phthalates	28327.0	

Group: 6 Station: EB-38
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	61.0	
Total benzofluoranthenes	3570	
benzo(ghi)perylene	808.0	
dibenzo(a,h)anthracene	471.0	
di-n-octyl phthalate	1717	
antimony	3.20	
iron	37000	
manganes	420	
nickel	49.0	*
mercury	.62	

Group: 6 Station: WP-12
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
N-nitrosodiphenylamine	75.0
benzo(a)pyrene	1877.0
Total benzofluoranthenes	3405
di-n-octyl phthalate	6166
iron	32000
manganes	580
Total phthalates	6166.0

Group: 6 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
di-n-octyl phthalate	530.0
iron	36000
manganes	520

Group: 6 Station: WP-14
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
iron	34000	
manganes	630	

Group: 6 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
benzo(a)pyrene	2173.0	
Total benzofluoranthenes	3928	
chrysene	2440.0	
benzo(ghi)perylene	1756.0	
indeno(1,2,3-cd)pyrene	893.0	
di-n-octyl phthalate	625.0	
iron	28000	
manganes	430	
High molecular wt. PAH	13631.0	

Group: 6 Station: WP-16
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW	
di-n-octyl phthalate	1331	
iron	27000	
manganes	410	
nickel	44.0	*

Group: 7 Station: EB-33
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW	
di-n-octyl phthalate	3243	
total PCBs	2280.0	
iron	30000	
manganes	310	
nickel	44.0	*
mercury	1.00	

Group: 7 Station: EB-35
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	276.0	
anthracene	1636.0	
phenanthrene	2574	
fluoranthene	5882	
benzo(a)anthracene	3125.0	
benzo(a)pyrene	5882.0	
Total benzofluoranthenes	11213	
chrysene	5147.0	
benzo(ghi)perylene	5147.0	
dibenzo(a,h)anthracene	1048	
indeno(1,2,3-cd)pyrene	4412.0	
pyrene	6250	
butyl benzyl phthalate	1820	
di-n-octyl phthalate	37868	
lead	430	
nickel	49.0	*
zinc	260.0	
mercury	1.30	
High molecular wt. PAH	48106.0	
Total phthalates	42800.0	

Group: 7 Station: EB-36
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	308.0	
4,4'-DDT	15.0	
manganes	210	
nickel	50.0	*

Group: 7 Station: EB-38
Toxicity code: 0 Benthic code: 3 Microtox code 0

Benthic	Concentration DW	
phenanthrene	2970	
butyl benzyl phthalate	812.0	
di-n-octyl phthalate	4158	
4,4'-DDT	28.0	
manganes	310	
nickel	58.0	*
mercury	.72	
Total phthalates	5840.0	

Group: 7 Station: WP-01
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	440

Group: 7 Station: WP-02
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
fluoranthene	2744
benzo(a)anthracene	1715.0
benzo(a)pyrene	3602.0
Total benzofluoranthenes	4117
benzo(ghi)perylene	1235.0
indeno(1,2,3-cd)pyrene	1012.0
pyrene	3774
manganes	380
High molecular wt. PAH	20429.0

Group: 7 Station: WP-03
Toxicity code: 0 Benthic code: 2 Microtox code 0

Benthic	Concentration DW
di-n-octyl phthalate	423.0

Group: 7 Station: WP-04
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	340

Group: 7 Station: WP-05
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	420

Group: 7 Station: WP-06
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	520

Group: 7 Station: WP-07
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
benzo(a)anthracene	1757.0
benzo(a)pyrene	1622.0
benzo(ghi)perylene	2568.0
indeno(1,2,3-cd)pyrene	2432.0
pyrene	2838
di-n-octyl phthalate	500.0
4,4'-DDT	10.0
manganes	460
High molecular wt. PAH	17028.0

Group: 7 Station: WP-08
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	630

Group: 7 Station: WP-09
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
manganes	1000
nickel	40.0

Group: 7 Station: WP-10
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
benzo(ghi)perylene	944.0
di-n-octyl phthalate	3571
manganes	360

Group: 7 Station: WP-11
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
acenaphthylene	643.0 *
anthracene	1273.0
phenanthrene	3150
fluorene	643.0
fluoranthene	6299
benzo(a)anthracene	4462.0
benzo(a)pyrene	6824.0
Total benzofluoranthenes	8005
chrysene	6693.0
benzo(ghi)perylene	5381.0
dibenzo(a,h)anthracene	1155
indeno(1,2,3-cd)pyrene	5249.0
pyrene	7349
Low molecular wt. PAH	6139.0
High molecular wt. PAH	51417.0

Group: 7 Station: WP-12
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
iron	32000
manganes	460
FINES	.97

Group: 7 Station: WP-13
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
di-n-octyl phthalate	2605	
iron	29000	
manganes	380	
nickel	42.0	*
Total phthalates	7123.0	

Group: 7 Station: WP-14
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
N-nitrosodiphenylamine	63.0	
fluoranthene	2375	
di-n-octyl phthalate	68602	
iron	30000	
manganes	380	
nickel	40.0	*
silver	.61	
mercury	.88	
Total phthalates	69723.0	
FINES	.91	

Group: 7 Station: WP-15
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW
di-n-octyl phthalate	1264
4,4'-DDT	11.0
iron	30000
manganes	450
silver	.58
FINES	.93

Group: 7 Station: WP-16
Toxicity code: 0 Benthic code: 1 Microtox code 0

Benthic	Concentration DW	
iron	30000	
manganes	500	
nickel	40.0	*
silver	.58	
FINES	.93	

Group: 8 Station: EV-20
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
acenaphthene	558.0

Group: 9 Station: DR-10
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	5400.0

Group: 9 Station: DR-11
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	530.0

Group: 9 Station: DR-14
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
lead	700

Group: 9 Station: DR-23
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1800.0

Group: 9 Station: DR-25
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	790.0
zinc	523.0

Group: 9 Station: DR-26
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
zinc	1211.0

Group: 9 Station: DR-27
Toxicity code: 3 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
cadmium	10.40
zinc	2600.0
mercury	2.30

Group: 9 Station: DR-28
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	2500.0

Group: 9 Station: DR-29
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	2200.0

Group: 9 Station: DR-30
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	650.0

Group: 9 Station: DR-31
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	560.0

Group: 9 Station: DR-33
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1200.0

Group: 9 Station: DR-34
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1300.0

Group: 9 Station: DR-35
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	620.0

Group: 9 Station: DR-36
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1500.0

Group: 9 Station: DR-38
Toxicity code: 1 Benthic code: 0 Microtox code 0

Amphipod	Concentration DW
total PCBs	1400.0

TABLE B-6A. COMMENCEMENT BAY AET SEDIMENT QUALITY VALUES[a]
(ug/kg dry weight for organics; mg/kg dry weight for metals)

Chemical	Benthic AET	Amphipod AET
Low molecular weight PAH	5,200	5,200
naphthalene	2,100	2,100
acenaphthylene	>560	>560
acenaphthene	500	500
fluorene	540	540
phenanthrene	1,500	1,500
anthracene	960	960
High molecular weight PAH	18,000	12,000
fluoranthene	3,900	1,900
pyrene	4,300	2,600
benzo(a)anthracene	1,600	1,300
chrysene	2,800	2,300
benzofluoranthenes	3,700	3,000
benzo(a)pyrene	2,400	1,600
indeno(1,2,3-c,d)pyrene	690	690
dibenzo(a,h)anthracene	260	260
benzo(g,h,i)perylene	740	740
Total PCBs	420	1,100
Total chlorinated benzenes	670	400
1,3-dichlorobenzene	>170	>170
1,4-dichlorobenzene	260	120
1,2-dichlorobenzene	>350	50
1,2,4-trichlorobenzene	51	64
hexachlorobenzene (HCB)	130	230
Total phthalates	>5,100	>5,100
dimethyl phthalate	160	160
diethyl phthalate	>73	>73
di-n-butyl phthalate	>5,100	>5,100
butyl benzyl phthalate	>470	>470
bis(2-ethylhexyl)phthalate	>3,100	1,900
di-n-octyl phthalate	>420	>420

TABLE B-6A. (Continued)

Chemical	Amphipod AET	Benthic AET
Pesticides		
p,p'-DDE	--	--
p,p'-DDD	--	--
p,p'-DDT	3.9	>5.8
aldrin	--	--
chlordane	--	--
dieldrin	--	--
heptachlor	--	--
gamma-HCH (lindane)	--	--
Phenols		
Phenol	500	1,200
2-methylphenol	63	>72
4-methylphenol	1,200	670
2,4-dimethylphenol	>50	29
pentachlorophenol	>140	>140
Miscellaneous extractables		
hexachloroethane	--	--
hexachlorobutadiene	290	270
1-methylphenanthrene	310	370
1-methylnaphthalene	670	670
biphenyl	260	270
dibenzothiophene	240	250
dibenzofuran	540	540
benzyl alcohol	73	73
benzoic acid	>690	650
N-nitrosodiphenylamine	220	28
Volatile organics		
trichloroethene	--	--
tetrachloroethene	>210	140
ethylbenzene	>50	37
total xylenes	>160	120
Metals (mg/kg dry weight)		
antimony	5.3	3.1
arsenic	93	85
beryllium	--	--
cadmium	6.7	5.8
chromium	--	--
copper	310	310
iron	27,000	26,000
lead	660	300
manganese	230	200
mercury	1.1	0.52

TABLE B-6A. (Continued)

nickel	39	39
selenium	--	--
silver	>0.56	>0.56
thallium	0.24	0.24
zinc	490	260
Conventional variables		
total organic carbon	15%	15%
total volatile solids	22%	22%
percent fine-grained	>89%	>89%

[a] ">" in AET columns indicate that a definite AET could not be established because there were no impacted stations with chemical concentrations above the highest concentration among nonimpacted stations.

APPENDIX C

SUMMARY OF REVIEW OF DATA FOR INCLUSION IN PUGET SOUND DATABASE

TABLE C-1. SUMMARY OF REVIEW OF PUGET SOUND DATA

Study (References)[a]	Chemistry			Benthic Infauna				Toxicology		
	Analytical Techniques	Detection Limits	Scope of Chemicals	Synoptic?	Sampling/ Subsampling	Replication	Reference sites available?	Synoptic?	Frozen?	Accepted Technique?
Alki Extension (9,15)	OK	OK	OK	Yes	OK	OK (5 rep)	Yes	N.A.	N.A.	N.A.
Commencement Bay (14)	OK	high for pesticides	limited volatiles	Yes	OK	OK (4 rep)	Yes	Yes	No	Yes
Duwamish Head (12)	OK	OK	OK	Yes	OK	Excluded[f]	—[g]	Yes	Excluded[j]	—[g]
Duwamish River I, II (2)	OK	OK	no volatiles, acids	N.A.[d]	N.A.	N.A.	N.A.	Yes	No	Yes
Eight Bay (1)	OK	high for many organics	OK	Yes	Excluded[e]	—[g]	—[g]	Yes	No	Yes
Everett Harbor (16) cores	c	OK	mostly PAH	N.A.	N.A.	N.A.	N.A.	Yes	No	Yes
(16) grabs	c	OK	mostly PAH	Yes	OK	OK (5 rep)	Excluded[h]	N.A.	N.A.	N.A.
OMPA 2, 19 (6,7)	OK	OK	no volatiles, polars	Yes	Excluded[e]	—[g]	—[g]	N.A.	N.A.	N.A.
Seahurst (4,5,8,11,13,17)[b]										
TPPS (3,10) Phase IIIA	OK	OK	no volatiles	Yes	OK	OK (4 rep)	No for 17/26 sta.	Yes	Excluded[j]	—[g,k]
Phase IIIB	OK	OK	no volatiles	Yes	OK	OK (4 rep)	No for 6/26 sta.	Excluded[i]	—[g]	—[g]

[a] References:

1. Battelle (1985a)
2. Chan et al. (1985a,b)
3. Comiskey et al. (1984)
4. Dinnell et al. (1984)
5. Landolt et al. (1984)
6. Malins et al. (1980)
7. Malins et al. (1982)
8. Nevissi et al. (1984)
9. Osborn et al. (1985)
10. Romberg et al. (1984)
11. Stober et al. (1983)
12. Stober et al. 1984a)
13. Stober et al. 1984b)
14. Tetra Tech, Inc. (1985)
15. Trial et al. (1985)
16. U.S. Department of the Navy (1985)
17. Word et al. (1984).

[b] The chemical and biological data for the Seahurst study are not currently in a form that allows for easy compilation, although infaunal data are of good quality. Sampling efforts were not always focused on the same stations for biological and chemical tasks of the seven sampling phases of this study. A station-by-station correlation of all data is not currently available. Furthermore, sediments used for benthic infaunal analyses were collected up to 6 months before sediments collected for chemical analyses (Matsuda, B., 20 September 1985, personal communication). This time lag may not be critical for stations resampled at the identical location, but it adds uncertainty. Because of the intractability of the data and uncertainties regarding how many of the data are synoptic, Seahurst infaunal data are not recommended for use in this project. Sediments used for amphipod bioassays were not collected synoptically with sediments used for chemical analyses.

[c] The selected organic priority pollutants reported in this study (almost exclusively PAH) were analyzed by procedures subject to interferences by fatty acid methyl esters and related compounds. The relatively nonspecific GC detection system used for PAH (flame ionization detection, as opposed to mass spectrometry) and the co-elution of interfering substances with PAH resulted in an inability to confirm all compound identities and their quantification. In addition, a confirmation column was not used to verify peaks identified as PCBs. However, the data were accepted after a careful review.

[d] Not applicable (i.e., this biological indicator was not tested).

[e] These infaunal data were excluded from the database because of the subsampling procedure used. Grab samples were subsampled with cores after retrieval. As noted in "Recommended protocols for sampling and analyzing subtidal benthic macroinvertebrate assemblages in Puget Sound" [Puget Sound Estuary Program; Tetra Tech (1986) draft]: "Subsamples are not recommended for benthic infaunal analyses because it is unknown what effect the sampling

process has on the spatial distribution of motile organisms. For example, surface-dwelling organisms may move to the edges of the sample as the grab is being retrieved. If the sampling process disrupts the natural spatial patterns of the organisms, collection of a representative subsample for infaunal analysis may not be possible."

[f] Only one or two replicates were available for infaunal stations in this study. Such levels of replication could not provide an estimate of variance that would be comparable to infaunal data from the other studies considered (these studies had either four or five replicates).

[g] Dashes indicate that the data from this study have already been excluded because of another review criterion.

[h] These infaunal samples were not sieved prior to analysis. No appropriate unsieved reference samples were available for statistical comparisons.

[i] Bioassay and chemistry samples were not taken from the same sediment homogenate. They were collected at different times.

[j] Freezing may alter sediment properties (e.g., effective particle size) and is therefore not recommended (Swartz et al. 1984). Samples that were stored at 4° C are not excluded. Sediments used for microtox bioassays in the Commencement Bay Remedial Investigation were stored for less than 3 wk at 4° C in test tubes that were flushed with nitrogen and then sealed. Under these inert atmospheric conditions, the storage time is not expected to have an effect on the results (see Appendix H).

[k] Uncertainties about the reliability of the Phase IIIA bioassays are described in TPPS documents (Comiskey et al. 1984). The bioassay method used in Phase IIIA was not consistent with methods used in the other studies considered.

APPENDIX D

EVALUATION OF STATISTICAL RELATIONSHIPS AMONG CHEMICAL AND BIOLOGICAL VARIABLES USING PATTERN RECOGNITION TECHNIQUES

by

Tetra Tech, Inc. / G.A. Erickson & Associates

prepared for

Resource Planning Associates

for

Puget Sound Dredged Disposal Analysis
and
Puget Sound Estuary Program

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INTRODUCTION

OBJECTIVES

The main findings of the application of a pattern recognition software system (ARTHUR) to sediment chemistry and biological data from 56 Commencement Bay and Carr Inlet stations are presented in this appendix. As specified in the Sediment Quality Values Work Plan (August 1985), the objectives of the pattern recognition analysis task were:

- To identify statistical relationships among sediment contaminants and biological effects
- To identify relationships that may be useful in developing sediment quality values
- To summarize additional analyses that may be needed in the future to refine or verify the apparent relationships.

These analyses were not intended to be used to establish sediment quality values, but apparent associations identified by the analyses provided guidance for the appropriate application of approaches to develop chemical-specific sediment quality values. All objectives were realized. The pattern recognition analyses were successful in:

- Providing corroboration of trends among chemical variables in a Commencement Bay data set and an independent Puget Sound chemical data set that had been previously analyzed using ARTHUR (Quinlin et al. 1984; more limited site-specific bioeffects information was available for this earlier study)
- Confirming chemical-biological trends that had been previously identified in the Commencement Bay data set using alternative data analysis techniques (Tetra Tech 1985a)
- Identifying new relationships among chemical and biological indicators (e.g., apparent "sensitive species" to certain chemical contaminants) that warrant additional investigation
- Providing evidence that dry-weight as well as organic carbon normalization of chemical data resulted in interpretable trends with respect to biological effects.

APPROACH TO EXPLORATORY MULTIVARIATE DATA ANALYSIS

The problem represented by the Commencement Bay data is the potential complexity of relationships expected among toxic materials, physical/chemical parameters of the system, and biological communities. The purpose of exploratory analysis is to use multivariate techniques to quickly determine

unbiased relationships among the samples or among the 64 benthic abundance variables, 15 taxonomic group variables, 3 bioassay variables, 1 total species count variable, 10 conventional chemistry and grain size variables, and 100 chemical variables.

Exploratory analyses do not require any assumptions concerning the distribution of variables because no statistical hypothesis testing is conducted. Two principal techniques, factor analysis and cluster analysis, were used in these analyses. Factor analysis helps to define linear relationships among the measured variables that may reveal more fundamental physical, chemical, or biological forces and processes affecting the samples. Cluster analysis helps to define relationships among the samples that may reveal natural grouping or categorization that can be interpreted based on factor analysis results or other fundamental influences on the samples. Additional discussion of these techniques is presented in the Methods section (see Exhibit D-1).

In defining relationships among samples and variables, factor analysis and cluster analysis were also useful for identifying potential "anomalies." The term "anomalies" indicates data values identified in an early stage of statistical analysis as exhibiting unusual characteristics relative to other data values. A stepwise analysis was important in evaluating the effects of these anomalies on interpretations of the data. For the most part, these data were associated with samples collected adjacent to major pollution sources. Later analyses that excluded these values were used to evaluate trends observed in initial analyses that included anomalies, and to explore underlying trends that may have been masked by the anomalies.

ANALYTICAL SCOPE

The data analyzed are a subset of stations in the database compiled for development of chemical-specific sediment quality values for Puget Sound (see Commencement Bay Figure A-1 in Appendix A). An additional 88 Commencement Bay stations analyzed for chemical concentrations only were included in the evaluation of chemical-chemical relationships (i.e., a total of 144 chemistry stations; most are shown in Figure 1). The Work Plan limited the scope of analyses to the Commencement Bay/Carr Inlet stations because of three factors:

1. Considerable data manipulation would have been required to compile and enter biological data from other data sets (e.g., benthic species-level abundance data, percent toxicity response) in addition to the chemical data already being entered, which would have delayed the overall project schedule. The only biological data required to determine sediment quality values (see Section 5 of the main report) were codes in the database that specify whether each biological indicator was or was not significant at each station.

2. A combination of all appropriate data sets is not recommended until the large chemical and biological data set generated for the Elliott Bay Toxics Action Plan is available. This combined

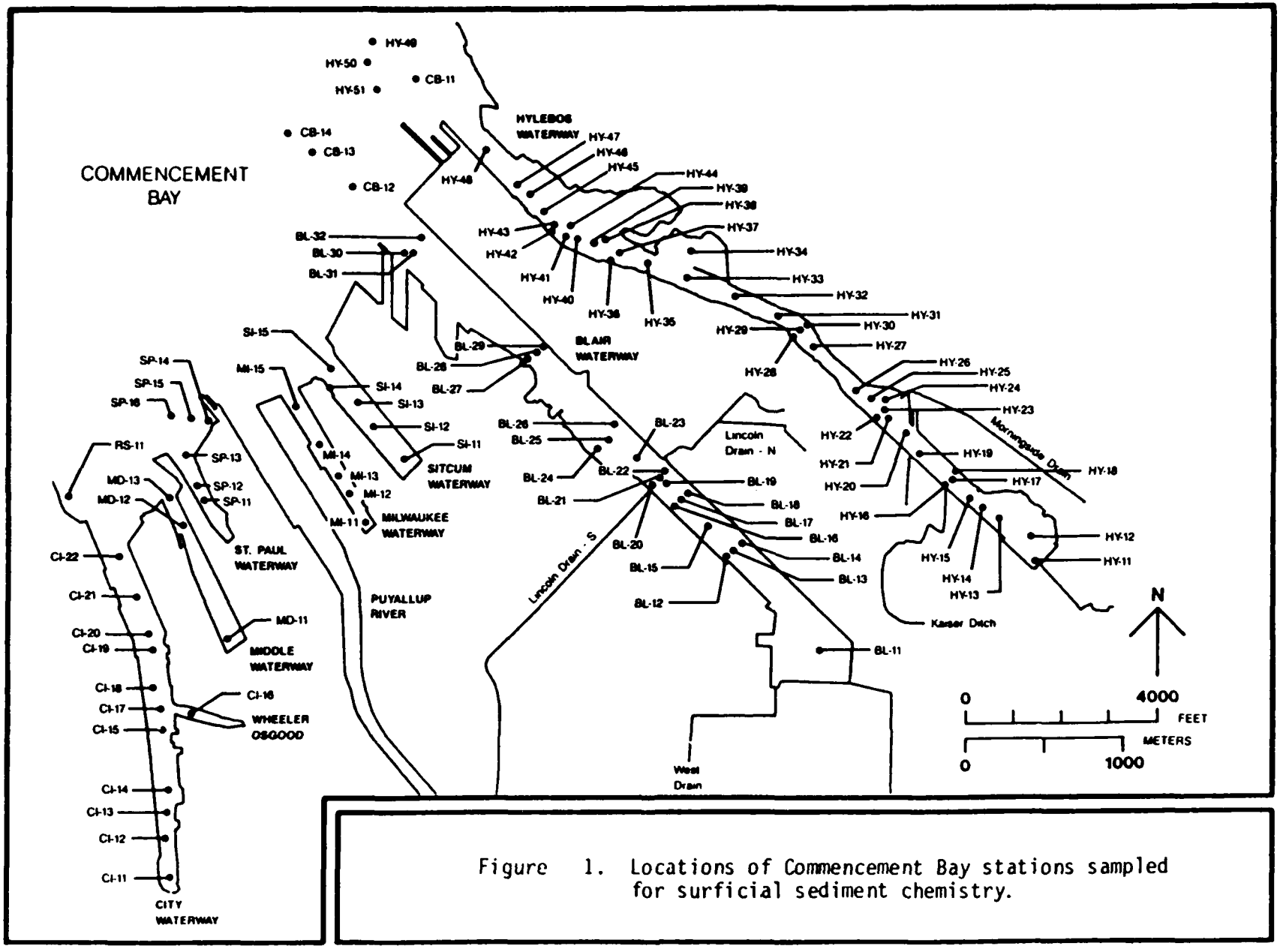


Figure 1. Locations of Commencement Bay stations sampled for surficial sediment chemistry.

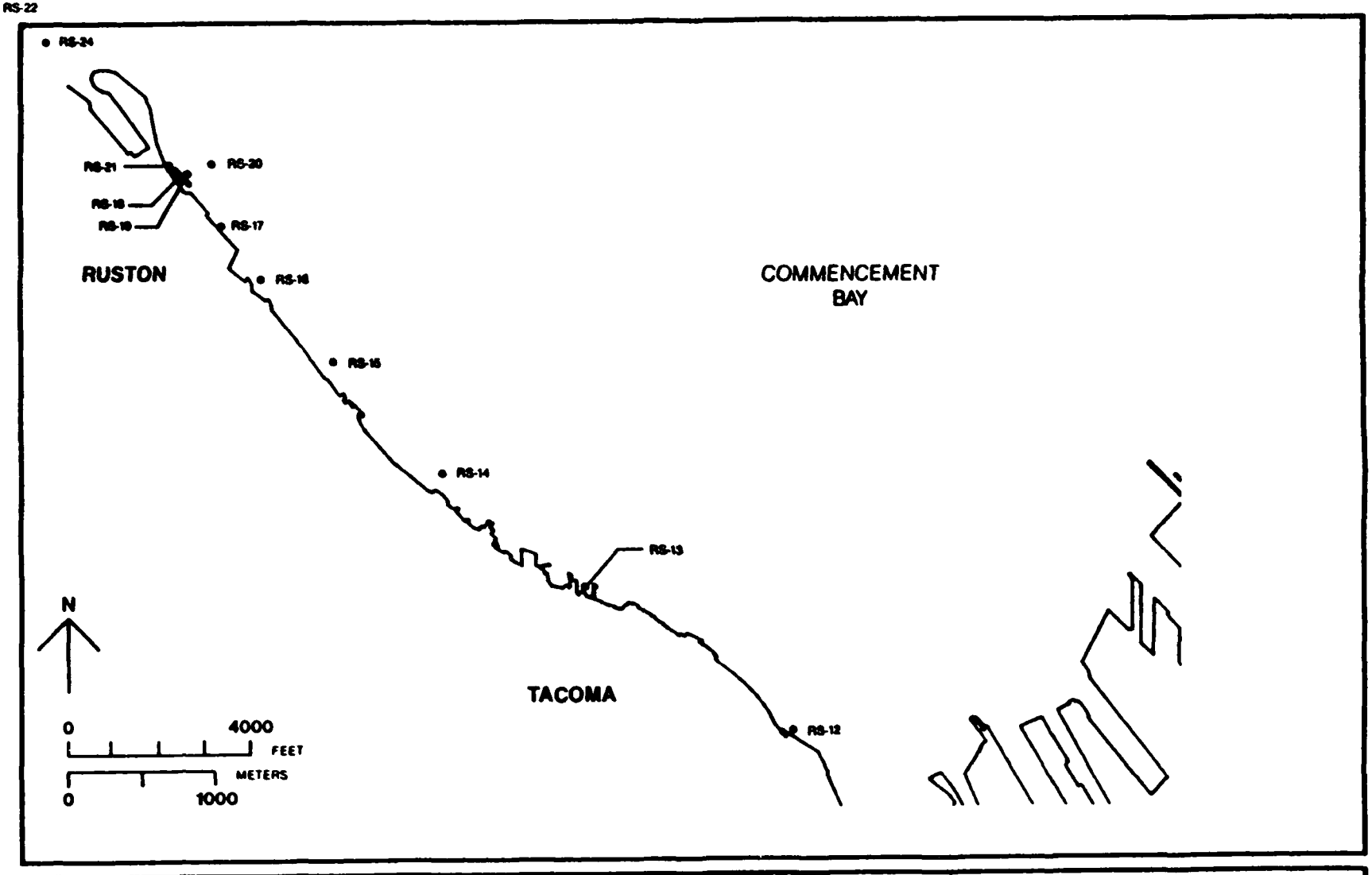


Figure 1. (Continued).

data set may be subjected to the most efficient data reduction and analysis techniques determined in this task.

3. Of the data sets identified for the sediment quality values project (see Appendix C), only the Commencement Bay/Carr Inlet data set contained a full complement of paired chemistry, toxicity (amphipod, oyster larvae, Microtox bioassays), and benthic infaunal data for analysis of the possible relationship of sediment chemistry to site-specific biological effects. The pattern recognition analyses enabled a more detailed investigation of these data than was possible under the constraints of the earlier Superfund investigation (e.g., use of species abundances rather than total taxa abundances in multivariate analyses of chemical-biological relationships; Tetra Tech 1985a).

Four caveats were recognized in the application of pattern recognition techniques to this project. **First**, the pattern recognition results were used only to identify potential relationships among variables as supplemental information for the development of sediment quality values, not to derive quantitative equations such as may be required for specifying a predictive model for sediment quality. The relationships discussed in this appendix can be investigated further by a suitable experimental design, further sampling and analysis, and appropriate statistical tests. As directed in the Work Plan, suggested analyses to refine or verify the relationships are summarized at the end of this report.

Second, no statistical confirmation (hypothesis) tests were required for the exploratory tests conducted on the data, and data uncertainties were not employed. These analyses have produced findings that suggest possible chemical-biological relationships. Confirmation that these relationships occur with a defined statistical confidence would require hypothesis testing. As discussed in the previous section, pattern recognition techniques do not require <u>any</u> statistical assumptions about variable distributions when used in an exploratory mode.

For example, the chemical data used in the analysis were first autoscaled (i.e., by a transformation similar to a z-score transformation). Autoscaling is a one-to-one mapping of the values of a variable from one reference system to another. The mapping preserves the shape of the variable distribution, zero-centers the distribution, and uniformly scales the variance. Also, factor analysis (used as part of the pattern recognition procedure) does <u>not</u> require variables to be normally distributed, especially where the approach is being applied for information compression (i.e., a Karhunen-Loeve transformation; see for example Watanabe 1973) as was done in this work. Hence, data transformations and knowledge of the data distributions become important only if multivariate hypothesis testing were to be conducted.

The ARTHUR program can incorporate data uncertainties in its statistical analyses, but these capabilities were not applied in this study because of resource constraints. It was assumed that, for the trends observed,

environmental variability exceeded the expected analytical variability of the measurements. As a test of this assumption, additional pattern recognition tests were performed with subsets of the data to verify the repeatability of some findings (e.g., the identification of potentially sensitive benthic species). The conclusions reached in this report are based on consideration of these additional tests.

Third, the data set is biased in the greater number of stations from an area that is generally recognized as polluted. Only 5 of the 56 biological stations were located outside the defined Commencement Bay Remedial Investigation area: four in Carr Inlet and a fifth in deep water outside Hylebos Waterway. This constraint is not considered severe because sediments sampled within the Commencement Bay system showed a substantial range in concentrations for the chemicals measured, and many chemicals were undetected at several of the stations. Also, statistically significant bioeffects (e.g., toxicity or depressed benthic infaunal abundances) occurred at only 29 of the 52 Commencement Bay stations.

Therefore, although there are substantially more stations from Commencement Bay than from a defined reference area, conditions within Commencement Bay range from low pollution and effects to high pollution and effects. Therefore, a potential for identification of effects on pollution-sensitive species remains. The data are especially useful for identifying potential relationships among chemicals and species that are not extremely sensitive to pollutants.

Fourth, a complete discovery of relationships in the data set is not guaranteed with pattern recognition analyses. Although the data analyses techniques used in this project provide a reasonably comprehensive multivariate analysis of the data, it is not expected that all relationships have been identified. Nonlinear relationships among variables are hard to determine. The results indicate some additional experiments and analyses that should be performed. Although the findings may be used as guidelines for the appropriate development of sediment quality values or for regulatory actions, such actions must be consistent with the general biogeochemical understanding of the environmental systems under study.

DISCUSSION OF MAJOR RESULTS

GENERAL APPROACH

The combination of pattern recognition techniques in ARTHUR were used to confirm appropriate groupings of chemicals and normalizations of chemical data, identify sensitive benthic species and system-wide relationships among chemicals and bioeffects, and determine the importance of area-specific contamination on the ability to discern potential chemical-bioeffects relationships. The approach used in this study combined statistical methods in sequences that are typical of exploratory evaluation of complex data sets. The sequence of statistical manipulations (including treatment of undetected chemicals) are described in detail in Exhibit D-1. The general sequence of steps was:

1. Autoscale the data to put the variables on a common footing of "unit variance", and list univariate statistical parameters

2. Apply factor analysis techniques to calculate factors representing more efficient dimensions of variation in the data

3. Interpret the factors for underlying chemical or biological meaning

4. Project the scaled measurement values onto the new factor axes and plot the data according to these "scores"

5. Evaluate the factor plots for indications of anomalies (i.e., unusual values) or structure and relationships among the stations

6. Apply cluster analysis techniques to explore for intrinsic group association between the stations

7. Apply other selected techniques, as appropriate, to calculate interfeature correlations, variable variance weights between groups of samples, or variable selection to look for important variables.

Data Description

Data analyzed from Commencement Bay/Carr Inlet included:

- Chemical data for 144 stations (0-2 cm sediment samples; most stations are shown in Figure 1)

- Chemical, bioassay, and benthic infaunal data for a subset of 56 stations (Figure A-1 in Appendix A; benthic data were missing for two of these stations).

The latter chemical-biological data set incorporated 192 variables, including:

- Bioeffects data for 64 benthic abundance variables, 15 taxonomic group abundance variables, 3 bioassay variables, and a "species richness" variable representing the total number of unique benthic infauna species at each station

- Chemical concentration data for 100 organic compounds, metals, and metalloids

- Conventional chemical data for 10 variables (e.g., grain size, total organic carbon, total sulfides).

Separate pattern recognition analyses were conducted using chemical variables normalized to (1) sediment dry weight, (2) total organic carbon content of the sediment, and (3) total percent fine-grained material in each sample. These different data normalizations were used to determine chemical-chemical relationships (i.e., groups of chemicals with covarying distributions in the environment), and chemical-biological effects relationships. The importance of each kind of data normalization is briefly summarized in the following sections.

Dry Weight Normalization--

Most sedimentary contaminants are associated predominantly with the solid material in bulk sediments, not with the interstitial water. Thus, dry-weight contaminant concentrations are preferred to wet-weight concentrations. Use of dry-weight concentrations precludes the possibility that variations in sedimentary moisture content will obscure informative trends in chemical data. Pattern recognition analyses were also conducted using biological effects data and chemical concentration data normalized to sediment dry weight to determine whether a relationship existed between biological effects and the total mass of chemical in a given volume of sample (i.e., represented by the dry weight concentration).

Total Organic Carbon Normalization--

Chemical concentration gradients, particularly of nonpolar, nonionic organic compounds, have been observed to correlate positively with sedimentary organic carbon content (e.g., Choi and Chen 1976). This observation is commonly interpreted in one of two ways: (1) organic matter is the "active fraction" of sediment and serves as a sorptive sink for neutral, and possibly polar or metallic, compounds, or (2) carbon-rich particles may be an important transport medium for contaminants [e.g., PAH may tend to be associated with soot particles (Prahl and Carpenter 1983)]. Also, if organic matter is a sorptive sink for contaminants, toxic biological effects from exposure to contaminated sediments should decrease with increasing organic carbon content (see Appendix H for more detailed discussion). Hence, pattern recognition analyses were conducted with biological effects data and chemical concentrations normalized to organic carbon content to examine whether increases in toxicity or biological effects correspond to increased contaminant

concentrations relative to total organic carbon content. Total organic carbon was also used as a variable in the analysis of dry-weight normalized chemical data.

Normalization to Percent Fine-Grained (<63um) Particles--

On a limited spatial basis, contaminant concentrations are often inversely correlated with particle size. Thus, contaminants (especially metals) may be concentrated in the fine-grained particles of bulk sediments. This observation is often explained in terms of surface area, in that finer particles have greater specific surface area, and thus greater sorption capacity, than larger particles. Because organic carbon content also tends to vary inversely with particles size, normalizing to percent fines may be effectively equivalent to normalizing to organic carbon content. The percent fine-grained material in each sample was also included as a variable in dry-weight and TOC normalized analyses.

Statistical Procedures

Statistical procedures applied to these data included factor analysis, cluster analysis, and category classification. Major chemical and biological factors derived from the total data set are briefly described in the next two sections, followed by a presentation of biological-chemical relationships, the influences of different normalizations of sediment chemistry, and the importance of small-scale geographic effects. Most of the discussion of benthic infauna-chemistry results focuses on individual species, which were not examined in detail in previous studies. Preliminary analysis of the statistical results by G.A. Erickson and Associates was performed without specific knowledge of the results of the Commencement Bay Remedial Investigation (Tetra Tech 1985a).

Factors derived in factor analysis are mathematical (usually linear) combinations of individual variables, and represent different aspects of the data set. The goal of factor analysis is to explain as much of the variation in the data with as few dimensions (factors) as possible. In the current study, up to 10 factors were extracted from the data set and documented. The 5 factors that accounted for the greatest amount of variability in the data set were examined in detail. Each of these 5 factors accounted for at least 5 percent of the total variability and, in combination, accounted for approximately 65-75 percent of the total variability in the data set.

The variables making up a factor may have either a positive or negative loading (i.e., influence) on the total value of the factor. When several variables load strongly in either the positive or negative direction onto a factor, the factor may serve as a replacement for this combination of variables, thus reducing the number of variables in the system. If these factors are interpretable as physical, chemical, or biological influences on a system, they provide additional insight on the relationships between the variables making up the factor.

CHEMICAL FACTORS

Each of the following four chemical factors were extracted from the chemical data set as linear combinations of the concentrations of related chemicals. Chemicals for each factor are listed in decreasing order of the strength of their loading:

1. **A phenols and light aromatic hydrocarbon factor:** 4-methylphenol, isopimaradiene (a diterpene), 2-methoxyphenol (guaiacol), an alkylated benzene isomer (tentatively identified as a cymene isomer), and phenol.

2. **A metals factor:** nickel, iron, barium, zinc, total metals (the sum of U.S. EPA priority pollutant metals), selenium, arsenic, manganese, beryllium, lead, antimony, copper, cadmium.

3. **A chlorinated compound factor:** hexachloroethane, 1,2,4-trichlorobenzene, hexachlorobenzene, hexachlorobutadiene, other tri-, tetra-, and pentachlorinated butadienes, total PCBs [often joined by some polynuclear aromatic hydrocarbon (PAH), e.g., dibenzo(a,h)anthracene or indeno(1,2,3-cd)pyrene].

4. **A high molecular weight PAH (HPAH) factor:** total HPAH, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, total benzofluoranthenes, methylpyrenes, benzo(a)pyrene, chrysene, benzo(a)anthracene.

These factors indicated groups of chemicals with similar geographic distributions. For example, the metals factor was strongly influenced by the concentrations of metals at stations near the ASARCO smelter along the Ruston-Pt. Defiance Shoreline (Figure 1); the chlorinated compounds factor was strongly influenced by concentrations of chlorinated compounds at stations toward the mouth of Hylebos Waterway (Figure 1). Concentrations of HPAH near the Kaiser Ditch toward the head of Hylebos Waterway strongly influenced the HPAH factor.

Similarly interpretable factors were derived from several NOAA data sets on other areas of Puget Sound (Quinlin et al. 1984). These previous factors included HPAH, low molecular weight PAH (LPAH), metals, and DDTs and high molecular weight chlorinated hydrocarbons (e.g., PCBs). The similarity of these derived factors in different data sets from around Puget Sound suggest similar chemical-chemical relationships in each area (at least for these select chemicals). Because of this covariance, it is recommended that sediment quality values be derived for the sum of these variables as well as for the individual chemicals.

BIOLOGICAL FACTORS

In a manner similar to the derivation of chemical factors, several factors dominated by biological variables emerged from an evaluation of the benthic infauna and conventional chemical data set (e.g., grain size, organic carbon). These data were evaluated separately from the toxic chemical

data to examine features that might suggest community relationships among benthic infauna. The resultant factors sometimes included significant contributions from grain size variables (e.g., percent sand and silt content), but not from other conventional chemical variables (e.g., TOC, sulfides, total volatile solids, oil and grease). The inclusion of conventional chemistry variables in this analysis enabled some interpretation of habitat type as an important characteristic of benthic communities. For example, the following 3 factors contained combinations of biological variables that could be interpreted from an environmental perspective (run #17, Table D-4 in Exhibit D-1; variables listed for each factor are in decreasing order of their loading on varimax rotated factors; benthic infauna are in terms of abundance):

1. **A factor composed primarily of molluscs, ostracods, and decapods, some species of which are pollution-tolerant and most of which are abundant in Commencement Bay waterways):** This factor includes Total molluscs, Axinopsida spp., Axinopsida serricata, Nucula tenuis, Euphilomedes spp., Euphilomedes producta, Total abundance, Macoma spp., Macoma carlottensis, Eteone longa, Pinnixa spp., Lumbrineris spp.

2. **A factor composed primarily of benthic infauna associated with fine-grained sediment types:** includes Tharyx multifilis, Tharyx spp., Total polychaetes, Total abundance, [-Sand], Lumbrineris spp., [+ Silt], Lumbrineris sp. group 1, [+ Clay], Glycera capitata, Leitoscoloplos pugettensis, Macoma elimata

3. **A factor composed primarily of benthic infauna associated with sandy sediment types:** includes Prionospio steenstrupi, Prionospio spp., Odostomia spp., Mysella tumida, Mitrella gouldi, Total crustaceans, Mediomastus spp., Leptochelia dubia, [+ Sand], [- Silt], - Lumbrineris sp. group 1.

Variables preceded by a minus sign (-) in these lists have a negative loading on the factor (i.e., are inversely correlated with variables having a positive loading). Non-biological variables (i.e., sand and silt content) are shown in brackets. Sand, silt, and clay were the only non-biological variables included in the analysis that loaded strongly on these 3 factors (e.g., organic carbon content did not load strongly on these factors).

The first two factors showed a high degree of correlation in most of the Commencement Bay study areas. The third factor had a stronger influence from Carr Inlet stations as well as selected Commencement Bay stations (e.g., St. Paul Waterway stations near a pulp and paper discharge).

BIOLOGICAL-CHEMICAL RELATIONSHIPS

Statistical relationships among biological and chemical variables were examined to ensure that the prediction of sediment quality values would reflect known empirical trends. Many studies have documented that the presence of toxic substances can result in decreased abundances of, or sublethal effects on, affected organisms (e.g., Gary 1979; Boesch and Rosenberg

1981; Eagle 1981; Gray 1982; Wolfe et al. 1982). In cases where opportunistic or pollution-tolerant species have shown an initial increase in abundance after an exposure to toxic chemicals (e.g., Capitella capitata at the West Falmouth oil spill site), high abundances of those taxa have usually been attributed to their abilities to become established in a disturbed or polluted environment and in the absence of competition for resources. Thus, there is little or no documentation of a significant enhancement of benthic organisms as a direct response to a toxic chemical, although such a response is theoretically possible. There is also no evidence that enhancement occurs for one species or taxonomic group in the presence of toxic chemicals without a significant depression being observed in the abundance of another species or group.

Hence, the development of sediment quality values has generally assumed that increasing concentration of certain toxic chemicals results in an increase in biological effects. In the current pattern recognition study, no a priori assumption was made by the statistician concerning the direction of population change in response to a toxic chemical effect. All significant correlations among chemical and biological variables, whether positive or negative, were examined using scatterplots of the data distributions. Examination of scatterplots was also used to prevent blind acceptance of apparent positive or negative trends between two variables based on summary statistical results.

Approach

A series of analyses was used to identify apparent biological-chemical relationships. Results of these analyses are provided in the following sections. Briefly, the steps followed are:

1. Examine correlations among variables as a preliminary check for linear relationships

2. Identify sensitive species using factor analysis:

   - Conduct factor analyses using all chemical-biological stations in the data set to identify factors to which chemical and biological variables contributed in opposite directions (i.e., are inversely correlated)

   - Check the stability (i.e., reproducibility) of these factors, and the possible existence of additional mixed biological-chemical factors by re-running factor analyses on subsets of the whole data sets (i.e., subsets were defined geographically according to the known distribution of different types of major chemical sources in the study area)

   - Using data from all chemical-biological stations, examine scatterplots of the individual chemical and biological variables contributing to the mixed biological-chemical factors to verify their implied inverse relationships.

3. Interpret scatterplots of the primarily chemical and primarily biological factors (discussed in previous sections) to identify possible relationships between combinations of chemicals and combinations of biological variables (note: because factor analysis attempts to derive independent factors characteristic of the data set, a correspondence between these factors is not necessarily expected; there is an implied correspondence only among variables that load onto a common factor).

4. Perform cluster analyses using the factors to define groups of stations according to similarities in the species compositions and abundances of infaunal organisms; check to see if differences among these clusters can be attributed to differences in the associated sediment chemistry or sediment toxicity.

Significant Correlations Among Variables

To derive chemical-chemical variable coefficients, biological-biological variable coefficients, and biological-chemical coefficients, correlation coefficients were calculated for the 192 variables of the various data sets. Correlation coefficients give an indication of the degree to which two variables are related linearly. In multivariate data sets, care must be taken in interpreting correlation coefficients where multiple correlations are present among variables. For example, copper may correlate strongly with the amount of clay present in samples, and the mere presence of a large percentage of clay may also be unsuitable for some benthic organism. A negative correlation between copper concentrations and the abundance of the benthic organism could be misinterpreted unless the effects of the covarying clay have been removed (e.g., by normalizing copper concentrations to percent clay content).

Correlation matrices were scanned for coefficients that were significant for pairs of variables (i.e., at least at the 95 percent confidence interval; $P<0.05$). At this stage of the analysis, data for all stations were included to determine if there were system-wide correlations among variables. Very strong correlations were observed in the 144 station chemical data set for several chemical-chemical variable pairs (e.g., significant coefficients of $r>0.8$ were found for a number of variables associated with LPAH and HPAH).

Only a few of the linear chemical-biological correlations exceeded a coefficient of $r=0.7$ ($r^2=0.5$; i.e., a linear relationship between the variables accounts for approximately 50 percent of the variability):

- "Other" taxa versus aniline ($r=+0.986$), 2,4,5-trichlorophenol ($r=+0.780$), and isophorone ($r=+0.697$)

- Nematoda versus aniline ($r=+0.985$), 2,4,5-trichlorophenol ($r=+0.781$), and isophorone ($r=+0.700$).

In both cases, these results appeared to be driven by a single unusual data value. The "Other" taxa are dominated by Nematoda, which are present

in very high abundance at Station CI-11 at the head of City Waterway. Aniline, 2,4,5-trichlorophenol, and isophorone were detected at this station, but were either undetected or present at lower concentrations at all other stations.

At smaller correlation coefficients (e.g., $r>0.4$ to 0.7), some additional biological variables exhibited significant correlations ($P<0.001$) with chemical variables. Of these biological variables, bioassay responses (i.e., percent amphipod mortality and oyster abnormality) were significantly correlated with the largest number of chemicals ($P<0.001$; $r>0.4$). These bioassay response variables were also negatively correlated with the numbers of unique species at each station [i.e., amphipod mortality ($r= -0.468$) and oyster abnormality ($r= -0.537$)]. This inverse relationship between numbers of unique species and bioassay responses suggests that this measure of species richness may be sensitive to toxicological responses of indicator organisms.

Of 51 biological variables retained for the combined chemical-biological evaluations, 37 had correlations significant at the 95 percent confidence level ($P<0.05$) with at least one organic/inorganic chemical or conventional (e.g., grain size) variable. Ten chemical or conventional variables that were significantly correlated with >10 percent (i.e., ≥ 4) of these biological variables are listed in Table 1. The number of times each variable was positively and negatively correlated with biological variables is also indicated.

All of the individual chemicals in Table 1 that were negatively correlated with more than one biological variables are either crustal elements that derive predominantly from natural sources (e.g., nickel, beryllium, and chromium) or compounds that could derive as natural biological products [e.g., 9-hexadecenoic acid methyl ester; fatty acid methyl esters are possibly derived from microbial methylation of naturally occurring fatty acids (Ehrhardt et al. 1980)]. The suggested interrelationships between metals and biological variables (Table 1) may simply reflect silt/sand correlations with biological variables because the metals also have significant positive correlations with percent silt content and negative correlations with percent sand content. A similar grain size dependency was not observed for organic compounds.

Overall, when data from all 56 chemical-biological stations in Commencement Bay/Carr Inlet were combined in a simple correlation analysis, no strong evidence was found for a chemical-benthic species relationship that could be interpreted as an adverse effect of a pollution source common to the entire area. This lack of obvious linear relationships between pairs of chemical-biological variables suggested the need for more complex factor analysis involving combinations of several variables.

Identification of Potentially Sensitive Species

Factor analysis and factor plots (i.e., scatter plots where at least one of the axes is a derived factor from factor analysis) were performed using the combined chemical-biological data set (56 stations). As a test of

TABLE 1. FREQUENT SIGNIFICANT CORRELATIONS AMONG CHEMICAL OR CONVENTIONAL VARIABLES AND BIOLOGICAL VARIABLES [a]

Conventional/Chemical Variable	Number of Significant Correlations		
	Negative	Positive	Total
Silt	9	8	17
Sand	10	7	17
Nickel	6	0	6
9-Hexadecenoic acid methyl ester	3	2	5
Total organic carbon	3	2	5
Benzo(ghi)perylene	0	4	4
Beryllium	2	2	4
Chromium	2	2	4
Isophorone	1	3	4
Benzyl alcohol	0	4	4

[a] Significant correlations ($P<0.05$) based on all 56 biological stations throughout Commencment Bay/Carr Inlet.

the stability of the relationships indicated by factors derived with the entire chemical-biological data set, stations were assigned to one of the following five groups and subjected to additional factor analysis. These subset analyses were used to separate the influence of grossly different known sources of chemicals, because similar toxicity and benthic infaunal responses could be expected from completely different chemical exposures:

1 - All biological stations in the relatively low contaminated Blair and Milwaukee Waterways, and reference stations in Carr Inlet (Figure A-1 in Appendix A)

2 - All biological stations in the adjacent Middle and City Waterways (Figure A-1) (with a mixture of contaminants)

3 - All biological stations in upper Hylebos Waterway (Figure A-1; exposed to major sources discharging some chlorinated compounds but mainly metals and PAH)

4 - All biological stations in lower Hylebos Waterway (Figure A-1; exposed to major sources discharging primarily chlorinated compounds)

5 - All biological stations in Sitcum Waterway and along the Ruston-Pt. Defiance Shoreline (Figure A-1; evidence of significant metals contamination in both areas)

6 - All biological stations in St. Paul Waterway (Figure A-1; exposed to the discharge of a major pulp and paper facility including high concentrations of phenolic substances).

In the five subset analyses conducted, stations in groups 2 through 6 were tested in combination with group 1 stations, believed to be the least contaminated. This pairing of groups ensured a contrast between stations with low contamination and stations with higher concentrations of chemicals in each subset analysis. The factor analysis results were then examined to determine which chemical and biological variables loaded onto the same factor. Variables chosen for further study were those with the highest (absolute value) loading on each factor, down to a level that explained over 50 percent of the total variance contained by the factor, or to where the loadings decreased noticeably in magnitude.

Most of the factors in these analyses appeared to be primarily chemical or primarily biological factors. A single mixed chemical-biological factor appeared frequently in the different subset analyses. Biological and chemical variables on this mixed factor were loaded with opposite signs. The frequencies with which variables were prominent on this factor are listed in Table 2. Frequently appearing taxa were Praxillella gracilis (Polychaeta), Euclymeninae (Polychaeta), Euphilomedes producta (Ostracoda), and Nucula tenuis (Pelecypoda). Frequently appearing chemicals were naphthalene, anthracene, benzo(ghi)perylene, pyrene, 2-methylnaphthalene, total organic carbon, 9-hexadecenoic acid methyl ester (tentative identification), and retene (probable identification). This factor was present in the factor analysis of all 56 stations, and its persistence and the repeated appearance of

TABLE 2. NUMBER OF OCCURRENCES OF ANTI-CORRELATED VARIABLES IN A MIXED CHEMICAL-BIOLOGICAL FACTOR FROM FACTOR ANALYSES OF DATA SUBSETS

Chemical Variable	Number of Occurrences[a]	Biological Variable	Number of Occurrences[a]
9-Hexadecenoic acid methyl ester	5	Euclymeninae	6
Benzo(ghi)perylene	4	*Praxillella gracilis*	5
Beryllium	4	*Nucula tenuis*	4
Acenaphthalene	3	*Euphilomedes producta*	3
Total organic carbon	3	*Nemocardium centifilosum*	4
Retene	3	*Mitrella gouldi*	2
Unidentified diterpene[b]	3	*Phyllochaetropterus prolifica*	2
2-Methylnaphthalene	2	*Axinopsida serricata*	2
Anthracene	2	Total molluscs	2
Pyrene	2	*Macoma elimata*	2
Naphthalene	2	*Euphilomedes*	2
		Callianassa spp.	2

[a] The variables listed were present in a mixed biological-chemical factor in repeated factor analyses of the entire data set and subsets of the data (separated geographically as discussed in text). The number of occurrences indicates the number of factor analyses in which the variable appeared in the factor; these chemical and biological variables were loaded on the factor in opposite directions (i.e., were anti-correlated).

[b] Tentatively identified (with low confidence) as kaur-16-ene.

the variables in Table 2 in different subset analyses (including analyses normalized to organic carbon or fine-grained material) strongly suggests that the factor is not an artifact.

These results led to the direct examination of potential relationships between the biological and chemical variables that frequently appeared in this mixed chemical-biological factor. Scatterplots of these variables demonstrated several instances where selected benthic infaunal taxa showed strong tendencies for lower abundances at higher chemical concentrations. An example of this inverse correlation behavior is shown in Figure 2. Praxillella gracilis (Polychaeta) ranged in abundance up to 387 individuals/m^2 at stations where pyrene concentrations were less than about 1900 ug/kg dry weight. At higher pyrene concentrations found at 8 stations, the abundance of this polychaete never exceeded 16 individuals/m^2. Approximate chemical concentrations above which abundances of benthic taxa were consistently low in these scatterplots are summarized in Table 3.

These taxa were not the most abundant species identified, but were moderately abundant. As a result, their possible chemical sensitivity was not readily apparent using traditional statistical techniques. With the exception of Euphilomedes producta, none of these species have been identified previously as possible indicator organisms. Their potential use as potential sensitive indicators of chemical contamination should be explored further. Euphilomedes spp. often exhibit enhanced abundances in response to moderate organic enrichment of the sediments (Word 1978, 1980).

Inverse Relationships Among Chemical Factors and Biological Factors

Several factor plots indicated an inverse relationship between predominantly taxonomic factors and predominantly chemical factors, or factors that combined chemicals or conventional sediment characteristics (e.g., organic carbon content) with measures of sediment toxicity. As discussed previously, an inverse relationship may be most characteristic of a direct toxic response of an organism to chemical contamination. For example, in pattern recognition analyses run with only the biological effects data and conventional sediment variables (i.e., excluding toxic chemicals), higher species abundances appear to be associated with areas low in organic enrichment and sediment toxicity as shown in Figure 3.

Figure 3 represents a factor projection scatter plot of the stations as they relate to a biological factor (vertical axis; composed primarily of taxa) and a conventional-bioassay factor influenced primarily by volatile solids content, TOC and toxicity response. The upper right portion of the plot contains no stations, indicating that high infaunal abundances are not coincident with organically-enriched sediments that are toxic in laboratory tests.

Similar, but sometimes less obvious relationships were observed for individual chemicals. This is not surprising because the composition of equally toxic sediments can vary widely over the entire study area. Hence, general variables such as organic carbon content or bioassay response may

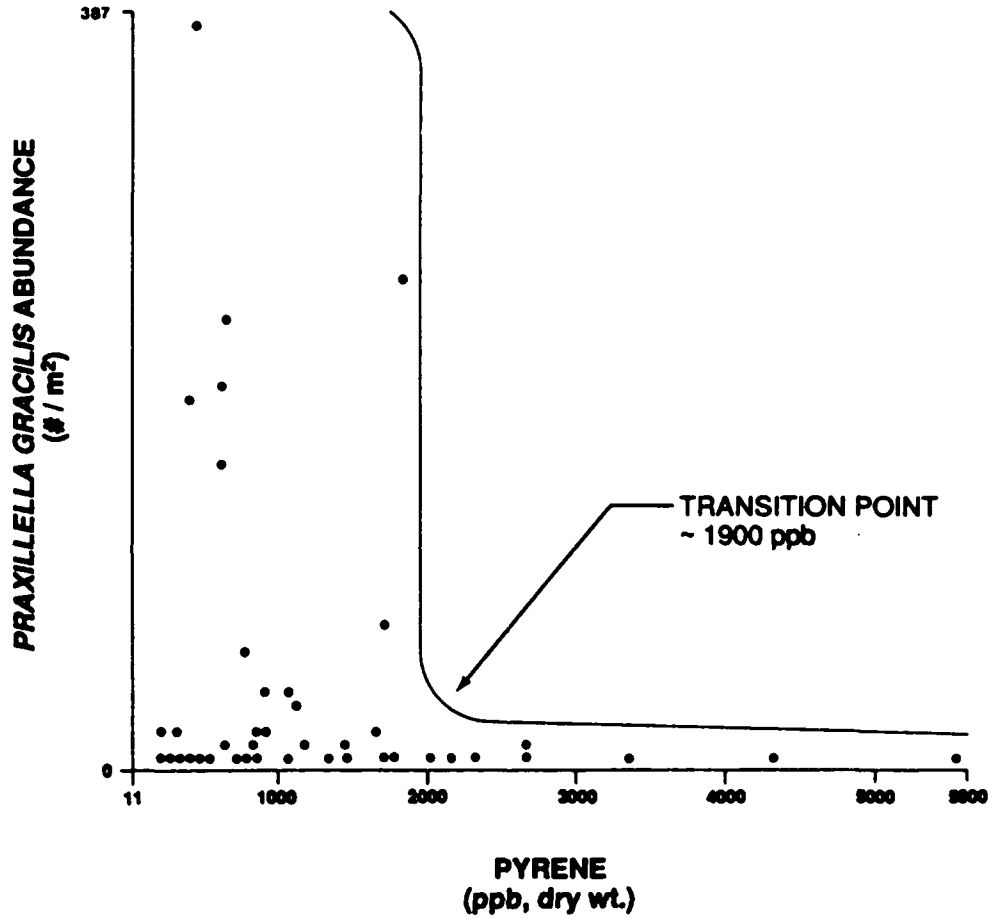


Figure 2. Scatterplot of the abundance of Praxillella gracilis and sediment concentration of pyrene.

TABLE 3. CRITICAL CONCENTRATIONS OF CHEMICALS INDICATED BY SENSITIVE SPECIES

Chemical	Low Abundance Threshold Concentration by Species [a]			
	Praxillella gracilis	Euclymeninae	*Euphilomedes producta*	*Nucula tenuis*
Naphthalene	1100	1100	1300	1400
2-Methyl naphthalene	380	390	380	565
Anthracene	560	560	560	--
Pyrene	1900	1900	1900	3300
Benzo(ghi)perylene	400	450	--	570
Retene	270	510	270	--
9-Hexadecenoic acid Methyl Ester	560	560	1800	1700
Total organic carbon	3 %	3 %	7 %	4 %

[a] Above these concentrations, abundances of the species indicated were uniformly low; concentrations in ug/kg dry weight (ppb) unless otherwise indicated.

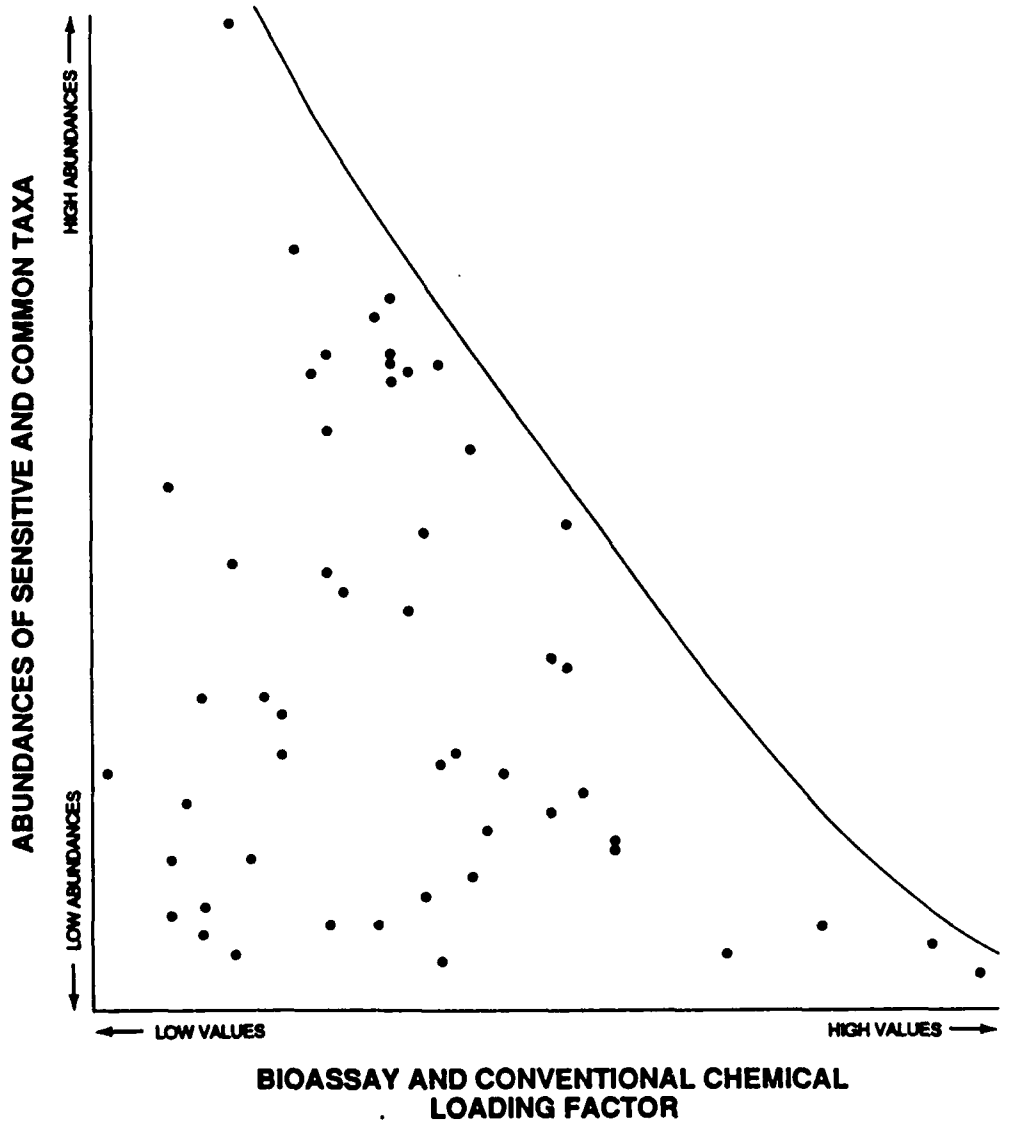


Figure 3. Scatterplot of a major "biological" factor and a "bioassay/conventional chemical" factor.

show stronger relationships with the distribution of benthic effects in the overall data set than any one or group of chemicals.

In several computer runs, it was clear that higher population abundances indicated by biological factors occurred only within a restricted, low value range of the chemical factor (e.g., see Figure 4). This behavior was also observed in factor plots based only on conventional, bioassay, and benthic variables (e.g., see Figure 5). The relationships observed indicate that abundances of benthic organisms do respond to chemical contamination and in a manner that parallels (but does not perfectly duplicate) the responses observed in bioassays.

Infaunal Classification Analyses

Numerical classification analyses were performed on the benthic infaunal data to define groups of stations (i.e., clusters) based on the similarity of taxonomic composition of infaunal organisms. The resulting station clusters were evaluated to determine if they could be distinguished on the basis of observed differences in biological/toxicity effects or chemical measurements. Euclidean distance (standardized to the maximum similarity) was used as a similarity measure, and a hierarchial clustering strategy was used to generate the station groups (see Appendix A).

The similarity measure used is sensitive to the absence of species as well as to the number of individuals of species that are present. The Euclidean distance can result in high resemblance between stations that do not have many attributes *in common, but whose* attribute scores are low (Boesch 1977). Such resemblances are expected among heavily impacted stations although different taxa may be present at the stations. This similarity would not be expected to be found using the Bray-Curtis similarity measure as previously applied with these data (Tetra Tech 1985a).

Clusters of stations were determined based on their similarity in species composition and abundance as defined by five discrete factors generated in a factor analysis of the 64 numerically dominant infaunal species. Several factor analyses were conducted during a stepwise series of tests with intervening technical review. Preliminary factor analysis indicated five "anomalous" stations that were removed prior to the final factor and cluster analyses. As previously discussed, were primarily associated with samples collected adjacent to major pollutant sources. These data were excluded from subsequent analyses for three reasons:

- The effect of these particular data was clear from the preliminary analyses
- The preliminary trends observed required reexamination without the effects of the anomalies
- Any underlying trends that may have been "masked" by the anomalous data points needed to be understood.

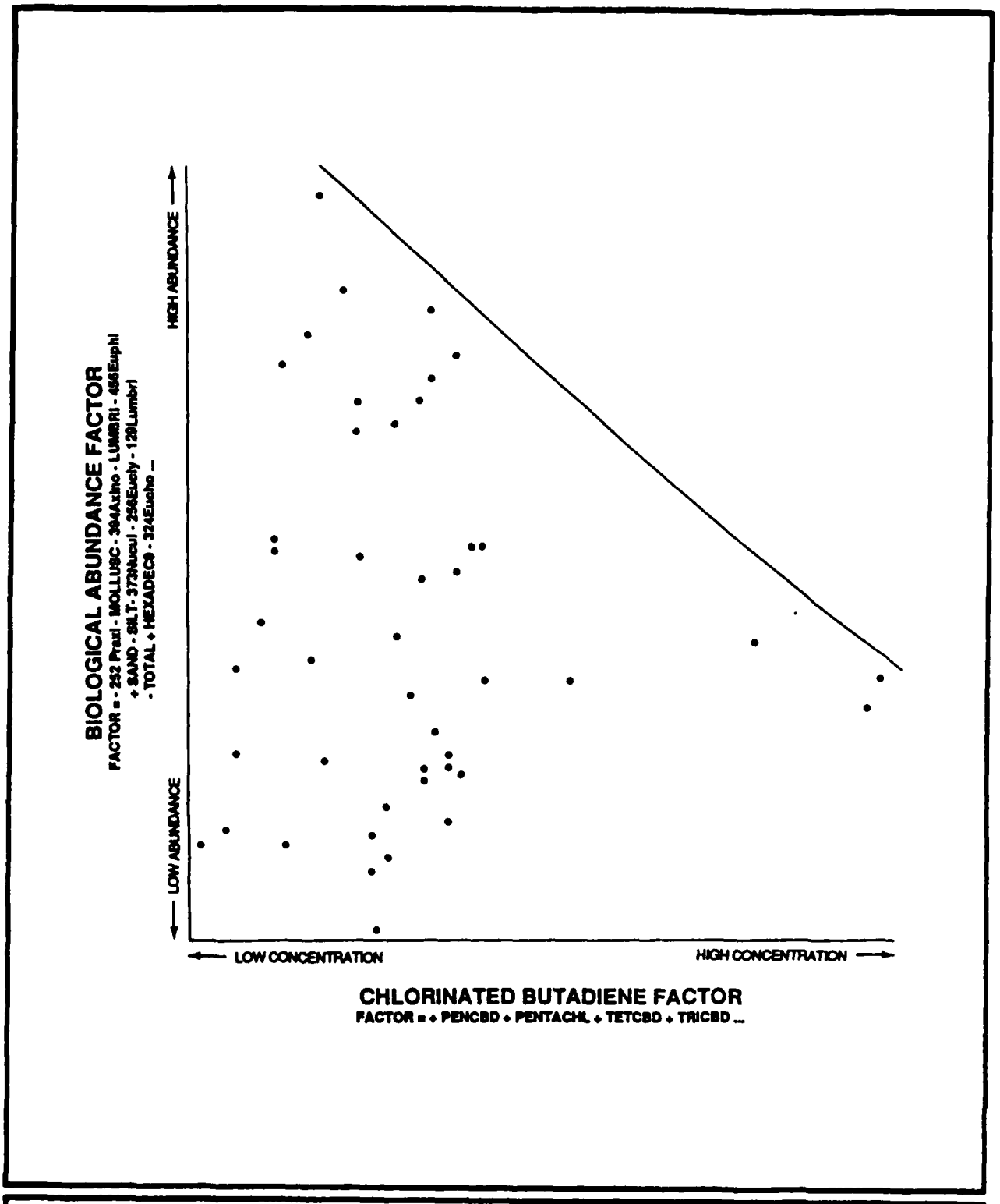


Figure 4. Scatterplot of a major "biological" factor and a "chlorinated butadiene" factor.

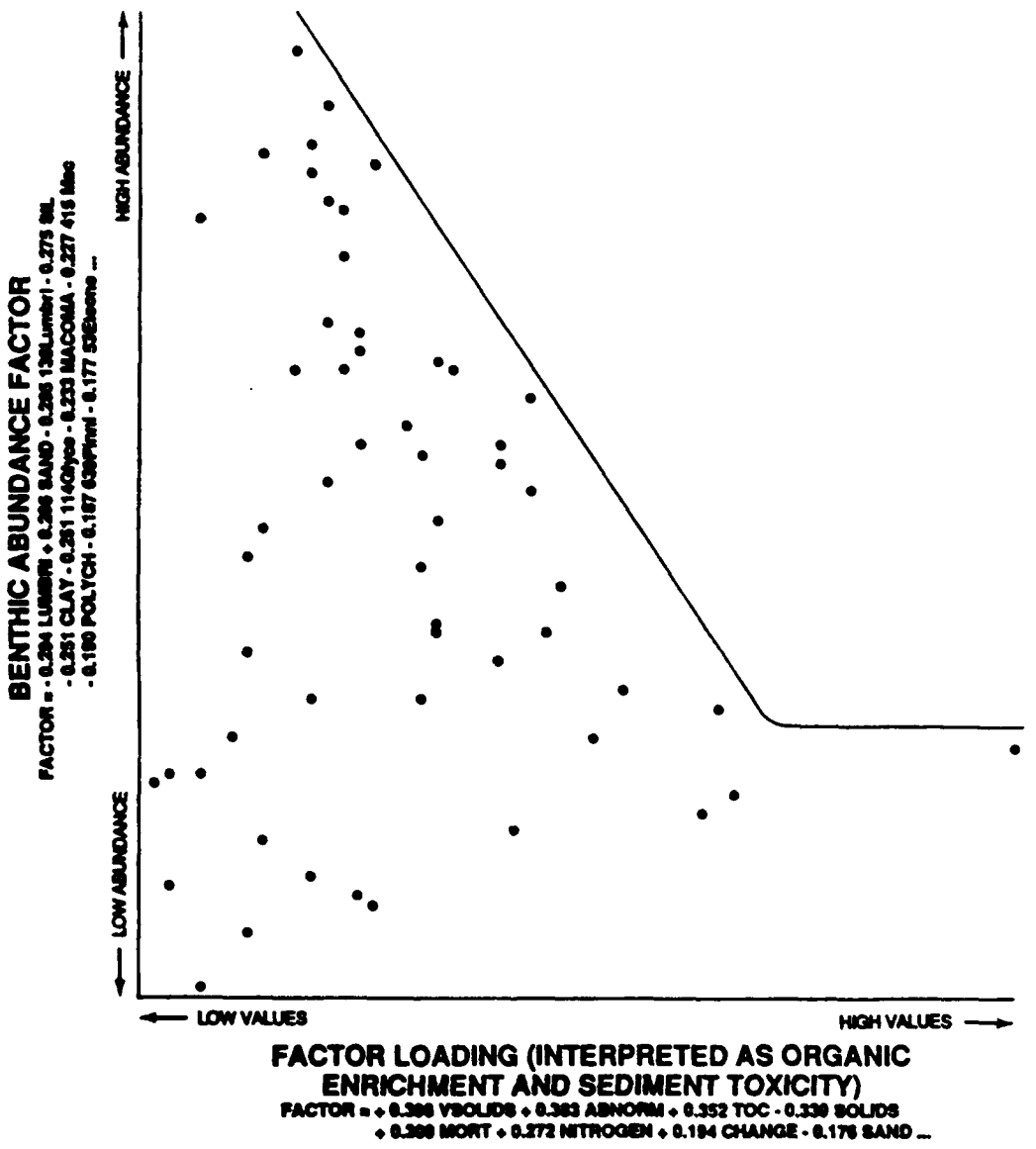


Figure 5. Scatterplot of a "biological" factor and an "organic enrichment/sediment toxicity factor.

Because the Commencement Bay study design was intentionally focused around potential sources to determine concentration gradients, such anomalies were expected. Concern regarding treatment of anomalies is higher and more critical in experimental designs based on random sampling (either spatially or temporally). Thus, the treatment of anomalies in the staged analysis conducted for this project was considered appropriate.

A dendogram showing the grouping of stations at different dissimilarity values is shown in Figure 6. Stations with statistically significant sediment toxicity or statistically significant depressed abundances of major taxonomic groups ($P<0.05$; Tetra Tech 1985a) are also indicated.

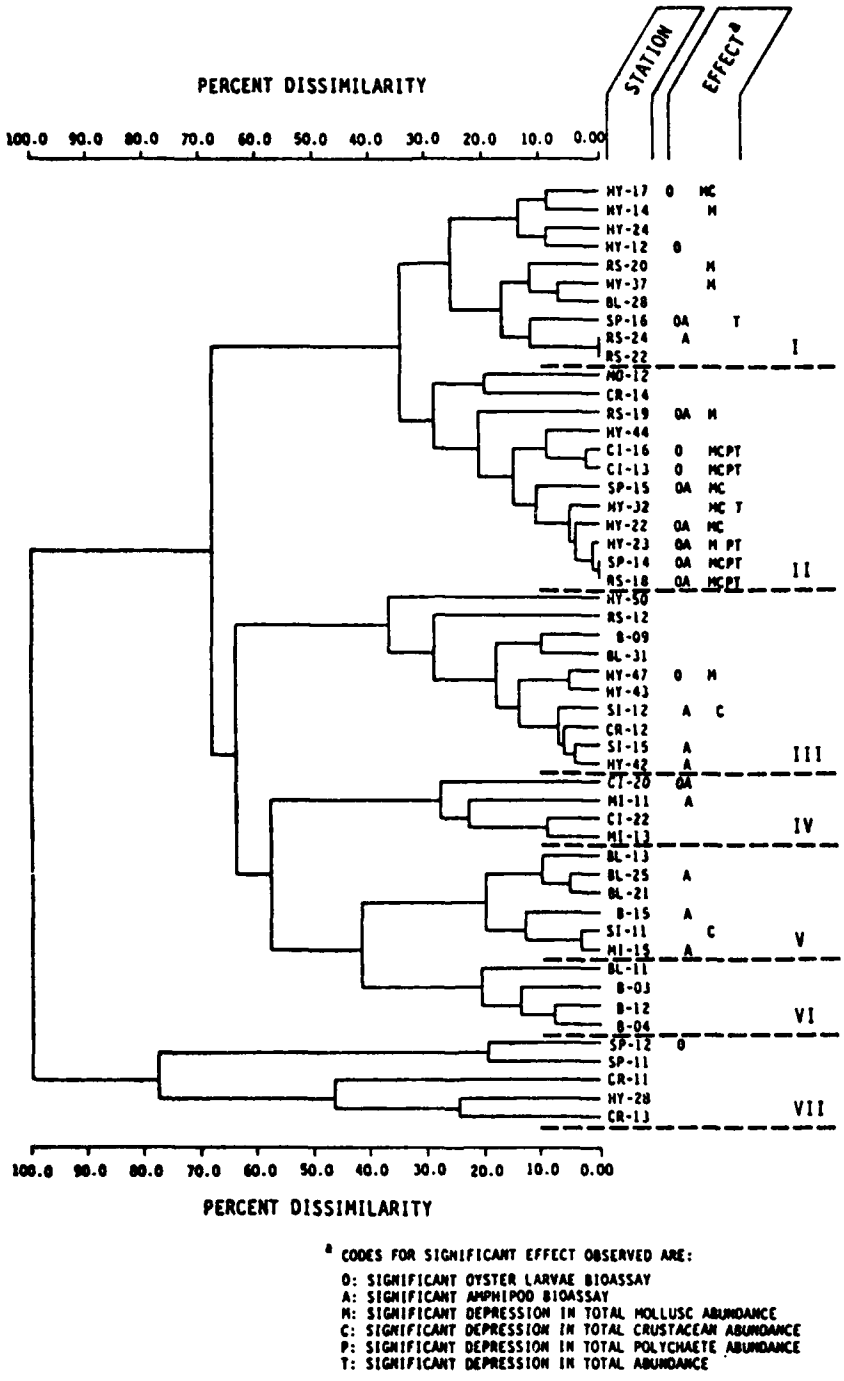
Seven groups of stations were defined at inter-group dissimilarities ranging generally from 30 to 40 percent (Figure 6). Group VII displayed the highest intra-group dissimilarity as well as the highest dissimilarity to other groups. The station clusters are characterized by no or few bioeffects in Clusters V, VI, and VII (i.e., effects indicated only by a single toxicity bioassay or, even less frequently, by a single major taxonomic infaunal indicator) to a group almost entirely composed of stations with multiple indications of biological effects (i.e., Cluster II). Cluster II contained all of the stations where sediments exhibited the most severe effects (e.g., >50 percent mortality or abnormality in toxicity tests, and almost complete absence of benthic infaunal organisms).

Factor projection plots (i.e., scatterplots of pairs of factors) were examined to determine the major factors contributing to the definition of these clusters. The factor that clearly distinguished the low biological effects clusters from Cluster II (high biological effects) had the following composition of variables (in order of the loading by each variable):

Factor = -0.354 *Praxillella gracilis* - 0.320 *Axinopsida serricata* - 0.318 *Nucula tenuis* - 0.283 *Euphilomedes producta* - 0.270 *Eteone longa* - 0.263 *Pholoe minuta* - 0.238 *Euchone incolor* - 0.234 Euclymeninae - 0.208 *Lumrineris* sp. gr. 1...

Stations in Cluster II had uniformly high values for this factor (i.e., low abundances of the indicated species). Several of these species are the same as reported in Table 2, which listed apparently sensitive species that appeared to be inversely correlated with selected chemicals in factor analyses of the complete chemical-toxicity-infauna data set. *Axinopsida serricata* was the dominant mollusc found in the waterways, and *Euphilomedes* spp. was the dominant crustacean taxon. The other four factors from factor analysis either did not contribute to the separation of these particular clusters or had a minimal effect. Hence, stations that appear to be strongly impacted on the basis of statistically significant ($P<0.05$) bioassay responses and depressions in major taxonomic groups, have similar low abundances of individual species that may be sensitive to chemical contamination.

Sediments from three stations in Cluster II did not exhibit statistically significant effects in previous studies (Tetra Tech 1985a). Of these stations, sediments from Station MD-12 had high concentrations of several



[a] CODES FOR SIGNIFICANT EFFECT OBSERVED ARE:

O: SIGNIFICANT OYSTER LARVAE BIOASSAY
A: SIGNIFICANT AMPHIPOD BIOASSAY
M: SIGNIFICANT DEPRESSION IN TOTAL MOLLUSC ABUNDANCE
C: SIGNIFICANT DEPRESSION IN TOTAL CRUSTACEAN ABUNDANCE
P: SIGNIFICANT DEPRESSION IN TOTAL POLYCHAETE ABUNDANCE
T: SIGNIFICANT DEPRESSION IN TOTAL ABUNDANCE

Figure 6. Hierarchial classification analysis using 5 factors from factor analysis of 64 numerically dominant infaunal species.

chemicals at or near the level above which effects were always found at other stations, and Stations CR-14 and HY-44 had coarse sediments (i.e., >75 percent rocks and sand) that are not expected to support high abundances of organisms. Hence, when only benthic species data comprise the clustering factors, the factors do not necessarily distinguish between sediments with potential major chemical impacts and all sediments that may have low abundances of sensitive species because of presumed natural factors.

The most frequent significant indicator in the no-effects to low-effects groups of stations was a significant amphipod bioassay response. A significant amphipod bioassay in the absence of other indicators of bioeffects occurred only at stations with sediments containing greater than 80 percent fine-grained material. This response has been interpreted as possibly indicating a grain size effect in the bioassay rather than necessarily a toxic effect, although not all sediments with high percentages of fine-grained material are significantly toxic by this bioassay (Tetra Tech 1985a). A toxic effect cannot be ruled out; it is also possible that the amphipod bioassay may be more sensitive to some forms of contamination than are other indicators.

In general, the cluster results suggest that laboratory bioassay results and determinations of significant depressions in major taxonomic groups are reasonably sensitive to changes in the structure of benthic communities. They further suggest that a high degree of concordance may be expected among these indicator variables.

Preliminary analyses were conducted to determine if the sediment concentration of some toxic chemical factor was higher in a group of stations having high toxicity compared with a group of stations with lower toxicity, but similar benthic cluster assignments. No clear relationships were found with specific chemicals, likely because the stations composing each group had diverse chemical sources. Additional analyses are warranted after controlling for gross differences in chemical composition within a particular benthic cluster. These analyses were not conducted because the current data set contains only a few stations that have closely related benthic assemblages and similar chemical sources, which limits the confidence with which a statistical analysis can be made. Solutions to this problem are discussed in the summary (see Additional Analyses Recommended to Refine or Verify Results).

UTILITY OF ORGANIC CARBON OR GRAIN-SIZE NORMALIZATIONS

The grain-size dependency suggested for metals in a previous section (i.e., Significant Correlations Among Variables) may indicate a need to normalize chemical concentrations for the content of fine-grained materials in the sediments to distinguish any independent effect of the chemicals. Likewise, a normalization of organic compounds to total organic carbon may be appropriate because of the known correlation between these variables. Exploratory runs were made with both of these normalizations. In terms of the biological relationships, few new observations emerged. The results tend to corroborate the findings determined with the dry-weight normalized data, especially the general patterns of decreased abundances of sensitive species with selected combined chemical factors.

Normalization to percent fine-grained material seemed to produce results in factor analysis that were nearly identical to dry-weight calculations. Normalization to TOC was also consistent in indicating potentially sensitive species, with the possible suggestion of additional species that may decline in abundance with increased concentration of certain chemicals. The apparently sensitive species indicated in all three types of runs were:

- Axinopsida serricata
- Total mollusc abundance
- Nucula tenuis
- Euphilomedes producta
- Euclymeninae
- Praxillella gracilis.

Additional sensitive species suggested by the TOC normalized analyses were:

- Macoma elimata
- Nemocardium centifilosum
- Lumbrineris spp.
- Euchone sp. A
- Nephtys cornuta.

Generally, it appears that analyzing the variables without normalizing to fines or organic carbon content provides the majority of interpretable information. This fact may indicate that the primary influence of chemicals in sediments on the biological systems and individual species is related to the total volume concentration (mass) that is present for a chemical. Second order effects may be related to the relative content to fines and organic carbon. However, until the actual mechanisms of chemical-organism interactions are determined (e.g., in laboratory studies), all data sets should be analyzed with and without normalization to these "master" variables, to confirm the results seen in these calculations.

EFFECTS OF STATION LOCATION ON FACTOR LOADINGS

A more distinctive effect than chemical concentration normalizations, and hence of more general concern, were the substantial differences observed between individual study areas (e.g., waterways) represented in the data set. These differences indicate the importance of intensively sampling small regions, in addition to larger-scale sampling to yield an integrated picture of Puget Sound sediment systems.

Distinctive Basin Behavior in Chemical Factors

The most extreme chemical variations observed were in the Hylebos Waterway (chlorinated organics and HPAH) and in the Ruston area (metals). These major chemical differences are not unlike those that may be observed throughout Puget Sound (e.g., Eagle Harbor creosote contamination, or lead contamination around Harbor Island).

A factor plot based on analysis of chemistry data for 144 Commencement Bay/Carr Inlet stations is shown in Figure 7. The results clearly identify the well-known geographic variations in chemical concentrations in this system. The factor plotted on the horizontal axis is strongly influenced by HPAH compounds. The factor plotted on the vertical axis is primarily composed of chlorinated organic compounds. In both factors, the highest concentrations are represented by stations from Hylebos Waterway. Within Hylebos Waterway, sediments near the head of the waterway have the highest PAH concentrations. Sediments toward the mouth of the waterway have the highest chlorinated organic compound concentrations. A similar plot for a metals factor and a chlorinated organics factor demonstrates the relative differences between Hylebos Waterway and the Ruston-Pt. Defiance Shoreline (Figure 8). Analyses were performed with and without these "anomalous" samples to verify the stability of statistical trends.

Because of these substantial chemical differences, the relatively small size of the biological data set (56 stations), and the large number of variables in the problem, relationships between sensitive species and chemical concentration were substantially blurred when all of the data were analyzed together. By analyzing subsets of the data (e.g., two waterways at a time), combined chemical-biological factors emerged (see section on Identification of Sensitive Species).

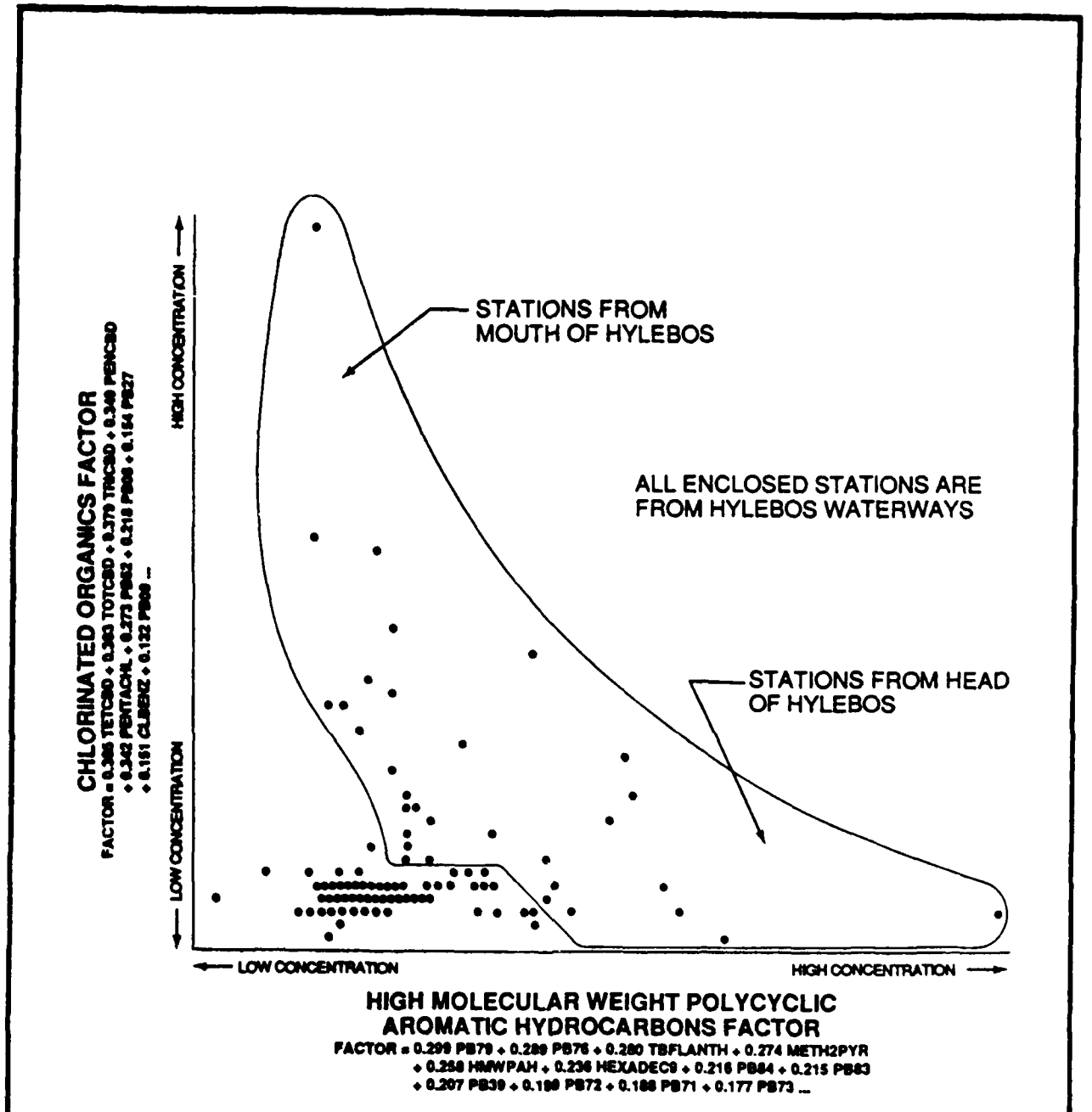


Figure 7. Scatterplot of a "chlorinated organics" factor and a "PAH" factor.

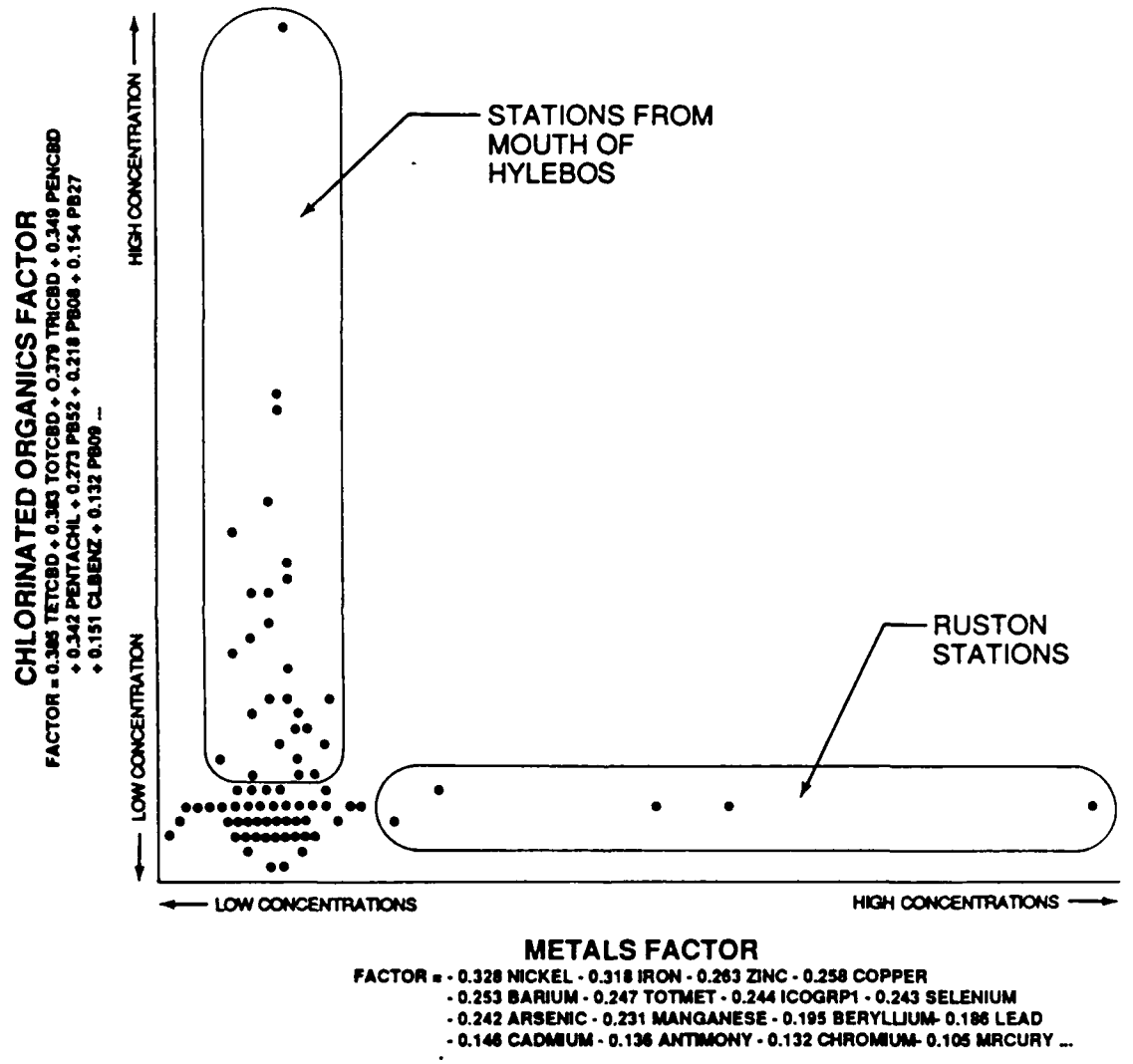


Figure 8. Scatterplot of a "chlorinated organics" factor and a "metals" factor.

SUMMARY

Many of the pattern recognition results have corroborated previous results obtained with traditional statistical techniques (Tetra Tech 1985a) and have not been reported in detail here. This corroboration indicates that traditional techniques have been useful in obtaining the majority of interpretable information contained in the data set, and satisfies one of the major objectives of conducting the pattern recognition analyses (i.e., to validate historical findings). The results of this study are also generally supportive of other previous Puget Sound analyses of chemical-chemical interrelationships using ARTHUR (e.g., Quinlin et al. 1984; Chapman et al. 1984).

MAJOR STATISTICAL RELATIONSHIPS

Major statistical relationships among sediment contaminants and biological effects that were identified using pattern recognition techniques include:

Chemical Factors

Four chemical factors were interpretable from analysis of the complete set of 144 chemistry stations: (1) a phenols and light aromatic hydrocarbon factor; (2) a metals factor; (3) a chlorinated compound factor; and (4) a high molecular weight PAH factor. Previous studies identified similar groups of significantly correlated chemicals (e.g., groups of hydrocarbons, metals, and chlorinated compounds). These results suggest that these major pollutant groups have approximately similar compositions throughout Puget Sound, although local variations certainly exist. Assuming that the composition of chemicals is important in the type and magnitude of bioeffects produced, this similarity implies that sediment quality values for these chemicals may be applicable to much of Puget Sound. Given that different combinations of chemical sources occur in different areas of Puget Sound, there is still a concern that different synergistic effects may occur in these different areas. This concern cannot be resolved by extrapolation of the results in this report, except to note that a multitude of different chemical sources found over a reasonably large geographic area is already represented in the Commencement Bay/Carr Inlet data set.

Biological Factors

Three biological factors were interpretable from analysis of the 54 benthic infauna stations:

1) A factor composed primarily of molluscs, ostracods, and decapods, some species of which are pollution-tolerant and most of which are abundant in Commencement Bay waterways

2) A factor composed primarily of benthic infauna associated with fine-grained sediment types

3) A factor composed primarily of benthic infauna associated with sandy sediment types.

These factors showed little correlation with chemical factors, and appeared to be most strongly influenced by natural conditions (e.g., variations in sand and silt content).

Biological-Chemical Relationships

Factor analysis provided a means to calculate factors that contained contributions from both chemical and biological variables (i.e., there was an apparent relationship among these variables). One factor identified in the overall data set, and verified in reanalyses with subsets of the data, contained chemical variables that were inversely correlated with benthic infauna variables on the same factor. These results were interpreted to indicate potential sensitive species to chemical contamination in Commencement Bay. These relationships were further analyzed using individual scatter plots of the species abundance for the chemicals of interest. Several of these species had not previously been reported as potentially sensitive indicators of contaminated sediments, including two polychaetes (Praxillella gracilis, and Euclymeninae), and a clam (Nucula tenuis). A fourth species, Euphilomedes producta, has been recognized as a potential indicator organisms for moderate organic enrichment (showing enhanced abundances), but has not previously been shown to exhibit a negative correlation with increasing pollutant concentrations.

Some of the factor plots displayed a general reduction in infaunal abundances where higher values of selected chemicals (e.g., metals, HPAH), bioassay responses, or organic enrichment were observed. Three important points were apparent after review of the results:

- No one chemical or chemical group accounted for all toxicity or benthic effects on a system-wide basis

- When analyzed at the system-wide level, the most apparent species-chemical relationships did not always predict the most severe bioeffects observed in localized "hotspots" in Commencement Bay (i.e., off major discharges; however, these stations were distinguished in a cluster analysis on infaunal data)

- Associations between bioeffects and chemical concentrations can be observed in the most biologically impacted areas, but generally only when the data set has been geographically segmented.

Factor and cluster analyses on the benthic infaunal species data separated a cluster that was almost entirely comprised of stations with sediments exhibiting both statistically significant sediment bioassay responses and depressions in the abundance of several major taxonomic groups. Sediments from stations in three other clusters typically had none of these significant effects, or less frequently, exhibited only a single significant effect (e.g., often an amphipod bioassay response only). The factor that distinguished the low- to no-effect clusters from the highly impacted cluster was strongly

influenced by potentially sensitive species summarized above. Overall, these analyses indicated that laboratory bioassay results and determinations of significant depressions in major taxonomic groups are reasonably sensitive to changes in the structure of benthic communities. The results also suggest that in Commencement Bay and Carr Inlet, a high degree of concordance may be expected among those indicator variables (especially the oyster larvae bioassay and benthic depressions). This concordance was indicated by the following items in this study and the previous remedial investigation (Tetra Tech 1985a):

- "Impact" versus "no impact" designations made by benthic and bioassay indicators agreed at 67-79 percent of the 48 stations in the Commencement Bay Remedial Investigation (and at 83-100 percent of the 6 stations in a separate dredging study conducted concurrently with identical methods in Blair Waterway and included in the ARTHUR analyses)

- A significant depression in the abundance of at least one major taxonomic group was observed in 6 of 7 cases (86 percent) that also exhibited significant toxicity in both the amphipod and oyster larvae bioassays

- Eighty-nine percent of the cases exhibiting a significant depression in the abundance of at least two major taxonomic groups occurred in a similarity cluster (assigned on the basis of species-level benthic data) that contained 75 percent of the cases exhibiting significant toxicity in both amphipod and oyster larvae toxicity

- All 6 cases exhibiting a significant depression in the abundance of at least three major taxonomic groups occurred in this same similarity cluster; 83 percent of these cases exhibited toxicity in the oyster larvae bioassay, 50 percent exhibited toxicity in the amphipod bioassay.

The amphipod bioassay results for Commencement Bay showed the least agreement in comparison with the benthic infauna results. This lower degree of concordance may result from a sensitivity of the amphipod bioassay to fine-grained sediments. However, in sediments containing <70 percent fine-grained material, significant benthic depressions were observed in 100 percent (6 cases) of the sediments exhibiting significant amphipod mortality (no benthic data were available for a seventh station).

Appropriate Normalization of Chemical Data

There does not appear to be any justification based on pattern recognition analyses to recommend one normalization technique over others for exploring potential biological-chemical relationship; normalization of chemical data to either organic carbon or a grain-size variable (i.e., percent fine-grained material) tended to produce the same results in factor analysis as chemical data normalized to dry weight of sediment. The abundance of a few additional species not apparent using dry-weight normalized data may decrease with

increased concentrations of chemicals relative to organic carbon content. These species include: Macoma elimata, Nemocardium centifilosum, Lumbrineris spp., Euchone sp. A, and Nephtys cornuta.

RECOMMENDATIONS FOR DEVELOPING SEDIMENT QUALITY VALUES

Results of the pattern recognition analyses recommended for consideration in developing sediment quality values include:

1. Given that the total concentration for some chemical groups (e.g., HPAH) correlates well with the concentrations of all individual components of that group, it may not be necessary to set sediment quality values for each individual chemical in the group. Correlations established by pattern recognition analyses were used to support the definition of appropriate chemical groups for the derivation of sediment quality values.

2. Benthic species that appear to have a predictable and significant response to contaminants or conventional sediment variables (e.g., apparent PAH-sensitive species, or species sensitive to organic enrichment) may be useful as indicators for assessing benthic effects. The agreement between benthic effects assessed according to major taxonomic groups (e.g., Polychaeta, Crustacea, and Mollusca) and those assessed by potential sensitive species (e.g., Praxillella gracilis) identified by pattern recognition techniques was examined in the development of sediment quality values.

3. Hyperbolic, or inverse, relationships between the response of selected biological indicators and contaminant concentrations were observed. This evidence is supportive of a critical assumption in most sediment quality approaches that a threshold concentration exists, above which a chemical can be expected to elicit a negative biological response.

ADDITIONAL ANALYSES RECOMMENDED TO REFINE OR VERIFY RESULTS

An attempt to include associated fish histopathology data in previous ARTHUR analyses (Quinlin et al. 1984) was inconclusive with respect to chemical influence on the biological systems. This lack of correspondence may result from the mobile nature of fish, their integrative feeding patterns, and their higher positions in the food chain. Because of these reasons and resource constraints, a multivariate testing of Commencement Bay histopathology data with sediment chemistry data was not conducted. Unless additional evidence becomes available that would prompt an analysis, it is recommended that further analyses focus on the influence of chemicals on biological systems in intimate contact with the sediments. Additional analyses are recommended below.

Data Set Expansion

The data sets for which chemical and associated biological effects data are available for the same sediment sample, or identical sampling

location are still too small. This is especially true given the number of variables that are potentially of interest and the apparent chemical complexity of the Puget Sound system (typically requiring some form of segmentation to derive interpretable results). Data acquisition is recommended in two directions.

More Intensive Sampling--

First, given the extensive variation in urban embayments such as Commencement Bay, further data gathering should intensively sample small geographic regions to supplement more dispersed sampling over the entire Puget Sound. Specifically, one-third or more sampling stations should have 2-4 additional sampling stations chosen in close proximity (e.g., 50-100 yd). This sampling strategy will help evaluate the microscale variation that seems to be present in chemical concentrations and biological effects. A major problem with multivariate techniques apparent in this application is the difficulty in distinguishing a particular localized chemical effect when the biological effect produced by one chemical is similar to the effect produced by another chemical in a different part of the system under study. Hence, large data sets combining multiple areas with completely different chemical influences will likely be difficult to interpret, but large data sets covering a small area (exposed to some combination of sources) will make the most efficient use of a multivariate approach.

More "Pristine" Sampling--

Second, more samples from less affected (reference) areas must be included. All data sets analyzed to date have been biased toward polluted areas. Experimental designs containing 20-33 percent of the sampling stations (and samples) in areas believed to be less affected by anthropogenic influences are recommended.

Data Analysis

The suggestions above are for further data gathering, regardless of which data analysis methods are used. The exploratory approach applied in this project viewed the chemical, toxicity, and biological variables as descriptors of the sediment stations. This approach could be supplemented by some other analytical approaches and methods to resolve some of the difficulties in multivariate analysis encountered in this study. These approaches include path modeling (canonical correlation) and classification methods.

Path Modeling (Canonical Correlation) Analysis--

Path modeling is a new technique that is an advance of regression analysis. The technique allows variables to be assigned to sectors of influence in a manner that approaches modeling the system. Canonical correlation is a method that calculates the degree of correlation between factors in the independent variables with factors in the dependent variables. A simple two-block path modeling calculation is similar to a canonical correlation analysis.

Both techniques could be applied to sediment chemical and biological data to partially overcome the complexity of separate influences from different chemical groups (or sources). In a combined data set, such as Commencement Bay or Elliott Bay, this approach may reveal distinct factor relationships without having to break the data set into appropriate subsets (e.g., geographic units). Although analysis of data subsets (as conducted in this project) get to the same relationships, this approach requires substantial insight or intuition on the part of the research team.

Classification Modeling for Screening--

Separate from the above recommendation, classification techniques such as available in the ARTHUR system could be used as an interim decision system, based on the existing data sets. For example, embayment data can be grouped into stations that are above or below some accepted sediment quality value for biological effects. Once these designations have been made, classification methods can be "trained" to decide which group status to assign to new sediment samples based on values of selected chemical variables. Part of the classification analysis would pinpoint which variables are key to the decision-making process.

An initial approach would look at the classification accuracy achieved when a few of the most influential factor variables are used. Other techniques can be used to evaluate the importance of each chemical variable. This approach could complement sediment quality values for specific chemical concentrations and may allow screening analysis of sediments based on a few simple measurements (e.g., bioassays with selected chemical measurements).

EXHIBIT D-1

TECHNICAL BACKGROUND ON PATTERN RECOGNITION TECHNIQUES

OVERVIEW OF MULTIVARIATE DATA ANALYSIS METHODS

A general overview of multivariate methods is presented in this section followed by a description of specific tasks performed in the exploratory analysis performed for this project. ARTHUR is a system consisting of about 70 separate routines for data preprocessing, display, unsupervised learning, and supervised learning operations for general pattern recognition. It is used for exploratory data analysis (factor and cluster analysis), anomaly evaluation, selected feature-time plots, feature distribution statistics and interfeature correlations, and classification/ prediction model development.

PREPROCESSING

Preprocessing includes transformation of variables and manipulation of samples. Transformation of variables can include scaling (this operation preserves the shape of the original variable distribution), mathematical functional operations (eg., logarithmic), and linear combinations of variables. Manipulation of samples can include changing property/category value (restratifying), random deletion, and specific deletion and assignment to test sets.

The types and combinations of preprocessing steps that can be applied to data are possibly infinite in number. The most common preprocessing steps can be applied using either a combination of or individual methods from 16 routines in the ARTHUR system. These steps include feature scaling, linear combinations of features, feature ratios, feature selection, weighting, category changes, merge sets, split sets, random subsets, and missing data filling.

Feature/variable scaling is commonly employed to eliminate dependence on units of measure and to put all variables on a common footing of relative (within feature) variance. The autoscaling option in ARTHUR method SCALE was used in this project. This transformation subtracts the mean value of the variable from each measured value and divides by a term proportional to the variance. This transformation is similar to the standard normal variable transformation (z-transform), and is a one-to-one mapping of the values of a variable from one reference system to another.

DISPLAY

Display routines are provided in the ARTHUR system to allow plots of data versus selected axes of information, and to allow other graphical information representations. Several of the methods have line-printer graphical output to portray performance results (eg., regression methods plots of residual errors, hierarchical cluster analysis dendograms).

Plots of the data versus selected pairs of variables, eigenvectors or factors can be done on line-printer, Calcomp, or Tektronix terminal output.

The line-printer routine is the method VARVAR (Variable by Variable plotting). A method for nonlinear mapping of higher dimensional information to 2-space is also provided (NLM).

UNSUPERVISED LEARNING

Unsupervised learning consists of applying exploratory techniques, in an unbiased manner, to search for relationships among the samples (stations) and among the variables measured for the samples. The main techniques include factor analysis, cluster analysis, and data plots.

Factor Analysis

Factor analysis is a mathematical data analysis approach that is aimed at representing the variation (or information) in the data in the fewest dimensions. The data are initially represented by their measured values for the original variables. This is usually described as the distribution of samples in the measurement space (or NVAR-space, where NVAR = the number of original variables). The first step in factor analysis is usually calculation of principal component (pc) axes which fit the distribution of samples in an ordered manner; the first axis lies along the direction of the greatest variation in the data, the next lies orthogonal (perpendicular) to the first, along the next greatest variation in the data, etc. The samples can be projected onto these axes and plotted. The next steps in factor analysis are usually retention of a subset of the pc-axes, rotation by small amounts and reorthogonalization of the axes, and interpretation according to the variables that have the highest loadings onto the axes (or factors).

Factor analysis was typically done using the following sequence of methods in the ARTHUR system: KAPRIN, KAVECT, KAVARI, KAVECT, KAORTH, and KAVECT (optional CHSUB followed by the above sequence again). KAPRIN performs principal component extraction. KAVARI performs Varimax rotation on the various pc. KAORTH performs reorthogonalization of the rotated vectors. KAVECT prints out detailed information on the pc/factors, including variance retained and factor loadings of each variable. CHSUB was used to randomly keep 80 percent of the samples in each category before recalculating pc's and factors.

The linear principal component extraction step in KAPRIN is invariant with respect to the number of pc's calculated (up to the limit of the original number of variables) as long as the samples and variables in the data remain unchanged. Deletion of a few anomalous samples can have major effects on the calculated pc's. Varimax rotation and reorthogonalization are steps that can be useful for interpretation of principal components such as physical, chemical, or other factors. These steps, along with randomly calculated subsets, were used to help identify, interpret, and ascertain which were the major factors and the most strongly contributing variables in the data.

Cluster Analysis

Cluster analysis was done on the samples using the hierarchical clustering method (HIER) in the ARTHUR system. Both single-link and complete-link connection dendograms were calculated and printed on line-printer plots.

Single-link connection similarity calculations start with the two samples in the data that lie closest in the n-dimensional space of the measurements, where n is equal to the number of measurements made on each sample (or station). This distance is the simple Euclidean distance, and corresponds to the calculated similarity between the two samples. The similarity measure for each sample X_i and X_j is defined as:

$$S_{ij} = 1 - d_{ij}/MAX(d_{ij})$$

where

$$d_{ij} = [\sum_{k=1}^{M} (X_{ik} - X_{jk})^2]^{0.5}$$

and

$MAX(d_{jj})$ is the largest interpoint distance.

The most unlike samples give $S_{ij}=0$, and identical objects give $S_{ij}=1$. The initial two samples selected with this algorithm are defined as a cluster. The method then looks for the next smallest distance in the data set. If this involves one of the previous samples, the new sample is connected to the first cluster with a similarity value representing its distance from the nearest sample already in the cluster. If the next smallest distance involves two samples, neither of which is already in a cluster, then a new cluster is begun using these two samples, and the method moves on to look for the next smallest distance. These steps are repeated until all samples are connected.

Complete-link similarity calculations start the same way as single-link for the first two samples. Other clusters are built up by linking samples previously not in a cluster by distance-similarity and by graphing samples to clusters by maximum distance to the samples in the cluster.

Interpretation of cluster analysis results is similar for both single- and complete-link methods. Groups of samples linked at higher similarity values must be examined using external knowledge to identify whether some common basis is obvious for explaining why the samples appear to form a cluster. If a basis is not obvious, classification methods can be used to determine if classification accuracies into the apparent groups are high and which are the important variables. The variables that are important can point toward a possible explanation for the observed clusters.

Anomaly Evaluation

Potential sample anomalies were evaluated using a combination of methods contained in the ARTHUR system. The two approaches most frequently used in this study employed factor plots and cluster analysis.

The factor analysis approach uses the following sequence of methods in the ARTHUR system: KAPRIN,KATRAN,VARVAR,KAVARI,KATRAN,VARVAR. This sequence calculates the principal component or factor axes (KAPRIN followed by KAVARI), projects the data onto the new axes (KATRAN), and plots the data versus selected factor pairs as axes (VARVAR). Any bad samples in the data tend to adversely influence the calculation of the factors. As a result, they show up as well-separated points (anomalies) on the data plots, even when only the most significant factor pairs are used as axes.

The cluster analysis approach uses the standard output information from hierarchical cluster analysis to identify potential anomalies. The method sequence in the ARTHUR system is DIST,HIER. The output information is in the form of a connection dendogram. Potential anomalous samples appear with very low connection similarity values in the dendogram, indicating that they are quite different from all of the other samples in the data set.

SUPERVISED LEARNING

Supervised Learning consists of methods to develop classification or prediction models, developed on a "training set" of samples that have known category/property values, testing of the models on the training set and any available "test-set" samples, evaluation of the variables important to the models, and the physical/chemical implications of the models.

Category Classification

Category classification is aimed at developing models that accurately classify samples into discreet groups or into continuous categories (eg., low, middle, and high concentration groups). The methods include K-Nearest Neighbor (KNN), principal component modeling (SIMCA), discriminant analysis (LEDISC and REGRESS), and Bayesian Probability (BAYES).

KNN uses a committee vote of nearest neighbors to classify. The underlying philosophy is that the closer two samples are in the multidimensional measurement space, the more similar they should be. SIMCA (SIPRIN + SICLAS) uses principal components (eigenvectors) for each group to define the position and distribution of the group in the measurement space. Classification of a sample is based on the smallest distance between the sample and the pc-models for the categories. Discriminant analysis uses a linear function to separate two categories, based on positioning the separation by a minimization of squared-error. BAYES classification is most suited to large data sets with many samples, where the distribution histograms for each variable can be accurately characterized for each category. Classification is made on the basis of a summation of probabilities that the sample

belongs to each category weighted by the variable-category probabilities for the measurement values of the sample.

TYPICAL SEQUENCE OF METHODS

Appendix A-1 is the interactive dialogue from computer run #17 (output code INMC9). It illustrates the typical sequence of methods applied to the data for exploratory analysis.

Univariate Distribution Parameters

Autoscaling of the variables was one of the first methods applied to the data sets, under almost all circumstances. Using the method SCALE in ARTHUR, each variable was transformed to a new feature with zero mean and unit variance. It removes the units of measure from the variables, and puts them all on a common footing of variance (this transformation does not change the original shape of the variable distribution). In addition, the method SCALE calculates distribution parameters for each variable over the data set, consisting of mean, standard deviation, normalized standard deviation, minimum value, maximum, range, and coefficients of skewness and kurtosis.

Feature Correlations

The correlation matrix of all interfeature correlations was calculated once on the autoscaled data for each data set. This step provides complementary information to the principal component and factor analysis calculations. The method CORREL in ARTHUR calculates the correlation coefficient, the low and high values of the 95 percent confidence interval about the coefficient, and the probability that the correlation would be calculated if the sample were drawn from a random parent population. The correlation matrix was scanned after each run for values with a probability <0.001 and coefficients above r=0.500.

Basic Exploratory Analysis

Below is a listing of methods and option parameters that would be typical of those used to do initial exploratory work with the data.

ARTHUR	VAX level command to start ARTHUR program
NMC9	four-character code to identify run output
(title)	unique title to identify the run
INPUT,1,...	read data from file named in response to ARTHUR prompt, according to parameters specified to define number of variables, data format, etc.
INFILL,1,1$	missing data fill by means for categories
SCALE,1,2$	autoscale variables, list univariate statistics
CORREL,2$	calculate interfeature correlations
KAPRIN,2,4,0,0,10$	principal component (pc) extraction of 10 pc's
KAVECT$	lists detailed eigenvector information
KATRAN,2,3,4,5	data projection onto five pc axes

VARVAR,3,0,-1,1,0,1$	plots of data versus pairs of pc's
STATUS,-1	lists status of files in use by ARTHUR
SAVE,3	saves eigenvector projected data
SAVE,7	saves ARTHUR run lineprinter output file
EXIT	end ARTHUR run

Infill shows how much data is missing and what feature values are missing for each sample. SCALE autoscales the data and prints out univariate statistical information on the distribution parameters of each variable (feature) over the entire data set. CORREL calculates and prints the interfeature correlation matrix. The correlation matrix lists the 95 percent confidence interval values about the correlation coefficient and the probability (in parentheses) that the correlation could have come from a parent population with zero interfeature correlation for the two variables.

Methods KAPRIN and KAVECT calculate the linear principal components (eigenvectors) and list the detailed information on the eigenvectors, including variance retained by each, feature loadings and communalities. Methods KATRAN and VARVAR project the data onto principal component axes and plot the data in two dimensions versus pairs of the first five pc's in the above menu. Sample index and category plots are all generated. Structure (grouping in the plots) and anomalies should be examined.

After applying the above menu of methods to get an initial view of data structure and relationships between variables, a more extended series of methods, below, can be applied to give more information on relationships between the samples and between the variables:

Additional Exploratory Analysis

The following menu of methods is a list of typical methods that would provide a more detailed look at the relationships between variables, data plots, and cluster analysis relationships. The sequence starts after several initial steps have been applied, including autoscaling the data and putting the scaled features into file 2.

KAPRIN,2,4,0,0,10$	extract and print 10 eigenvectors
KAVECT$	list information on all 10 pc's
KAVARI,4,4,0,0,5$	Varimax rotation of 5 pc's
KAVECT$	list info on 5 rotated pc's
KAORTH,4,4$	orthogonalize rotated pc's
KATRAN,2,3,4,5$	project data onto rotated axes
VARVAR,3,0,-1,1,0,1$	plot data for rotated axes
DIST,2,3$	calculate intersample distance matrix
HIER,3,0,1$	cluster analysis (complete link)
TUTRAN,2,3$	transpose the scaled data matrix
DIST,3,3$	add distance (over sample space)
HIER,3,0,1$	cluster analysis on features

The above sequence starts with extraction of linear principal components (eigenvectors) in KAPRIN, and listing detailed information about the pc's and the variables that contribute to each, in KAVECT. Additional information

on underlying relationships between the variables is obtained by applying Varimax rotation and reorthogonalization to the pc's to calculate factors that may be more easily interpreted, chemically or biologically. Interpretation is based on each variable's contribution (and loading) on each pc given in KAVECT and the HIER dendogram to see which features/variables are most similar over the samples. The interpretation will need the knowledge and intuition of the scientists/analysts working on the problem as to whether the variable associations (factors) make sense biologically, chemically, or physically. The data plots for the rotated eigenvectors can supplement the previous plots.

PATTERN RECOGNITION TECHNIQUES APPLIED TO COMMENCEMENT BAY DATA

The pattern recognition tasks used in this project were divided into four areas: (1) data entry and validation, (2) analysis of chemical information for the sampling stations, (3) analysis of relationships among biological and chemical variables, and (4) documentation. These tasks are described in the following sections.

DATA SETS EVALUATED

Three data sets were studied. The data sets are briefly described in the following paragraphs. The variables in each data set are listed in Tables D-1, D-2, and D-3. All data sets were received as ASCII files on IBM-PC compatible floppy diskettes, accompanied by descriptive material and hard-copy printouts for verification.

Set 1 -- CHEMBIO

This data set consisted of 56 station samples characterized by 116 variables and parameters listed in Table D-1. The stations were located in nine waterways/areas: Blair (12 stations), Carr Inlet (4), Milwaukee (3), City (6), Middle (1), Hylebos (14), Ruston (8), Sitcom (3), and St. Paul (5). The variables included chemical and biological measures.

Set 2 -- MSQSGVAL

This set consisted of 144 stations in the above waterways/areas characterized by 114 chemical variables and parameters. The data set did not include any biological/benthic variables and was only used for detailed chemical factor analysis to complement factor analysis on the data sets that had fewer stations.

Set 3 -- CB2

This set consisted of 54 of the 56 CHEMBIO stations characterized by abundance measures for 64 berthic infauna variables. A measure of total individual species counted at each station was later included with this data set. After exploratory data analysis, a subset of the variables from this set were added to the CHEMBIO set for later analyses on chemical-biological relationships.

The pattern recognition tasks applied in this project are divided into four areas: 1) data entry and validation, 2) analysis of chemical information for the sampling stations, 3) analysis of relationships between biological variables and chemical information, and 4) documentation. These tasks are described in the following sections.

TABLE D-1. VARIABLES IN CHEMBIO DATA SET, COMBINED CHEMICAL AND BIOLOGICAL DATA FOR 56 STATIONS IN THE COMMENCEMENT BAY AREA

Variable	Number	Complete Name
PA65	,1	phenol
PA34	,2	2,4-dimethylphenol
PA21	,3	2,4,6-trichlorophenol
PA64	,4	pentachlorophenol
PB36	,5	2,6-dinitrotoluene
PB37	,6	1,2-diphenylhydrazine
PB62	,7	N-nitrosodiphenylamine
PB01	,8	acenaphthene
PB55	,9	naphthalene
PB77	,10	acenaphthalene
PB78	,11	anthracene
PB81	,12	phenanthrene
PB80	,13	fluorene
PB39	,14	fluoranthene
PB72	,15	benzo(a)anthracene
PB73	,16	benzo(a)pyrene
TBFLANTH	,17	Total benzofluoranthenes
PB74	,18	benzo(b)fluoranthene
PB75	,19	benzo(k)fluoranthene
PB76	,20	chrysene
PB79	,21	benzo(ghi)perylene
PB82	,22	dibenzo(a,h)anthracene
PB83	,23	indeno(1,2,3-cd)pyrene
PB84	,24	pyrene
PB08	,25	1,2,4-trichlorobenzene
PB09	,26	hexachlorobenzene
PB25	,27	1,2-dichlorobenzene
PB26	,28	1,3-dichlorobenzene
PB27	,29	1,4-dichlorobenzene
PB52	,30	hexachlorobutadiene
PB12	,31	hexachloroethane
PB53	,32	hexachlorocyclopentadiene
PB66	,33	bis(2-ethylhexyl)phthalate
PB67	,34	butyl benzyl phthalate
PB68	,35	di-n-butyl phthalate
PB69	,36	di-n-octyl phthalate
PB70	,37	diethyl phthalate
PB71	,38	dimethyl phthalate
PB54	,39	isophorone
PP92	,40	4,4'-DDT
PV23	,41	chloroform
PV85	,42	tetrachloroethene
PV87	,43	trichloroethylene
PV38	,44	ethylbenzene

TABLE D-1. (Continued)

TPCBS ,45	Total PCB's
A65850 ,46	benzoic acid
A95487 ,47	2-methylphenol
A108394 ,48	4-methylphenol
A95954 ,49	2,4,5-trichlorophenol
B132649 ,50	dibenzofuran
B62533 ,51	aniline
B100516 ,52	benzyl alcohol
B91576 ,53	2-methylnaphthalene
TRICBD ,54	Total trichlorinated butadienes
TETCBD ,55	Total tetrachlorinated butadienes
PENCBD ,56	Total pentachlorinated butadienes
TXYLENES,57	Total xylenes
ANTIMONY,58	antimony
ARSENIC ,59	arsenic
BARIUM ,60	barium
BERYLLIU,61	beryllium
CADMIUM ,62	cadmium
CHROMIUM,63	chromium
COPPER ,64	copper
IRON ,65	iron
LEAD ,66	lead
MANGANES,67	manganese
NICKEL ,68	nickel
SELENIUM,69	selenium
SILVER ,70	silver
THALLIUM,71	thallium
ZINC ,72	zinc
MERCURY ,73	mercury
SEG ,74	station waterway segment (location code)
SOLIDS ,75	% dry weight (dry wt/wet wt)
VSOLIDS ,76	volatile solids (total organic content)
TOC ,77	total organic carbon
NITROGEN,78	organic nitrogen
SULFIDE ,79	free sulfide
GREASE ,80	oil and grease (freon extractable portion)
ROCKS ,81	coarse fraction of sediment size
SAND ,82	sand fraction of sediment size
SILT ,83	fine fraction of sediment size
CLAY ,84	very fine fraction of sediment size
POLYCH ,85	Total polychaete abundance
OLIGO ,86	Total oligochaete abundance
MOLLUSC ,87	Total mollusc abundance
CRUSTA ,88	Total crustacea abundance
ECHINO ,89	Total echinoderm abundance
OTHER ,90	Misc species abundance
TOTAL ,91	Total abundance
THARYX ,92	Tharyx multifilis abundance
PRIONOSP,93	Prionospio spp. abundance
LUMBRI ,94	Lumbrineris spp. abundance

TABLE D-1. (Continued)

AXINOPS ,95	Axinopsida spp. abundance
MACOMA ,96	Macoma carlottensis abundance
PSEPHID ,97	Psephidia lourdi abundance
AMPHIPOD,98	Total amphipod abundance
EUPHILO ,99	Euphilomedes spp. abundance
MORT ,100	% Amphipod mortality
ABNORM ,101	% Oyster larvae abnormality
CHANGE ,102	% Change in luminescence (microtox)
METHYLET,103	1-methyl-2-(1-methylethyl)benzene
MOXYPHEN,104	2-methoxyphenol
PENTACHL,105	pentachlorocyclopentane
BIPHENYL,106	1,1'-biphenyl
DIBENZOT,107	dibenzothiophene
METHYL2P,108	2-methylphenanthrene
METHYL1P,109	1-methylphenanthrene
HEXADEC9,110	9-hexadecenoic acid methyl ester
ISOPIMAR,111	isopimaradiene
KAUR16EN,112	unidentified diterpenoid hydrocarbon
METHYLPY,113	1-methylpyrene
RETENE ,114	retene
METH2PYR,115	2-methylpyrene
COPROSTA,116	coprostanol

TABLE D-2. VARIABLES IN MSQSGVAL DATA SET (DATA SET CONTAINS 144 SEDIMENT SAMPLES IN THE COMMENCEMENT BAY AREA)

Var #	Var Name	Complete Variable Name
1.	PA65	phenol
2.	PA34	2,4-dimethylphenol
3.	PA21	2,4,6-trichlorophenol
4.	PA64	pentachlorophenol
5.	PB36	2,6-dinitrotoluene
6.	PB37	1,2-diphenylhydrazine
7.	PB62	N-nitrosodiphenylamine
8.	PB01	acenaphthene
9.	PB55	naphthalene
10.	PB77	acenaphthalene
11.	PB78	anthracene
12.	PB81	phenanthrene
13.	PB80	fluorene
14.	PB39	fluoranthene
15.	PB72	benzo(a)anthracene
16.	PB73	benzo(a)pyrene
17.	TBFLANTH	Total benzofluoranthenes
18.	PB74	benzo(b)fluoranthene
19.	PB75	benzo(k)fluoranthene
20.	PB76	chrysene
21.	PB79	benzo(ghi)perylene
22.	PB82	dibenzo(a,h)anthracene
23.	PB83	indeno(1,2,3-cd)pyrene
24.	PB84	pyrene
25.	PB08	1,2,4-trichlorobenzene
26.	PB09	hexachlorobenzene
27.	PB25	1,2-dichlorobenzene
28.	PB26	1,3-dichlorobenzene
29.	PB27	1,4-dichlorobenzene
30.	PB52	hexachlorobutadiene
31.	PB12	hexachloroethane
32.	PB53	hexachlorocyclopentadiene
33.	PB66	bis(2-ethylhexyl)phthalate
34.	PB67	butyl benzyl phthalate
35.	PB68	di-n-butyl phthalate
36.	PB69	di-n-octyl phthalate
37.	PB70	diethyl phthalate
38.	PB71	dimethyl phthalate
39.	PB54	isophorone
40.	PP92	4,4'-DDT
41.	PV23	chloroform
42.	PV85	tetrachloroethene
43.	PV87	trichloroethylene
44.	PV38	ethylbenzene
45.	PP106	PCB-1242

TABLE D-2. (Continued)

46.	PP107	PCB-1254
47.	PP110	PCB-1248
48.	PP111	PCB-1260
49.	TPCBS	Total PCB's
50.	A65850	benzoic acid
51.	A95487	2-methylphenol
52.	A108394	4-methylphenol
53.	A95954	2,4,5-trichlorophenol
54.	B132649	dibenzofuran
55.	B62533	aniline
56.	B100516	benzyl alcohol
57.	B91576	2-methylnaphthalene
58.	TRICBD	Total trichlorinated butadienes
59.	TETCBD	Total tetrachlorinated butadienes
60.	PENCBD	Total pentachlorinated butadienes
61.	TXYLENES	Total xylenes
62.	BA	Basin Code
63.	ANTIMONY	antimony
64.	ARSENIC	arsenic
65.	BARIUM	barium
66.	BERYLLIU	beryllium
67.	CADMIUM	cadmium
68.	CHROMIUM	chromium
69.	COPPER	copper
70.	IRON	iron
71.	LEAD	lead
72.	MANGANES	manganese
73.	NICKEL	nickel
74.	SELENIUM	selenium
75.	SILVER	silver
76.	THALLIUM	thallium
77.	ZINC	zinc
78.	MERCURY	mercury
79.	SEG	station waterway segment (location code)
80.	SOLIDS	% dry weight (dry wt/wet wt)
81.	VSOLIDS	volatile solids (total organic content)
82.	TOC	total organic carbon
83.	NITROGEN	organic nitrogen
84.	SULFIDE	free sulfide
85.	GREASE	oil and grease (freon extractable portion)
86.	ROCKS	coarse fraction of sediment size
87.	SAND	sand fraction of sediment size
88.	SILT	fine fraction of sediment size
89.	CLAY	very fine fraction of sediment size
90.	CODE	station type designation
91.	TIO	
92.	METHYLET	1-methyl-2-(1-methylethyl)benzene
93.	MOXYPHEN	2-methoxyphenol
94.	PENTACHL	pentachlorocyclopentane
95.	BIPHENYL	1,1'-biphenyl

TABLE D-2. (Continued)

96.	DIBENZOT	dibenzothiophene
97.	METHYL2P	2-methylphenanthrene
98.	METHYL1P	1-methylphenanthrene
99.	HEXADEC9	9-hexadecenoic acid methyl ester
100.	ISOPIMAR	isopimaradiene
101.	KAUR16EN	unidentified diterpenoid hydrocarbon
102.	METHYLPY	1-methylpyrene
103.	RETENE	retene
104.	METH2PYR	2-methylpyrene
105.	COPROSTA	coprostanol
106.	LMWPAH	Light Molecular Weight Hydrocarbons
107.	HMWPAH	Heavy Molecular Weight Hydrocarbons
108.	ICOGRP1	elemental metals group 1
109.	TOTCBD	Total chlorinated butadienes
110.	PHTHAL	Total phthalates
111.	CLBENZ	Total chlorinated benzenes
112.	FINES	Silt + Clay sediment content
113.	TOTMET	Total elemental metals
114.	TOTORG	Total organics

TABLE D-3. VARIABLES CONTAINED IN CB2.DAT EXTENDED BENTHIC DATA SET

Var#	Name	Taxonomic Name	NODC Taxonomic Code
1.	16Nemert	Nemertea	43
2.	20Nemato	Nematoda	47
3.	37Pholoe	Pholoe minuta	5001060101
4.	53Eteone	Eteone longa	5001130205
5.	72Microp	Micropodarke dubia	5001210801
6.	98Platyn	Platynereis bicanaliculata	5001240501
7.	101Nepht	Nephtys cornuta	5001250104
8.	102Nepht	Nephtys cornuta franciscana	500125010498
9.	106Nepht	Nephtys ferruginea	5001250111
10.	114Glyce	Glycera capitata	5001270101
11.	129Lumbr	Lumbrineris spp	50013101
12.	135Lumbr	Lumbrineris sp. gr. 4	5001310194
13.	136Lumbr	Lumbrineris sp. gr. 3	5001310195
14.	138Lumbr	Lumbrineris sp. gr. 1	5001310197
15.	151Schis	Schistomeringos rudolphi	5001360598
16.	154Leito	Leitoscoloplos pugettensis	5001400102
17.	172Polyd	Polydora spp	50014304
18.	185Prion	Prionospio cirrifera	5001430502
19.	186Prion	Prionospio steenstrupi(= P.malmgreni)	5001430506
20.	187Prion	Prionospio (Minuspio) multibranchiata	5001430599
21.	197Spiop	Spiophanes berkelyorum	5001431004
22.	206Phyll	Phyllochaetopterus prolifica	5001490202
23.	207Spioc	Spiochaetopterus costarum	5001490302
24.	210Cirra	Cirratulus cirratus	5001500101
25.	214Thary	Tharyx multifilis	5001500302
26.	215Chaet	Chaetozone spp	50015004
27.	216Cossu	Cossura spp	50015201
28.	221Scali	Scalibregma inflatum	5001570101
29.	223Arman	Armandia brevis	5001580202
30.	231Capit	Capitella capitata	5001600101
31.	236Notom	Notomastus tenuis	5001600302
32.	238Medio	Mediomastus spp.	50016004
33.	252Praxi	Praxillella gracilis	5001630901
34.	256Eucly	Euclymeninae	5001631
35.	297Pista	Pista cristata	5001680701
36.	323Eucho	Euchone incolor	5001700204
37.	324Eucho	Euchone sp. A	5001700299
38.	338Tubif	Tubificidae	500902
39.	348Mitre	Mitrella gouldi	5105030204
40.	3520dost	Odostomia spp	51080101
41.	353Turbo	Turbonilla spp	51080102
42.	373Nucul	Nucula tenuis	5502020201
43.	386Megac	Megacrenella columbiana	5507010301
44.	391Parvi	Parvilucina tenuisculpta	551501010
45.	394Axino	Axinopsida serricata	5515020201
46.	399Mysel	Mysella tumida	5515100102
47.	407Nemoc	Nemocardium centifilosum	5515220301

TABLE D-3. (Continued)

48.	411Macom	Macoma elimata	5515310102
49.	412Macom	Macoma obliqua	5515310106
50.	415Macom	Macoma carlottensis	5515310112
51.	416Macom	Macoma nasuta	5515310114
52.	421Telli	Tellina modesta	5515310204
53.	429Pseph	Psephidia lordi	5515470501
54.	455Euphi	Euphilomedes carcharodonta	6111070301
55.	456Euphi	Euphilomedes producta	6111070303
56.	472Balan	Balanus crenatus	6134020104
57.	479Eudor	Eudorella pacifica	6154040202
58.	496Lepto	Leptochelia dubia	6157020103
59.	544Photi	Photis brevipes	6169260201
60.	599Capre	Caprellidae	617101
61.	619Calli	Callianassa spp.	61830402
62.	639Pinni	Pinnixa spp	61890604
63.	663Amphi	Amphiuridae	812903
64.	665Amphi	Amphiodia urtica	8129030104

Variable Added to Benthic Data After Exploratory Results

65.	DIVERSTY	Total Different Species Counted at Station	

DATA ENTRY AND VALIDATION

Data receipt, entry and validation was a more time-consuming process than originally estimated. Three data sets were incorporated into the data analysis.

Receive Data

Data were obtained on PC floppy diskettes. The data were in ASCII formatted files, with explanatory material and hard copy printouts for verification.

Read and Load Diskettes--

The ASCII files were read from the diskettes into SYMPHONY database or Microsoft WORD wordprocessing programs. Within these programs, the files were converted to ARTHUR format and rewritten to ASCII output files. These files were then uploaded on a mainframe computer system.

Data Validation

The data were printed using ARTHUR UTILIT after loading and were scanned for correspondence with the hard copy information at randomly selected data points throughout the set. ASCII files on diskettes were also scanned during wordprocessing or database conversion to ARTHUR format.

The remaining validation steps utilized the ability of various combinations of methods to pinpoint atypical values or samples. Potential sample anomalies were most frequently identified using a combination of factor analysis, plus data plots, and cluster analysis. Constant or redundant variables were identified using the method INDUMP in ARTHUR. Missing data were filled with the mean value for the variable over the appropriate waterway category to which the station was assigned.

CHEMICAL EVALUATIONS

After the data were entered into ARTHUR, they were analyzed by the combination of methods previously described to search for relationships among the variables, among the samples, and between the variables and characteristics of the samples. The primary aim was to identify fundamental chemical factors based on relationships among the chemical variables and to determine distinctions between the sampling stations in their assigned category, if present. Steps involved in chemical analysis of the data included:

1. Calculation and interpretation of factors
2. Evaluation of interfeature correlations
3. Examination of data plots versus selected factors
4. Examination of cluster analysis results for indications of natural groups, based on interpretable associations

5. Stratification of samples into test groups to determine the degree of differentiation and the relevance between the groups.

BIOLOGICAL EVALUATIONS

The relationships between chemical variables and variables characterizing biological aspects of the samples were evaluated using the same exploratory data analysis techniques employed in the evaluation of the chemical variables. Two types of biological variables considered were bioassay results that characterized stations as "active" or "inactive" in creating a significant effect on test tissue or organisms, and benthic infauna abundances for selected individual species and summary taxonomic groups.

The bioassay data were also used as the basis for sample stratification into subsets. The aim was to determine if chemical variables could distinguish between the bioassay groups and if so, were logically interpretable by the scientists on the team. The data were stratified into active and inactive groups, according to the bioassay results and accounting for major chemical differences between various waterways. These sets were then analyzed with variance weighting of variables, k-nearest neighbor classification, and principal component and factor plots.

The benthic abundance data were evaluated separately to examine biological factors that might suggest community relationships. The benthic data were then analyzed in combination with the chemical data to look for suggestions of influence by chemistry variations. The results of these evaluations are presented in the summary report.

DOCUMENTATION

Documentation for the study included an interim outline report covering initial exploratory results and presented to U.S. COE and U.S. EPA project review staff in mid-November. Results of interest, upon completion of all computer runs and interpretation of results, were documented in a separate summary report.

The specific detailed results are not reported for each computer run. The increase in the number of data sets included in the study and the larger number of preliminary exploratory runs that evolved precluded detailed reporting of all results. The focus of the reporting of results is on those runs that culminate a series of exploratory and preceding steps.

METHODS

DATA PREPARATION AND DATA SET CREATION

The following discussion is a description of the steps involved in transforming the three data sets for use in the ARTHUR system.

CHEMBIO Data

The CHEMBIO data set was received on floppy diskette on 15 October, 1985. Several conversion steps were applied to the CHEMBIO data to prepare it for exploratory analysis. Data coded as below detection limit were replaced by a random value between zero and the specified detection limit. A conversion program in dBaseIII changed all missing data to the missing data flag specific to ARTHUR.

The computer runs done with the CHEMBIO data are coded with NMC characters included in the Print Code. At later stages in the study, these codes also include benthic infauna abundance data (from CB2). Runs were also made with chemical variables normalized to fines and total organic carbon.

MSQSGVAL Data

After initial exploratory runs on CHEMBIO, concern was raised over whether the chemical factors would be representative of the data contained in a larger set of stations. To address this concern the MSQSGVAL data was received on 25 October. The data were comprised of 144 samples (stations) and 110 chemical variables. Two files were contained on the diskette: MSQSGVAL.LIS containing the values and MSQSGVAL.POR containing the variable names. The data were ARTHUR formatted, with the category number corresponding to station waterway groups comparable to CHEMBIO.

An initial exploratory data analysis was performed on the full MSQSGVAL data. Several anomalies were spotted; after interpretation of their effect on the entire data set those samples were removed, and the exploratory data analysis was repeated. Also, 12 variables had extensively missing data and the set was reduced to 98 variables for subsequent analysis.

CB2 Benthic Data

After initial exploratory results using CHEMBIO and MSQSGVAL were evaluated, it was decided to include an extended benthic infauna data set containing abundance values for 64 taxa at 54 of the 56 CHEMBIO stations. The CB2 data, in two files, were obtained on floppy diskette and uploaded to the mainframe computer on 10 December. Values for an additional variable, total individual species counted at each station, were added from hardcopy obtained from Tetra Tech.

The CB2 data were analyzed separately and then joined to the CHEMBIO set for analysis combined with conventional and previous biological variables. Following analysis of these results, the extended data set was trimmed to 142 variables and analyzed to provide chemical-biological results.

COMPUTER RUNS

Although 8 to 10 computer runs were anticipated at the start of the study, the analysis of the three data sets prompted a greater number of exploratory runs. Twenty-seven computer runs were made for the study.

The runs and a quick description of each, in the order in which they were done are listed in Table D-4. Reporting of results from these runs concentrates on #5-IMSQ2, #10-IMSQ7ZD, #12-IMSQ8, #15-INMC7, #16-INMC8, #17-INMC9, #18a-INC10ZD,and #23-IABC4.

SPECIFIC RESULTS FROM INDIVIDUAL AND COMPARED COMPUTER RUNS

In the following paragraphs, specific results from the individual computer runs or comparison between a set of runs are listed.

INMC2 and IMSQ2 Univariate Distribution Statistics and Differences

Statistics for mean, standard deviation, range, maximum and minimum values, and higher moments were obtained for each variable over the CHEMBIO and MSQSGVAL data sets. Examination of these statistics indicated substantial differences between the two data sets in several of the chemical variables. These differences, listed in Table D-5, indicate that some caution should be observed in accepting the results that suggest chemical-biological relationships may be present, based on CHEMBIO calculations. Because of its smaller sample size (56 versus 144 stations), CHEMBIO is less representative of Commencement Bay chemical variation than MSQSGVAL.

Valid "Anomalies"

During the Commencement Bay Superfund project, considerable effort was taken to validate the data in the data sets for this study. This quality assurance/quality control effort was aimed at correcting gross analytical errors in the data set prior to data interpretation.

Analysis using pattern recognition techniques indicated that apparent anomalies remained in the data sets. These anomalies were highly unusual, but nonetheless real and valid data (see Table D-6). In most cases, the unusual values derived from highly contaminated samples collected at stations closest to pollution outfalls. Interpretation of pattern recognition results was performed with and without these anomalies to ensure that their effect on the data set was understood.

TABLE D-4. PATTERN RECOGNITION ANALYSIS -- COMPUTER RUNS

Run #	Print Code	Data Set	Description
1	IGAEN	CHEMBIO/ NOMISSCR	initial exploratory run on combined chem & bio data -- 56 station set
2	IGAEM	MSQSGVL2	initial exploratory run on 144 station chemistry variable set
3	INMC2	CHEMBIO/ NOMISSCR	2nd exploratory run on 56 station set chemistry variables only
4	INMC3	CHEMBIO/ NOMISSCR	3rd exploratory run on 56 station set biological variables only
5	IMSQ2	MSQSGVL2	2nd exploratory run on 144 station set 98 chemistry variables retained
6	IMSQ3	MSQSGVL2/ OMSQ2	attempted replot run of KAORTH V2-V3 w/o major trend samples
7	IMSQ4	MSQSGVL2/ OMSQ2	exploratory run using TOC normalized chemical variables -- 144 station set
8	IMSQ5	MSQSGVL2/ OMSQ2	exploratory run using FINES normalized chemical variables -- 144 station set
9	CIS51	MSQSGVL2	outliers removed, 139 station chem vars, exploratory run
10	IMSQ7ZD	MSQSGVL2	outlier removed, 98 chem vars, short exploratory run
11	INMC4ZT INM42ZD	ONMC3 + OCB22	combined benthic/bio vars exploratory run (miscombined data)
12	IMSQ8	OMSQ4	generate chem factor scores for 144 station set (PMSQ8ZD & VMSQ8ZD data saved)
13	INM32	VNMC3 + VNMC2	listing of factor scores
14a	INMC5	NMC + OCB22	CHEMBIO + BENTHIC exploratory analysis -- created CNMC5.DAT
14b	INMC6	CNMC5	BIO-BENTH-CONVENTIALS Vars, 56 stations, restratified, exploratory run

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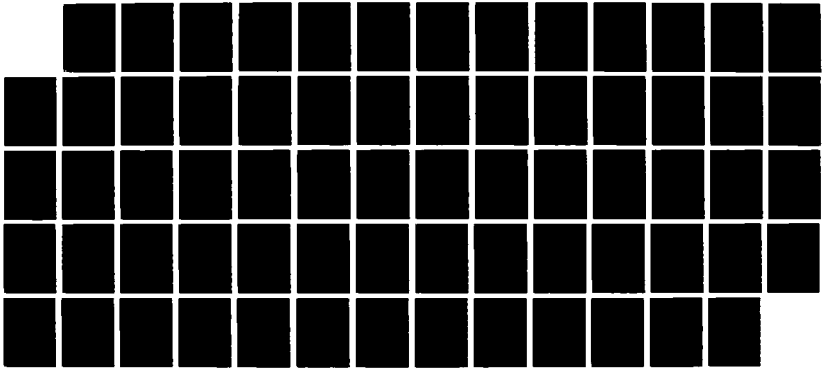

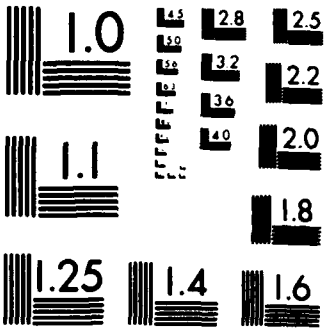
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TABLE D-4. (Continued)

15	INMC7	CNMC5	reduced to 66 BIO-BENTH-CONVENTIALS Vars, 56 stations, created CNMC7.DAT
16	INMC8	CNMC7	66 Vars, 51 stations, exploratory run
17	INMC9	CNMC7	66 Vars, outlier removed (51 stations), exploratory run (comp. INMC7 and INMC8)
18a	INC10	CNMC5	reduced combined set to 142 variables, 56 stations, chem-bio-benth exploratory
18b	INM11 & DVRS	DVRS + CNMC5	input of diversity data and joining to CNM5, saved as ACBBB.DAT
19	IACB1 & IACB2	ACBBB	subset factor analysis, saved 136 Var data set as BCBBB.DAT (Var 115 wrong)
20	IABC1	BCBBB + ACBBB	created BioBenth Cluster Stratification & analyzed (WEIG,SELE,DIST/KNN), saved ABCD
21	IABC2	ABCD	created Impact Category Stratification & analyzed similar to previous run
22	IABC3 & IAB32	ABCD	outliers removed, subset factor analysis recalculated for Waterway Stratification
23	IABC4	ABCD	combined bioassay, waterway, benthcluster stratification analysis
24	IABC5	ABCD	Variable by Variable scatter plots
25	IABC6	ABCD	Waterway stratified subset analysis with TOC normalization
26	IABC7	ABCD	Waterway stratified subset analysis with SILT normalization
27	IUTI1	ABCD	Utility listing of values for selected variables and species abundance plots versus SILT and SAND

TABLE D-5. COMPARISON OF MEANS AND STANDARD DEVIATIONS FOR VARIABLES IN MSQSGVAL (144 STATIONS) AND CHEMBIO (56 STATIONS)[a]

Variable Abbrev.	MSQSGVAL Mean	MSQSGVAL Std.Dev.	CHEMBIO Mean	CHEMBIO Std.Dev.
PA34	13.96	19.77	7.17	8.18
PA21	10.25	13.24	5.88	5.83
PA64	62.24	107.4	28.91	27.79
PB37	14.84	102.1	3.34	4.83
PB26	23.73	39.21	14.39	27.43
PB52	64.48	130.0	48.16	112.6
PB12	65.00	231.1	75.36	371.3
PB67	63.21	124.3	34.09	69.71
PB71	82.46	149.2	43.39	51.20
PP92	31.18	15.34	16.47	12.35
A65850	203.2	686.7	96.97	161.5
A108394	870.6	7989.	1957.	12,800.
A95954	12.44	12.68	6.43	7.29
B100516	35.78	53.68	22.28	26.73
SULFIDE	25.56	86.06	15.48	43.59
METHYLET	290.1	691.2	409.8	996.7
MOXYPHEN	96.66	362.4	176.9	566.3
PENTACHL	11.46	31.37	6.41	16.72
COPROSTA	133.0	285.3	85.84	379.1

[a] These variables had substantially different means and standard deviations between the two data sets; abbreviations are defined in Tables A-1 through A-3.

TABLE D-6. OUTLIER VARIABLES FROM PATTERN RECOGNITION ANALYSIS

Run # 3 INMC2 CHEMBIO 2nd exploratory run on 56 station set chemistry variables only

* KAPRIN Plots

Index#	StationID	Outlier in Eigenvector/Factor...
38	RS-18	V1(high), V2(low)
20	HY-22	V1(mod-high), V2(high), V3(mod-high), V5(high)
48	SP-14	V3(low), V4(mod-high)
7	CI-11	V4(low)

* KAORTH Plots

Index#	StationID	Outlier in Eigenvector/Factor...
38	RS-18	V1(high)
20	HY-22	V2(high)
48	SP-14	V3(low)
7	CI-11	V4(low)

Run # 5 IMSQ2 MSQSGVL2 2nd exploratory run on 144 station set 98 chemistry variables retained

* KAPRIN Plots

Index#	StationID	Outlier in Eigenvector/Factor...
113	SP-14	V4(low), V5(mod-high)

* KAORTH Plots

Index#	StationID	Outlier in Eigenvector/Factor...
(48)	HY-16	V1(mod-high); end of trend in stations 45-58
99	RS-18	V4(high)
102	RS-21	V4(high)
113	SP-14	V5(low)

Run # 7 IMSQ4 MSQSGVL2/ OMSQ2 exploratory run using TOC normalized chemical variables -- 144 station set

* KAPRIN Plots

Index#	StationID	Outlier in Eigenvector/Factor...
78	HY-46	V1(low), V3(high), V4(high)
131	RS-03	V5(high)

* KAORTH Plots

Index#	StationID	Outlier in Eigenvector/Factor...
78	HY-46	V2(high)
131	RS-03	V5(high)

TABLE D-6. (Continued)

Run # 8 IMSQ5 MSQSGVL2/ exploratory run using FINES normalized
OMSQ2 chemical variables -- 144 station set

* KAPRIN Plots

Index#	StationID	Outlier in Eigenvector/Factor...
103	RS-22	V2(low - opposite of 102 & 99)

* KAORTH Plots

Index#	StationID	Outlier in Eigenvector/Factor...
103	RS-22	V1(low)
113	SP-14	V5(low - slight hint of trend)

Chemical Factor Changes with Anomaly Removal

After initial interpretation using all data was complete, five anomalous values were removed from the MSQSGVAL data set and exploratory steps were recalculated on the remaining 139 stations. The five stations left out in this stage of the analysis were #48-HY-6, #78HY-46, #99RS-18, #102RS-21, and #113SP-14. Factor analysis results were compared for the run (#10-IMSQ7ZD) versus the original analysis containing all 144 stations (#5-IMSQ2). Three of the first five factors showed some correspondence in the variables having the greatest loadings. The correspondence list is shown in Table D-7, with common variables underlined.

Combined Chemical-Biological Results, Run #18a-INC10

After exploratory runs were made on the chemical and biological variables separately, they were combined in an analysis of potential chemical-biological variable relationships. The CHEMBIO data set was used and 38 benthic abundance variables were added from the CB2 data set after exploratory runs on those data alone. The resultant analysis focused on 142 chemical and biological variables.

Results from the principal component analysis are briefly summarized below, including the highest loading variables in order of their contribution:

#1. Heavy organics and metals (strongly influenced by station RS-18): PB81, B132649, PB01, NICKEL, PB39, DIBENZOT, PB80, METHYL2P, LEAD, PB72, CADMIUM, COPPER, MERCURY, SELENIUM, ANTIMONY, ARSENIC, THALLIUM, PB76, PB84, ZINC, PB62, B91576, PB78, METH2PYR, PB73, MANGANESE, ...

#2. Benthic infauna associated with sandy sediment types: SAND, -CLAY, -SILT, 154Leito, AMPHIPOD, 98Platyn, 106Nepht, 238Medio, -THARYX, 412Macoma, 207Spioc, -214Tharyx, 816Prion, 421Telli, -BERYLLIUM, CRUSTA, -138Lumbri, 496Lepto, PRIONOSP, LUMBRI, ...

#3. Mixed chemical-biological factor: MOLLUSC, 394Axino, AXINOPS, -PA21, -SULFIDE, -KAUR16EN, 456Euphi, -TOC, ANTIMONY, ARSENIC, 373Nucul, MERCURY, -PA65, -MOXYPHEN, SELENIUM, CADMIUM, -231Capit, THALLIUM, COPPER, -VSOLIDS, -OTHER, -20Nemato,...

#4. Chlorinated organics and HPAH: PB82, PB52, PB09, PB08, PB83, TPCBS, -MOXYPHEN, PB12, TBFLANTH, -ISOPIMAR, -A108394, PB73, ...

#5. Benthic infauna associated with silty sediment types (and including some organic compounds): 238Medio, TOTAL, EUPHILO, POLYCH, 207Spioc,

TABLE D-7. CHEMICAL FACTOR DIFFERENCES, Run #5-IMSQ2 vs Run #10-IMSQ7

IMSQ2 (144 stations) Factor & Variables	IMSQ7 (139 stations) Factor & Variables
1. PAH and some metals LMWPAH, PB80, PB81, PB01, B132649, PB39, LEAD, DIBENZOT, CADMIUM, PB78, METHYL2P, BIPHENYL, PB72, ANTIMONY, HMWPAH, ICOGRP1	1. PAH and other organics TOTORG, HPAH, PB84, LPAH, PB39, PB72, PB81, PB73, PB78, TBFLANTH, PB83, PB76, PB82, -SOLIDS, VSOLIDS, PB80, B91576, PB01, PB79, TOC, B132649, PB55, DIBENZOT
2. Metals ANTIMONY, ARSENIC, TOTMET, COPPER, CADMIUM, MERCURY, SELENIUM, ICOGRP1, -PB83, SOLIDS, LEAD, -PB79,	2. Metals ANTIMONY, TOTMET, ICOGRP1, COPPER, ARSENIC, CADMIUM, MERCURY, SELENIUM, LEAD, ZINC, IRON, NICKEL, BARIUM, MANGANESE,
3. Chlorinated Organics PB52, PB08, PENCBD, TETCBD, TOTCBD, TRICBD, PB09, PENTACHL CLBENZ, ...	3. Chlorinated Organics PB52, PENCBD, PB09, TETCBD, TOTCBD, PB08, TRICBD, PENTACHL, BERYLLIUM, -A95487, TPCBS, ...
4. Other Organics MOXYPHEN, A108394, PB55, KAUR16EN, METHYLET, -PB76, -TBFLANTH, RETENE, -HMWPAH, PB77, -PB83, -PB79, -PB82, ISOPIMAR, B91576, ...	4. Mixture -CHROMIUM, -IRON, PB08, PB52, PENCBD, B132649, TOTCBD, -SULFIDE TETCBD, -MANGANESE, PB92, -CLAY, TRICBD, RETENE, CLBENZ, PB36, -PB76, ...
5. Pulp Organics/ & Mn ISOPIMAR, KAUR16EN, A108394, METHYLET, MOXYPHEN, MANGANESE, A95487	5. Grain Size Related SILT, FINES, -SAND, CLAY, -METHYLPY, -PB12, -PB82, -SOLIDS

CRUSTA, 455Euphi, A95487, 16Nemert, MOLLUSC, VSOLIDS, PB55, 421Telli, PB77, -SOLIDS, B91576,...

A scatter plot of the stations versus factors 2 and 5 showed inversely correlated behavior for the two factors with the exception of stations RS-13 and RS-14, which were high in scores for both factors.

Conventional Chemical and Biological Results -- Run #17-INMC9

Prior to the complete chemical-biological run (#18a, above), the 56 CHEMBIO stations were evaluated for only conventional chemical, bioassay score, and biological/benthic variables. Factors mainly reflected biological loadings, with the exception of one factor loaded negatively with TOC, VSOLIDS and bioassay score variables, and positively with large grain size and biological variables. Results of the principal components analysis included the following factors:

#1. TOTAL, AXINOPS, MOLLUSC, 394Axino, LUMBRI, 138Lumbri, THARYX, SILT, 456Euphi, -SAND, POLYCH, 214Tharyx, 114Glyce, MACOMA, 415Macoma, ...

#2. -TOC, -ABNORM, SOLIDS, -VSOLIDS, CRUSTA, -MORT, 186Prionosp, 106Nepht, -CLAY, SAND, -CHANGE, PRIONOSP, 455Euphi, 238Medio, ...

#3. 102Nepht, -SOLIDS, 223Arman, -236Notom, 399Mysel, 421Telli, 352Odost, -411Macoma, SULFIDE, -20Nemato, 348Mitre, -CHANGE

#4. -342Eucho, 214Tharyx, THARYX, 16Nemert, 102Nepht, POLYCH, 207Spioc, -348Mitre, 411Macoma, -373Nucul, 353Turbo, -53Eteone, ...

Scatterplots of the stations versus the first two factors indicated that Sitcom and Pt. Defiance-Ruston stations had different behavior, even though they had been grouped in the same waterway category for analysis because of metals contamination in both areas. Also, Carr Inlet stations behaved considerably different than the Blair and Milwaukee stations with which they had been grouped. The upper Hylebos stations were in a tight group and the lower Hylebos stations were in a moderately tight group except for #28HY-44 and #30HY-50.

Scatter plots for factor 2 versus factor 4 indicated the possibility that the two benthic compositions represented species of different habitat orientations. Where one group was high, the other was low.

Correlations Among Variables

Linear Pearson correlation coefficients were calculated for the chemical and biological data. The biological variables were searched for chemical variable correlation coefficients that had a calculated probability of less than 0.05 of being drawn from a parent population with a truly random relationship (zero correlation). These were listed and the frequencies for which the chemical variables were observed were tabulated. These are listed in Table D-8, for both positive and negative r-values, with the total

TABLE D-8. CHEMICAL VARIABLES WITH ≥1 SIGNIFICANT (P<0.05) CORRELATIONS WITH BIOLOGICAL VARIABLES

Chemical[a]	Number of Observances (@ P < 0.05) Negative r's	Positive r's	Total Obs
MORT	1	-	1
ABNORM	2	1	3
NICKEL	6	-	6
MANGANESE	2	-	2
RETENE	-	2	2
PB77	-	3	3
A95487	-	3	3
SILT	9	8	17
SAND	10	7	17
PB27	1	2	3
HEXADEC9	3	2	5
TOC	3	2	5
CHANGE	1	-	1
PB36	3	-	3
PB68	-	3	3
METHYLPY	-	1	1
PB79	-	4	4
PB76	-	2	2
PB84	-	1	1
BERYLLIUM	2	2	4
PB26	-	2	2
PENCBD	-	1	1
PENTACHL	-	1	1
PB72	-	1	1
SOLIDS	-	1	1
PB67	-	1	1
CHROMIUM	2	2	4
PB66	1	1	2
PA64	1	1	2
PP92	-	1	1
COPROSTA	-	3	3
B62533	-	3	3
A95954	-	3	3
PB54	1	3	4
PA21	-	2	2
B100516	-	4	4
PB37	-	3	3
PA65	-	2	2
PB70	-	1	1

[a] Codes for variables are explained in Tables A-1 through A-3

number of observances out of 51 biological variables (13 taxonomic groups and 38 benthic species).

INTERACTIVE SCREEN LOG FOR RUN # 17 -- INMC9 OUTPUT CODE

An example of the screen log for a typical run on ARTHUR is recreated in this section. The run consisted of a second stage exploratory analysis of 66 conventional chemical, biological and benthic variables after removing five anomalous stations.

(Comments in quotation marks added to explain intent of following steps)

```
      Version 4.0 (Released 1 January 1985).
       AAA     RRRR  TTTTT  H  H  U  U  RRR
      A   A    R  R    T    H  H  U  U  R  R
     A-jmw-A   RRR     T    HHHH  U  U  RRR
     A     A   R R     T    H  H  U  U  R R
     A     A   R  R    T    H  H   UU   R  R

              General Pattern Recognition
              ***************************
           Multivariate Data Analysis System
         *  ***********************************

 ***************************************************
 * Copyright (c) Infometrix, Inc.  15 August 1984 *
 *              All rights reserved.               *
 ***************************************************
    Use of this program implies that the individual
 has read and agrees to the terms and conditions of
 the  Infometrix Software Program License Agreement
 for  ARTHUR  and  the  Limited Warranty  contained
 therein.
Set terminal to UPPER case and enter <CR> to continue:

Please enter 4 character identification code:
NMC9

Enter session title:
WEIGHT/FACTOR ANALYSIS OF CNMC7 W/ 5 ANOMALIES REMOVED

Option?   "Note - following steps brought data set CNMC7.DAT into file
1"
LET

Option  LET  called at 21:22:44 on 17-DEC-85.

Enter destination file# for copy of data (1 thru 6):
1

Let file #1 contain data from file named?
CNMC7
```

```
Option?  "Following sequence with CHDATA deleted 5 anomalous stations"
CHDATA,1,1,-1

Option  CHDA called at 21:23:05 on 17-DEC-85.

Enter the pattern-changes in form
TRAIN/TEST, 1st inc. sam. indx, last sam. indx, cat# (end 0$)
TRAIN,1,16,1
TRAIN,18,19,1
TRAIN,21,22,2
TRAIN,24,26,2
TRAIN,27,32,3
TRAIN,33,40,4
TRAIN,41,41,5
TRAIN,44,51,5
TRAIN,52,56,6


Option?
CHCAT,1,1,0

Option  CHCA called at 21:24:51 on 17-DEC-85.

Number Data Vectors In Training Set.....   51

Number Data Vectors In Test/evaluation Set...    0

Number of Categories...    6

Category  Members
     1       18
     2        5
     3        6
     4        8
     5        9
     6        5

Option?
UTILIT,1,-1

Option  UTIL called at 21:25:15 on 17-DEC-85.

Option? "Next step autoscales the data and prints univariate statistics"
SCALE,1,2

Option  SCAL called at 21:25:24 on 17-DEC-85.

Option? "Next step calculates variance weights between categories"
WEIGHT,2,3,-1,-1,3

Option  WEIG called at 21:25:39 on 17-DEC-85.
```

```
Option? "Next 8 steps generate factor analysis and factor plots"
KAPR,2,4,0,0,10

Option  KAPR called at 21:26:08 on 17-DEC-85.


    Eigenvalue       Var. Preserved
                     Each      Total
    1  1.205E+01      25.8      25.8
    2  8.365E+00      17.9      43.8
    3  5.221E+00      11.2      55.0
    4  4.437E+00       9.5      64.5
    5  3.435E+00       7.4      71.9

Option?
KAVE,0,0

Option  KAVE called at 21:26:35 on 17-DEC-85.

Option?
KATR,2,3,4,5

Option  KATR called at 21:26:53 on 17-DEC-85.

Option?
VARV,3,0,-1,1,0,1

Option  VARV called at 21:27:15 on 17-DEC-85.

Option?
KAVA,4,4,0,0,8

Option  KAVA called at 21:28:08 on 17-DEC-85.

    Eigenvalue       Var. Preserved
                     Each      Total
    1  8.366E+00      19.9      19.9
    2  6.511E+00      15.5      35.4
    3  6.296E+00      15.0      50.4
    4  5.015E+00      11.9      62.4
    5  4.776E+00      11.4      73.7

Option?
KAVE,0,0

Option  KAVE called at 21:28:30 on 17-DEC-85.


Option?
KATR,2,3,4,6
```

```
Option  KATR called at 21:28:44 on 17-DEC-85.

Option?
VARV,3,0,-1,1,0,1

Option  VARV called at 21:29:04 on 17-DEC-85.

Option? "Next step calculates the distance matrix using 6 factor scores"
DIST,3,4

Option  DIST called at 21:29:48 on 17-DEC-85.

Option? "Next step calculates hierarchical cluster analysis ..."
HIER,4,0,1          " ... dendogram using the factor distance matrix"

Option  HIER called at 21:29:59 on 17-DEC-85.

Option?
STATUS,-1

Option  STAT called at 21:30:27 on 17-DEC-85.

    File #  File Specification        File Purpose
    ======  ==================        ============
       1    ONMC9ZD                   a data file
       2    CNMC9ZD                   a data file
       3    VNMC9ZD                   a data file
       4    FNMC9ZD                   a data file
       5    PNMC9ZD                   a data file
       6    RNMC9ZD                   a data file
       7    INMC9ZD                   the printer file
       8    ANMC9ZD                   the interactive output file
       9    BNMC9ZD                   the ASCII data output file

Option? "Run completed, the next step saves the printer file on disk"
SAVE,7

Option  SAVE called at 21:30:57 on 17-DEC-85.

Option? "next step saves the factor projection data to disk"
SAVE,3

Option  SAVE called at 21:33:34 on 17-DEC-85.

Option? "All steps complete, so quit ARTHUR"
EXIT
FORTRAN STOP

$ LO
  COUSE2       logged out at 17-DEC-1985 21:34:29.85}
```

APPENDIX E

RECOMMENDED CONTAMINANTS OF CONCERN FOR MANAGEMENT OF DREDGED MATERIAL

RECOMMENDED CONTAMINANTS OF CONCERN

Several previous reports (e.g., Konasewich et al. 1982) have discussed criteria for the selection of contaminants of concern present in Puget Sound. In general, chemicals of concern have the following attributes:

- A demonstrated or suspected effect on ecology or human health (i.e., the focus of chemical concerns is on ultimate biological effects); toxic effects of chemicals are typically characterized by laboratory tests of acute or chronic toxicity to marine benthic organisms or tests of carcinogenicity or mutagenicity
- Environmental persistence of the parent compounds or of toxic metabolites
- A potential for remaining in a toxic form for a long time in the environment
- One or more present or historical sources of sufficient magnitude to be of concern (i.e., widespread distribution and high concentration relative to Puget Sound reference sediments).

Contaminants of concern recommended in this section were selected based on consideration of the above attributes, existing lists of contaminants of concern in Puget Sound [i.e., Konasewich et al. 1982; Quinlan et al. 1985; Jones and Stokes 1983], results of PSDDA/PSEP workshops held to establish procedures for environmental analysis of metals and organic contaminants (e.g., Tetra Tech 1986b, 1986c), and chemical data from a wide range of Puget Sound studies and sampling areas [e.g., Metro TPPS study (Romberg et al. 1984), Commencement Bay Remedial Investigation (Tetra Tech 1985), NOAA Technical Memorandum OMPA-19 (Malins et al., 1982), Eight Bay study (Battelle 1985b)].

Inorganic and organic contaminants of concern in dredged materials are listed in Tables E-1 and E-2, respectively. The lists comprise many U.S. EPA priority pollutants with several noteworthy additions and deletions summarized in the tables. Although the total number of contaminants in Tables E-1 and E-2 is fairly large, it is not recommended that different subsets of this list be used for different geographic areas of Puget Sound. Such a recommendation would have to be based on the assumption that certain chemicals are unlikely to occur in certain regions of Puget Sound. The a priori exclusion of chemicals is not advised. Potential pollution sources (e.g., highly populated and industrialized areas, isolated industrial facilities, agricultural runoff) are located in many regions of Puget Sound, and estuarine and atmospheric circulation can transport contaminants throughout most of Puget Sound. Justification for deletion of a particular chemical class (e.g., priority pollutant acid compounds) from the list of contaminants of concern in a particular geographic area should always be based on representative field analyses that confirm the absence (or acceptably low concentration) of the chemical class.

TABLE E-1. INORGANIC CONTAMINANTS OF POTENTIAL CONCERN IN PUGET SOUND SEDIMENTS[a]

Antimony	Chromium	Silver[b]
Arsenic[b]	Lead[b]	Zinc
Cadmium	Mercury[b]	Cyanide
Copper[b]	Nickel	

[a] The first group of elements consists of 10 of the 13 U.S. EPA priority pollutant metals and cyanide. The remaining 3 priority pollutant metals not recommended are beryllium, thallium, and selenium. Chromium may only be of local concern in areas where chromium-rich wastes are being discharged (e.g., chrome plating industries)

Beryllium and thallium are toxic but have not been found at concentrations that exceed reference levels in Puget Sound (see Tetra Tech 1986c). High selenium concentrations have been reported in a single Puget Sound study; these values are considered to be elevated most likely because of spectral interferences during the particular instrumental analysis used (see Appendix A in Tetra Tech 1986c). Other studies using alternative techniques have not found levels of selenium in excess of reference conditions.

[b] These elements have been suggested previously as contaminants of concern in Puget Sound (see Konasewich et al. 1982; Jones and Stokes 1983).

Note: Three non-priority pollutant metals (aluminum, iron, and manganese) are not of toxicological concern, but are useful for normalization of other metals data and as tracers of natural terrigenous material (see Appendix A in Tetra Tech 1986c).

TABLE E-2. ORGANIC CONTAMINANTS OF POTENTIAL CONCERN IN PUGET SOUND SEDIMENTS[a]

Phenols and Substituted Phenols (organic acids)

phenol	2,4-dimethylphenol
2-methylphenol[b,c]	pentachlorophenol[d]
4-methylphenol[b,c]	

Miscellaneous Organic Acids (selected samples only)[e]

2-methoxyphenol
3,4,5-trichloroguaiacol
4,5,6-trichloroguaiacol
tetrachloroguaiacol
mono- and di- chlorodehydroabietic acids

Low Molecular Weight Aromatic Hydrocarbons (neutrals)[d]

naphthalene	fluorene
acenaphthylene	phenanthrene
acenaphthene	anthracene

Alkylated Low Molecular Weight Aromatic Hydrocarbons (neutrals)[d,f]

2-methylnaphthalene	1-methylnaphthalene
1-, 2-, and 3-methyl phenanthrenes	

High Molecular Weight PAH (neutrals)

fluoranthene	benzo(k)fluoranthene
pyrene	benzo(a)pyrene
benzo(a)anthracene	indeno(1,2,3-c,d)pyrene
chrysene	dibenzo(a,h)anthracene
benzo(b)fluranthene	benzo(g,h,i)perylene

Chlorinated Aromatic Hydrocarbons (neutrals)

1,3-dichlorobenzene	1,2,4-trichlorobenzene
1,4-dichlorobenzene	hexachlorobenzene (HCB)
1,2-dichlorobenzene	

Total PCBs (mono- through decachlorobiphenyls)

TABLE E-2 (continued).

Chlorinated Aliphatic Hydrocarbons (neutrals)

trichlorobutadiene isomers[d,g]
tetrachlorobutadiene isomers[d,g]
pentachlorobutadiene isomers[d,g]
hexachlorobutadiene[d,g]

Phthalate Esters (neutrals)[d]

dimethyl phthalate
diethyl phthalate
di-n-butyl phthalate
butyl benzyl phthalate
bis(2-ethylhexyl)phthalate
di-n-octyl phthalate

Miscellaneous oxygenated compounds (neutrals)

isophorone
benzyl alcohol[b,h]
benzoic acid[b,h]
dibenzofuran[b,h]
polychlorodibenzofurans[d,i]
polychlorodibenzodioxins[i]
coprostanol[j]

Organonitrogen Compounds (organic bases)[k]

N-nitrosodiphenylamine
nitrogen heterocycles [e.g., 9(H)-carbazole][l]

Pesticides (neutrals)[m]

p,p'-DDE[d]
p,p'-DDD[d]
p,p'-DDT[d]
aldrin[d]
dieldrin[d]
alpha-chlordane
endrin[d]
heptachlor
alpha-HCH
beta-HCH
delta-HCH
gamma-HCH

Volatile Halogenated Alkenes (neutrals)

trichloroethene
tetrachloroethene

Volatile Aromatic and Chlorinated Aromatic Hydrocarbons (neutrals)

benzene
toluene
ethylbenzene
styrene (ethenylbenzene)
total xylenes
chlorobenzene

TABLE E-2 (continued).

NOTE: Compounds not recommended from the priority pollutant list include:

- Halogenated ethers (two volatile and five semivolatile compounds) are rarely reported in Puget Sound and are not expected to persist in sediments.
- Hexachlorocyclopentadiene has not been confirmed to be present in Puget Sound sediments, is easily degraded during laboratory analysis, and has no suspected sources in Puget Sound.
- Acrolein and acrylonitrile have not been detected in Puget Sound sediments and are difficult to analyze for in routine volatile analyses.
- Other priority pollutants not recommended are indicated in the following footnotes and in Table E-3.

[a] Additional compounds are listed in Table E-3. These additional compounds have been rarely or never detected in Puget Sound, but can be analyzed relatively easily with the compounds on this list.

[b] Indicates U.S. Hazardous Substance List (HSL) compound that is not also on the U.S. EPA priority pollutant list.

[c] 2-Methylphenol is an HSL compound and is a known component of krafft pulp effluents. 4-Methylphenol is an HSL compound that was reported at high concentration in numerous areas of Commencement Bay. There are few data available for this compound but it has been found in pulp mill effluent, and could derive from degradation of other substances. The occurrence of 4-methylphenol was highly correlated with sediment toxicity and effects on benthic biota in a problem area near a pulp and paper operation in Commencement Bay. The compound may also be derived as a groundwater contaminant in other areas.

[d] Compound or group of compounds has been designated previously as a contaminant of concern in Puget Sound (Jones and Stokes 1983; Konasewich et al. 1982; Quinlan et al. 1985).

[e] These compounds are recommended only for areas adjacent to pulp mills. Guaiacol was repored in Commencement Bay and is useful as an indicator of pulp mill effluent (both kraft and sulfite mills). Chlorinated guaiacols are toxic, persistent, and are excellent indicators of chlorinated pulp mill effluents (e.g., bleached kraft mills). Analytical recoveries of chlorinated guaiacols will probably be low (as is the case of chlorinated phenols) unless analytical procedures are modified to stabilize the compounds (e.g., by derivitization techniques). Chlorinated dehydroabietic acids are also good indicators of chlorinated pulp

TABLE E-2 (continued).

effluent and are toxic and persistent (based on studies of unchlorinated dehydroabietic acid). Modified analytical procedures (e.g., derivitization) will also be needed to recover resin acids.

f These non-priority pollutant compounds are often detected in Puget Sound sediments. Although this is not an exhaustive list of alkylated aromatic compounds, the compounds shown are accessible as analytical standards and are useful for determining alkylated/non-alkylated ratios for indicating PAH sources.

g Tri-, tetra-, and pentachlorobutadienes are non-priority pollutants that have been detected at highly elevated levels in certain areas of Puget Sound (e.g., Hylebos Waterway in Commencement Bay). Because standards are generally unavailable for these compounds, they are recommended for analysis only where chlorinated butadienes are suspected to have a major source (standards are available for hexachlorobutadiene).

h Dibenzofuran, benzyl alcohol, and benzoic acid are HSL compounds and have been detected frequently in Commencement Bay.

i Chlorinated dibenzofurans and dioxins are recommended as special analyses only, as determined by specific project goals. Both classes of compounds are of concern because of their severe toxic effects on higher organisms [only 2,3,7,8-tetrachlorodibenzodioxin (TCDD) is a U.S. EPA priority pollutant]. Few analyses have been conducted for these compounds in Puget Sound in the past. Recent data suggest that higher molecular weight isomers of the dibenzofurans and dioxins are relatively common (e.g., the much less toxic hexa- and octachlorinated forms), but 2,3,7,8-TCDD has not been detected in Puget Sound samples.

j Not a U.S. EPA priority pollutant, and not known to be toxic but is useful as a source indicator of sewage and agricultural wastes.

k The remaining 7 priority pollutant organic bases are seldom detecteed in Puget Sound and often present analytical problems (e.g., benzidine and 3,3-dichlorobenzidine). N-nitrosodiphenylamine can probably be recovered well with the PSEP organics full-scan procedure even though the procedure is not designed for high recovery of organic bases (i.e., by back-extracting rinse waters at pH>12)

l 9(H)-carbazole is a component of creosote and coal tar and has been reported in Puget Sound regions with these sources (although not exclusively with these sources)

m Toxaphene, a priority pollutant pesticide mixture, has not been recommended because it has not been reported in Puget Sound and requires some additional analytical work.

Detection of the chemicals in Tables E-1 and E-2 will require at least three different analytical procedures (for metals, volatile organics, and semivolatile organics). The lists in these tables are appropriate for dredged materials; a reduced list of contaminants may be appropriate for other matrices (e.g., biological tissues).

Organic priority pollutants that are not strongly recommended as contaminants of concern are listed in Table E-3. These compounds have been detected infrequently (or not at all) in Puget Sound, but are relatively easy to analyze along with chemically similar compounds listed in Table E-2 (e.g., the chlorinated phenols from Table E-3 could be analyzed along with pentachlorophenol listed in Table E-2). The analysis of the entire set of chemicals will not necessarily be more costly than analysis of a reduced set of chemicals because "full scan" analyses for metals, volatile organics, and semivolatile organics can be used to detect a wide range of chemicals with a single analysis for each of the three chemical groups.

In the evaluation of dredged material, contaminants of concern must be identified relative to their proposed disposal environment (i.e., aquatic, nearshore, or upland disposal). The specific contaminants of concern in a given sediment may be different at the dredged site and the disposal site because of differences in their environmental mobility and route of exposure to biological organisms. For example, physicochemical conditions of sediments are substantially altered in the transfer of material from the subtidal environment to an upland or nearshore environment. These changes can favor the leaching of acid soluble metals from otherwise stable solid matrices, or volatilization of some organic compounds (including various PCB congeners). As a result, substantially greater metals bioaccumulation or other loss from a terrestrial site could occur relative to that expected at the original marine site.

The general criteria listed above do not explicitly take into account these differences in disposal environments. An evaluation of dredged material should include consideration of the following additional factors (in order of decreasing importance):

- Available regulatory limits or other guidelines relating contaminant concentrations to biological effects relevant to the disposal site

- Concentrations of contaminants relative to reference conditions appropriate to the disposal site.

Although attention is usually focused on contaminant effects at the disposal site, contaminant release can occur at the dredging site during dredging operations. Dredged material destined for upland and nearshore disposal may require evaluation for contaminants of concern in both aquatic and terrestrial environments. Finally, contaminants of concern may vary geographically within one type of environment. Some contaminants may be of general concern, but such a list should not be used as the sole guide. Data required for evaluation of contaminants of concern in a dredged material

TABLE E-3. ADDITIONAL ORGANIC CONTAMINANTS OF LIMITED CONCERN[a]

Substituted Phenols (acids)

2-chlorophenol
2,4-dichlorophenol
4-chloro-3-methylphenol
2,4,6-trichlorophenol
2,4,5-trichlorophenol
pentachlorophenol
2-nitrophenol
2,4-dintrophenol
4,6-dinitro-o-cresol

Chlorinated Hydrocarbons (neutrals)

2-chloronaphthalene
hexachloroethane

Pesticides (neutrals)

alpha-endosulfan
beta-endosulfan
endosulfan sulfate
endrin aldehyde
heptachlor epoxide

Volatile Halogenated Alkanes (neutrals)

chloromethane
bromomethane
chloroethane
dichloromethane
1,1'-dichloroethane
chloroform
1,2-dichloroethane
1,1,1-trichloroethane
carbon tetrachloride
bromodichloromethane
1,2-dichloropropane
chlorodibromomethane
1,1,1-trichloroethane
bromoform
1,1,2,2-tetrachloroethane

Volatile Halogenated Alkenes (neutrals)

vinyl chloride
1,1'-dichloroethene
trans-1,2-dichloroethene
cis-1,3-dichloropropene
trans-1,3-dichloropropene

Volatile Aromatic and Chlorinated Aromatic Hydrocarbons (neutrals)

styrene (ethenylbenzene)[b]
chlorobenzene

[a] These priority pollutant compounds (except as noted) are not strongly recommended because they are seldom, if ever, detected in Puget Sound. However, these compounds can be analyzed relatively easily with the other chemicals in their class listed in Table E-2.

[b] Indicates U.S. EPA Hazardous Substance List (HSL) compound that is not also on the U.S. EPA priority pollutant list.

should include at least one analysis for a broad range of contaminants (subject to waiver for small dredging projects in areas away from suspected sources).

CONTAMINANTS OF CONCERN FOR AQUATIC DISPOSAL

Most Puget Sound studies have focused attention on contaminants of concern relative to the aquatic (marine) environment. Two NOAA studies have summarized evaluations for 463 contaminants in Puget Sound sediments: (1) Konasewich et al. (1982) presented a rationale for the inclusion of 15 contaminants or groups of contaminants based on a review of evidence for 230 inorganic and organic pollutants; (2) Quinlan et al. (1985) updated the previous NOAA report and reviewed data for an additional 233 pollutants. The latter report did not identify any new contaminants of concern, and argued for the deemphasis of one contaminant (i.e., mercury) on the basis of recent bioaccumulation data. Data suggesting the importance of some contaminants not addressed in the NOAA studies (e.g., alkylated phenols) have recently been released (Tetra Tech 1985). These more recent data also suggested that elevated mercury concentrations in some surface sediments may be associated with observed sediment toxicity and depressed abundances of benthic infauna.

CONTAMINANTS OF CONCERN FOR NEARSHORE AND UPLAND DISPOSAL

For nearshore and upland disposal, chemical concentrations measured in marine sediments should be comparable with those measured in terrestrial soils. Hence, contaminants of concern for terrestrial disposal sites may be identified through a review of available U.S. FDA limits for cropland soils, or by comparison with the overall crustal abundance (i.e., average content in soils of all types) of trace constituents. The concern for a given level of contamination relative to biological effects in terrestrial environments should be evaluated using terrestrial biological indicators.

APPENDIX F

RECOMMENDED ANALYTICAL DETECTION LIMITS

RECOMMENDED ANALYTICAL DETECTION LIMITS

Appropriate detection limits are a critical consideration for sediment quality management. For example:

- Sediment quality approaches that rely on observations of biological effects require chemical analyses that can detect low concentrations of potent toxic contaminants.
- Detection limits for samples must be considerably lower than the established sediment quality values against which they are tested.
- The reference approach requires sensitive chemical analyses for relatively uncontaminated reference sites. Analyses with high detection limits will give regulators very limited data upon which to base sediment quality values.

APPROACHES TO DETECTION LIMITS

Environmental analytical chemists have not universally agreed upon a convention for determining and reporting the lower detection limits of analytical procedures. Values reported as lower detection limits are commonly based on instrumental sensitivity, levels of blank contamination, and/or matrix interferences and have various levels of statistical significance. The American Chemical Society's Committee on Environmental Improvement (CEI) defined the following types of detection limits in an effort to standardize the reporting procedures of environmental laboratories (Keith et al. 1983):

- Instrument Detection Limit (IDL) -- the smallest signal above background noise that an instrument can detect reliably.
- Limit of Detection (LOD) -- the lowest concentration level that can be determined to be statistically different from the blank. The recommended value for LOD is 3 , where is the standard deviation of the blank in replicate analyses.
- Limit of Quantitation (LOQ) -- the level above which quantitative results may be obtained with a specified degree of confidence. The recommended value for LOQ is 10 , where is the standard deviation of blanks in replicate analyses.
- Method Detection Limit (MDL) -- the minimum concentration of a substance that can be identified, measured, and reported with 99 percent confidence that the analyte concentration is greater than zero. The MDL is determined from seven replicate analyses of a sample of a given matrix containing the analyte (Glaser et al. 1981).

The CEI recommended that results below 3 should be reported as "not detected" (ND) and that the detection limit (or LOD) be given in parentheses. In addition, if the results are near the detection limit (3 to 10 , which is the "region of less-certain quantitation"), the results should be reported as detections with the limit of detection given in parentheses.

The CEI definitions are useful for establishing a conceptual framework for detection limits, but are somewhat limited in a practical sense. The IDL does not address possible blank contaminants or matrix interferences and is not a good standard for complex environmental matrices. The LOQ accounts for blank contamination, but not specifically for matrix complexity and interferences. The high 10 level specified for LOQ helps to preclude false positive findings, but may also necessitate the rejection of valid data. The MDL is the only operationally defined detection limit and provides a high statistical confidence level but, like the LOQ, may be too stringent and necessitate the rejection of valid data.

Metals

The LOD (3) detection limit is appropriate for metals data. Interferences are a major determinant of attainable detection limits and are not accounted for in the LOD calculation. However, the LOD is appropriate because matrix and interelement interferences can be corrected for during instrumental analysis (e.g., by matrix matching and background corrections.)

Organic Analytes

Interferences are also a major determinant of detection limits of organic analytes, but cannot be corrected for easily during instrumental analysis. An alternative detection limit, the lower limit of detection (LLD), is recommended for data generated by gas chromatography-mass spectrometry (GC/MS). LLD are established by analysts based on their experience with the instrumentation and with interferences in the sample matrix being analyzed. LLD are greater than instrumental detection limits because they take into account sample interferences. To estimate LLD, the noise level should be determined in the retention window for the quantitation mass of representative analytes. These determinations should be made for at least three field samples in the sample set under analysis. The signal required to exceed the average noise level by at least a factor of two should then be estimated. This signal is the minimum response required to identify a potential signal for quantification. The LLD is the concentration corresponding to the level of this signal based on calibrated response factors. Based on best professional judgment, this LLD would then be applied to samples in the set with comparable or lower interference. Samples with much higher interferences (e.g., at least a factor of two higher) should be assigned LLD at a multiple of the original LLD.

FACTORS AFFECTING DETECTION LIMITS

The following factors influence the attainable detection limits for metal and organic analytes:

- Physical sample size available - In most cases, the more sample that is available for analysis, the better the detection levels that can be achieved. Thus, for a given method, larger samples will have lower detection limits than smaller samples.

- Presence of interfering substances - For example, the presence of elemental sulfur in a solvent extract to be analyzed by gas chromatography-electron capture detection (GC/ECD) will potentially obscure analyte peaks and raise the amount of analyte required for detection.

- Range of pollutants to be analyzed - For example, if only one compound is of interest, a method can be optimized for that compound without regard to potential effects on other compounds. Dedicated protocols can yield far lower detection limits than full-scan protocols.

- Instrumental sensitivity - For detection of most priority pollutant metals, inductively coupled plasma (ICP) emission spectrometry is less sensitive than graphite furnace atomic absorption (GFAA) spectrophotometry. Thus, GFAA detection allows for lower detection limits. However, simultaneous multi-element analyses are possible for ICP but not GFAA.

- Level of confirmation of results - For example, GC/ECD is more sensitive than GC/MS for chlorinated pesticide analysis. However, a single GC/ECD analysis does not provide positive identification of a compound, whereas GC/MS provides more information for molecular confirmation.

- Level of pollutant found in the field and in analytical blanks - For example, due to bottle preparation procedures, analytical blanks are often contaminated with varying concentrations of methylene chloride. This variation in contaminant level often precludes sensitive detection levels in tissue.

Organic Compounds

The choice of analytical procedures can affect the attainable detection limits of semivolatile organic compounds. Removal of interferences from extracts (e.g., removal of elemental sulfur by treatment with metallic mercury, removal of biological macromolecules by gel permeation chromatography) can significantly reduce the detection limits of many organic analytes. The separation and dedicated analysis of chemically distinct fractions can also reduce detection limits, but requires greater laboratory effort and expense than a full-scan analysis.

RECOMMENDED DETECTION LIMITS - LOW LEVEL

Certain program goals will require sensitive detection limits. For example, low detection limits will be required to assess pollutant concentrations in relatively uncontaminated reference areas. High detection

limits could yield undetected values, which would be of little use in establishing sediment quality values. Low detection limits would also be appropriate for programs that must determine pollutant concentrations corresponding to biological effects. In such cases, the LOD (for metals) and LLD (for organic compounds) would be more likely than LOQ to allow for reports of detected values. Whereas LOQ would provide more statistical confidence than LOD or LLD, they would be far more likely to result in undetected values. For samples that are to be evaluated with sediment quality values, detection limits should be less than half, preferably less than one tenth, the sediment quality values.

The detection limits recommended in this report are considered to be typically attainable values based on the best professional judgment and experience of analytical chemists who considered the instrumental sensitivity of affordable equipment, common problems with blank contamination and matrix interferences, and reasonable levels of laboratory analytical effort. The recommended values are not absolute, as analytical procedures and laboratory precision can affect attainable detection levels. State-of-the-art instrumentation and dedicated analytical procedures will enable laboratories to attain lower detection limits.

Metals

The following recommended limits are based on a 5-g (wet) sediment sample in a 100-mL digestate:

0.01 ppm (dry weight)	Hg
0.02 ppm (dry weight)	Be
0.1 ppm (dry weight)	Sb, As, Cd, Cr, Cu, Pb, Se, Ni, Ag, Tl
0.2 ppm (dry weight)	Zn

Instrumental techniques are major determinants of the attainable detection limits for metals. With the exception of mercury, all of the above metals can be detected at the specified levels with graphite furnace atomic absorption. Mercury should be detected by cold vapor atomic absorption. Other instrumental techniques can also be used to attain the specified levels (e.g., hydride generation atomic absorption can be used for arsenic, antimony, and selenium). Several metals (e.g., zinc) may occur at relatively high levels even in uncontaminated sediments. If instrumentation is available, it could be cost-effective to screen samples by ICP and then analyze undetected compounds with the more sensitive GFAA.

Organic Compounds

Attainable detection limits for organic analytes can vary considerably depending on extraction, extract cleanup, and instrumental detection techniques used. For a sample size of approximately 5 g (wet) and GC/MS detection, detection limits for most volatile organic analytes of interest should be in the range of 1-15 ppb (dry weight).

The detection limits of most semivolatile analytes should be in the range of 1-50 ppb (dry weight), assuming a 100-g (wet weight) sediment

sample size and GC/MS detection. If pesticides and PCBs are analyzed by a more sensitive instrumental technique, GC/ECD, detection limits for single-component pesticides should fall in the 0.1-5 ppb range and PCBs should be detectable at 5-20 ppb. To attain these detection limits for typically complex sedimentary extracts, extract cleanup steps will be required (e.g., adsorption chromatography and sulfur cleanup are necessary for extracts to be analyzed by GC/ECD).

RECOMMENDED DETECTION LIMITS - MODERATE LEVEL

Some projects involving dredged materials may not require very sensitive detection limits. Dredged materials to be disposed of at established disposal sites may be tested against fairly high sediment quality values. However, disposal in relatively uncontaminated areas may require analyses with low detection limits.

Metals

When samples are being evaluated in comparison to high sediment quality values, it is recommended that detection limits be at least 10 times lower than than the sediment quality values. In such cases, multielement ICP analyses may be sufficient and cost-effective (except for mercury, which requires cold vapor atomic absorption). Detection limits consistent with ICP analyses could also be appropriate when sediments are being screened for gross contamination.

Organic Compounds

The Contract Laboratory Program (CLP) has designed analyses to meet approximately 1,000 ppb (dry weight) or approximately 300-600 ppb (wet weight) detection limits. CLP detection limits could be appropriate for screening of samples for gross contamination. Lower detection limits (100 ppb dry weight) have been recommended for evaluation of dredged materials for the Fourmile Rock disposal site (U.S. Environmental Protection Agency/ Washington Department of Ecology 1984). In a recent roundtable discussion among Puget Sound chemists sponsored by PSEP/PSDDA, LLD in the range of 1-50 ppb dry weight were considered appropriate for all uses except screening-level analyses.

APPENDIX G

RECOMMENDATIONS FOR ANCILLARY SEDIMENT VARIABLES

RECOMMENDATIONS FOR ANCILLARY SEDIMENT VARIABLES

Variables other than organic and metal contaminants can provide useful data for assessing sediment quality or for facilitating development of chemical-specific sediment quality values. The physical and chemical ancillary variables considered to be of greatest use are:

- Total solids (dry wt/wet wt expressed as a percent)
- Total organic carbon content (as percent of dry wt sediment)
- Percent fine-grained (<63 um) particles (as percent of dry wt sediment)
- Iron and manganese content (ppm dry wt).

Recommendations for the use of these variables are discussed in the following sections. Other variables (e.g., sulfides, chemical oxygen demand, oil and grease) have use as gross indicators of sediment quality, but have limited use in the development of chemical-specific sediment quality values. These latter variables should not be used as replacements for such sediment quality values because substantial chemical contamination can be found in sediments that appear "acceptable" according to conventional measurements.

TOTAL SOLIDS

Total solids data are essential as they allow for calculation of contaminant concentrations on a dry-weight basis. Most sedimentary contaminants are associated predominantly with the solid material in bulk sediments, not with the interstitial water. Thus, dry-weight contaminant concentrations are preferred to wet-weight concentrations. Use of dry-weight concentrations precludes the possibility that variations in sedimentary moisture content will obscure informative trends in chemical data.

TOTAL ORGANIC CARBON

Chemical concentration gradients, particularly of nonpolar, nonionic organic compounds, have been observed to correlate positively with sedimentary organic carbon content. This observation is commonly interpreted in one of two ways: (1) organic matter is the "active fraction" of sediment and serves as a sorptive sink for neutral, and possibly polar or metallic, compounds (see Section 2.3 of the main report and Appendix H), or (2) carbon-rich particles may be an important transport medium for contaminants (e.g., PAH may tend to be associated with soot particles; Prahl and Carpenter 1983). Laboratory and field investigations suggesting a strong relationship between organic carbon content and nonionic organic compounds (e.g., geochemical studies and bioaccumulation studies) have led to the preferential use of organic carbon normalization for the equilibrium partitioning approach (JRB Associates 1984b) and the Screening Level Concentration approach (Battelle

1986; as discussed in Section 8.6 of the main report, this approach does not require use of organic carbon normalization).

Total volatile solids (TVS) is sometimes measured instead of total organic carbon (TOC). TVS only crudely approximates TOC because (1) organic matter can be volatilized during the total solids determination (which precedes TVS determination), (2) inorganic substances (e.g., carbonates) can be lost during high-temperature combustion (e.g., 550° C), and (3) TVS is a rough measure of organic matter content, not organic carbon content. Thus, a conversion constant for organic matter to organic carbon must be empirically derived and applied to TVS data.

PERCENT FINE-GRAINED (<63 um) PARTICLES

On a limited spatial basis, contaminant concentrations are often inversely correlated with particle size. Thus, contaminants may be concentrated in the fine-grained particles of bulk sediments. This observation is often explained in terms of surface area, in that finer particles have greater specific surface area, and thus greater sorption capacity, than larger particles. However, organic carbon content also tends to vary inversely with particle size in natural sediments (Choi and Chen 1976; JRB Associates 1984b). Thus, normalizing to percent fines may be effectively equivalent to organic carbon normalization.

Grain size, independent of its correlation with contaminant concentration, is an environmentally significant variable. It may play a role in sediment toxicity during bioassays (Tetra Tech 1985; Ott 1985) and affects benthic ecological structure. Thus, grouping of biological data according to sediment grain size could be a useful way to factor out natural environmental effects from contaminant-related effects. Grain size distribution should be an important factor when choosing reference samples for bioassays or benthic infaunal abundance assessments.

MANGANESE OR IRON CONTENT

Trace metals can be selectively enriched in iron and manganese oxides and hydrous oxides under oxidizing conditions (e.g., Jenne and Luoma 1975; Brannon et al. 1976). In such cases, normalization of metal concentrations to manganese and/or iron can reduce the effect of dilution of chemically enriched oxide and hydrous oxide phases with variable amounts of unrelated material in sediments. This normalization is not highly reliable, as site-specific and compound-specific differences affect the significance of oxide- and hydrous oxide-metal associations.

USE OF CONVENTIONAL VARIABLES IN SEDIMENT MANAGEMENT

In the present project, conventional variables were evaluated as tools for sediment management in two ways (1) conventional variables were used to normalize chemical concentrations when generating AET and SLC values (see Sections 5.3 and 5.4 of the main report), and (2) conventional variables were themselves used as indicators of sediment quality (e.g., a total organic carbon AET was developed, potentially as an indicator of organic enrichment).

Other uses (e.g., as geochemical indicators or as normalizing variables for analyses of chemical gradients) are valuable, but were not considered in this project.

For both the AET and SLC approaches, use of chemicals normalized to dry weight was consistently more accurate (by measures defined in Section 7.1) than use of chemicals normalized to organic carbon content or percent fine-grained sediment (see Tables 13 and 17 in Sections 7.1.1 and 7.1.4, respectively). AET values for organic carbon content, total volatile solids, and percent fine-grained material did not identify biologically impacted stations that were not identified by chemical variables (see Section 8.7). Thus, dry weight normalization is recommended for field-based approaches (i.e., AET, SLC) based on its greater predictive success relative to normalization to organic carbon content or percent fine-grained material.

The lower predictive success of sediment quality values for chemicals normalized to organic carbon content or percent fine-grained material is not considered to be a good basis for precluding further use of these variables. The available results suggest the need for further testing of the toxicological aspects of organic carbon normalization theory (e.g., how does organic carbon affect sediment toxicity and is this effect consistent with different kinds of organic matter and different test organisms). Such testing is currently being conducted by Battelle (1985b) and U.S. EPA (Newport).

APPENDIX H

RESPONSE TO COMMENTS ON DRAFT REPORTS

INTRODUCTION
(Prepared by the sponsoring agencies)

The preliminary result of the PSDDA/PSEP study on sediment quality values were initially presented in a series of four separate draft reports (Table H-1). These reports were distributed to a variety of technical and management experts at a number of agencies and consulting firms for their review. The draft reports generated significant interest and controversy, and numerous comments were received.

The comments submitted covered a variety of topics, ranging from correction of typographical errors to complete report reorganization. It is apparent that many of the technical and editorial comments could have been avoided had the reader been provided the entire series of draft reports at one time. With only partial information, it was difficult to put the different parts of the sediment quality study into perspective. The final sediment quality values report represents the revision and synthesis of the four draft reports into a single document. We hope that this reorganization will help put the overall Puget Sound sediment quality values effort into better focus.

The agencies sponsoring this study regard all comments received on the draft reports as important, useful, and constructive, and have seriously considered all concerns in preparation of the final report. In addition, in order to facilitate review and a better understanding of how the final report responds to the issues and concerns raised by reviewers, the agencies, with the assistance of Tetra Tech, Inc., have prepared the following response to comments section. This section generally addresses the majority of the technical comments received. Because specific comments were submitted based on review of separate draft reports, the response to comments section is divided accordingly. Where possible, however, an attempt has been made to identify the location in the final report where the reader may find additional information if desired. We hope that this section, combined with the specific changes made in the report itself, will be useful to you.

The development of sediment quality values for use in Puget Sound is an ongoing effort, with interim values currently being identified for use in Puget Sound by PSDDA and PSEP technical committees. If you have additional comments on the final sediment quality values report, or questions about companion efforts, please contact either Keith Phillips (U.S. Army Corps of Engineers, 764-3624) or Catherine Krueger (U.S. EPA, 442-1287).

TABLE H-1. LIST OF RELEVANT DRAFT REPORTS AND PREPARATION DATES

TASK 1:	Evaluation of Puget Sound data sets for the development of sediment quality values (October 1985)
TASK 2:	Evaluation of statistical relationships among chemical and biological variables using pattern recognition techniques (February 1986)
TASK 3:	Evaluation of approaches for the development of sediment quality values for Puget Sound (October 1985)
TASK 4 and 5a:	Application of selected sediment quality values approaches to Puget Sound data (March 1986)

[A fifth draft report (Task 5b) concerning an approach to risk exposure assessment has been finalized as a separate report (Tetra Tech 1986a)]

RESPONSE TO COMMENTS ON DRAFT SEDIMENT QUALITY VALUES REPORTS

TASK 1 REPORT: EVALUATION OF PUGET SOUND DATA SETS FOR THE DEVELOPMENT OF SEDIMENT QUALITY VALUES

1. **It was unclear what criteria were used for review/selection of data. Clearly define the criteria for data selection and the rationale for using these criteria (e.g., why were only synoptic data sets considered appropriate for use?).**

Selection of site-specific chemical/biological data for the compiled Puget Sound database was carried out in three basic steps:

- Identify synoptic data sets (see Appendix C of the final report): Available data sets were reviewed for synoptic collection of data and only synoptically collected chemical and biological data were considered further. (Note: a synoptic data set is one for which toxicity data are collected on the same sediment homogenate used for sediment chemistry and benthic infaunal samples are collected at the identical station locations and at the same time, or at nearly the same time, as sediment chemistry samples.)

- Review quality assurance information (see Section 5.1.1 of the final report): Potential data sets were reviewed for documentation of quality assurance (QA) methods and summaries of QA review (such documentation was typically provided in the reports in which the data were presented).

- Review data comparability (see Section 5.1.1 and Appendix C of the final report): Available data were also subjected to a more detailed review that focused on issues related to data comparability.

Synoptically collected data were used to maximize the probability of detecting trends among biological and chemical variables. Differences between independent chemical and biological samples collected at a "station" could hamper attempts at establishing correlations between chemical concentrations and biological effects. For this reason, it was considered essential that chemical and biological data be collected from nearly identical subsamples from a given location. For example, acceptable toxicity measurements were only those made on a subsample of the same sediment homogenate used for chemical analysis. Because such homogenization and subsampling may compromise the integrity of benthic samples (e.g., through loss of motile benthic organisms), benthic and chemistry samples could not be taken from the same homogenized sample. Instead, acceptable benthic infaunal analyses were those conducted on replicate sediment samples from the same station sampled for chemical analyses. Acceptable replicate samples were those from studies

with clear documentation of multiple positioning techniques used for station location. Reliable positioning is important for correcting for vessel drift between collections of replicate grab samples or for returning to the same station within a few days to complete chemical and biological components of a survey.

A detailed QA review of all data that were considered for inclusion in the database was beyond the scope of this project. However, the chemical and biological methods were reviewed for every data set considered in an attempt to ensure comparability of chemical, bioassay, and benthic infaunal data from all studies. Items reviewed for chemical data were analytical techniques, detection limits, and the chemical scope of pollutants analyzed (e.g., polar and nonpolar semivolatile organic compounds, metals, volatile organic compounds). The latter item was considered important to document for sediment quality value approaches that are based on field data (e.g., the toxicity endpoint and AET approaches), because the availability of a wide diversity of chemical data enhances the probability that toxic agents (or chemicals that covary with toxic agents) can be identified in sediments with observed biological impacts. No data sets were excluded from the database as a result of the review of chemical data.

The QA review of benthic infaunal data focused on sampling methods, and in particular, on subsampling techniques (e.g., cores taken from grab samples), and on the level of replication. The QA review of toxicological data focused on sediment storage (fresh vs. frozen) and on the general acceptance of bioassay methods used.

[see Appendix C and Section 5.1.1 for discussion relevant to comment #1]

2. **Reviewers were concerned that this effort apparently focused on U.S. EPA priority pollutants and did not address other chlorinated compounds such as those present in Commencement Bay samples.**

Data for several compounds that are not U.S. EPA priority pollutants were used in the sediment quality values project. The most comprehensive data set made available for this effort was from the Commencement Bay Remedial Investigation. Some of these samples did, indeed, contain a large number of chlorinated compounds that were only identified qualitatively. It was not within the economic scope of the investigation to quantify the several hundred compounds present in each sample. However, attempts were made to quantify chlorinated compounds considered to be representative of the major components.

The complex mixture of unidentified chlorinated compounds observed in Hylebos Waterway by several investigators tended to follow the distribution of one or more of the following identified chemicals. Chlorinated compounds detected and quantified included tri-, tetra-, and pentachlorobutadienes, hexachlorobutadiene, six different chlorinated phenols, five different chlorinated benzenes (including hexachlorobenzene, a major chlorinated compound in Hylebos Waterway), hexachloroethane, three chlorinated ethers (low concentrations only), PCBs, chloroform, three chlorinated ethenes, and a pentachlorocyclopentane isomer (tentative identification). While

these compounds were not all of the chlorinated compounds quantitatively noted in the extracts, they were considered to be representative of the major components.

In addition, Commencement Bay data made available for the sediment quality values effort included blank-corrected analyses for the 13 U.S. EPA priority pollutant metals, 3 additional metals (including iron and manganese used as natural indicators), 78 extractable U.S. EPA priority pollutant compounds, 12 additional U.S. EPA Hazardous Substance List compounds, and selected tentatively identified compounds for which all samples were analyzed. Twenty two of the samples were also analyzed for the 31 U.S. EPA volatile priority pollutants and/or 2,3,7,8-tetrachlorodibenzodioxin. Over 550 tentatively identified compounds were identified in a preliminary survey of 17 stations, from which 14 compounds were selected for scanning and quantification in the remainder of the Commencement Bay project based on their use as potential source markers, routinely high concentrations, or occasional extreme concentration.

As noted in the final Commencement Bay report (Tetra Tech 1985a; p. 3.71), there were no chemicals detected [and quantified] in historical Commencement Bay studies that were not also found in the study conducted for the remedial investigation.

[comment #2 applies to data presented in Appendix A]

3. Several reviewers were concerned that data sets that did not include volatiles and polar compounds were excluded from analyses. If so, what was the rationale for their exclusion?

Data sets were not included or excluded based on whether these compounds had been analyzed for in a particular project. For the final recommended data sets listed in the Task 1 draft report, and in Appendix C of the final report, the absence of data for these compounds was simply documented. This documentation served only to identify a limitation in the use of the data set for generating or validating sediment quality values for those particular compounds (including volatiles for a portion of the Commencement Bay data set). In one case, a data set that did not include either volatiles or polar compounds, and also did not include bioassay or benthic infauna data, was still recommended for use with associated fish histopathological data (should sediment quality values for this type of data be developed).

[see Appendix C for discussion relevant to comment #3]

TASK 2 REPORT: EVALUATION OF STATISTICAL RELATIONSHIPS AMONG CHEMICAL AND BIOLOGICAL VARIABLES USING PATTERN RECOGNITION TECHNIQUES

4. It was not clear to some reviewers what the objective of the ARTHUR analysis was, whether the objective was realized, and how the results of the analyses influenced development/recommendation of specific sediment quality values.

The ARTHUR statistical routine was used to perform exploratory analyses on a data subset to be included in the sediment quality values database. ARTHUR is a system comprised of approximately 70 different procedures that can be used for data processing, display, and pattern recognition analysis. These pattern recognition techniques can be used to quickly extract important information from complex data sets (192 chemical and biological variables were considered in this project). The statistical techniques incorporated into the pattern recognition system can also reveal relationships among variables that might be obscured in a preliminary nonstatistical analysis. Therefore, the objective of the this pattern recognition task was to investigate underlying trends among variables that might be useful in later development of sediment quality values. This objective was realized. The analysis was successful in:

- Providing corroboration of trends among chemical variables in the Commencement Bay data set and an independent Puget Sound chemical data set that had been previously analyzed using ARTHUR (e.g., see discussion on p. 34 of the draft report concerning groups of significantly correlated chemicals)

- Confirming trends that had been previously identified in the data set using alternative data analysis techniques (e.g., confirming the need for subset analysis by geographic region to establish chemical-biological relationships, and providing supportive evidence of a critical assumption in most sediment quality value approaches that a threshold concentration exists, above which a chemical can be expected to elicit a negative biological response)

- Identifying new relationships among chemical and biological indicators (e.g., apparent "sensitive species" to certain chemical contaminants; these preliminary results were then subjected to evaluation during the application of sediment quality value approaches)

- Providing evidence that normalization of chemical concentrations to total organic carbon or percent fine-grained material produces results in factor analysis that are nearly identical to those based on dry-weight normalized data. Hence, these results demonstrated that nearly all of the interpretable trends with respect to the chemical-biological effects data from Commencement Bay/Carr Inlet can be derived using dry-weight concentrations.

This latter result, in consideration of accuracy results for different normalization techniques from the Task 4 application of sediment quality value approaches (see Section 7 of the final report), suggests that dry-weight normalized data may be the most useful for identifying stations with known biological impacts (see additional discussion in comment #19/23).

These and other results described on p. 37 of the draft report were used to guide development of sediment quality values.

[see Appendix D for discussion relevant to comment #4]

5. **Although outliers are often considered to carry as much or more information than data which fit a given model, it appears that in some cases data were ignored or eliminated to gain refinement or to investigate subset trends. What procedures were applied to data that appeared to be outliers and why? How might the practice employed have affected the conclusions drawn?**

Use of the term "outlier" in the discussion of the results may have caused some confusion. In the final report, the term "anomaly" has been substituted. There was no attempt or plan to summarily throw out or ignore any data in the data set. The conclusions drawn in the study were made in consideration of analyses conducted with and without anomalous values because the ARTHUR analysis was conducted as a stepwise series of statistical tests with intervening technical review. All data were analyzed initially. The term "outlier" was intended to indicate data values identified in the early stage of statistical analysis as exhibiting unusual characteristics relative to other data values. For the most part, these data were associated with samples collected adjacent to major pollution sources. Further analyses were then applied to examine the behavior of the remainder of the data set without these unusual values, so that the initial trends might be checked and other trends might be more apparent (e.g., less likely to be masked by samples collected close to particular sources). This staged analysis was important in enabling a more complete interpretation of the available data to be incorporated into the final recommendations and conclusions (e.g., see discussion on p. 12; 16; 30-32 of the draft report).

For statistical analysis, the concern regarding treatment of anomalies is higher and more critical in experimental designs based on random sampling (either spatially or temporally). The Commencement Bay study was spatially biased because there were more samples concentrated around potential sources to determine concentration gradients. Thus, the treatment of anomalies described above was considered appropriate.

[see Appendix D for discussion relevant to comment #5]

6. **Assumptions were made throughout the report that the demonstration of chemical effects requires decreases in animal abundance with increasing contamination concentrations. Several reviewers commented that some species may initially show increased abundance with increased contamination (i.e., if contamination eliminates more pollution-sensitive species thereby allowing more pollution-tolerant species to increase in abundance as a result of decreased competition). How much uncertainty might this consideration add to the conclusion drawn?**

There was no a priori assumption made by the statistician that the only change expected to occur was "population decrease = chemical effect".

Changes in the species composition of benthic populations were also considered, although they were not directly observed in the analyses that were run. Many studies have documented that the presence of toxic chemicals can result in decreased abundances of, or sublethal effects on, affected organisms (see Gray 1979; Boesch and Rosenberg 1981; Eagle 1981; Gray 1982; Wolfe et al. 1982). In cases reported in the literature where opportunistic or pollution-tolerant species have shown an initial increase in abundance after an exposure to toxic chemicals (e.g., Capitella capitata at the West Falmouth oil spill site), high abundances of those taxa have usually been attributed to their abilities to become established in a disturbed environment and in the absence of competition for resources.

To our knowledge, a significant enhancement of benthic organisms as a direct response to a toxic chemical has never been demonstrated, although such a response is theoretically possible. There is also no evidence that enhancement occurs for one species or taxonomic group in the presence of toxic chemicals unless a significant depression occurs in another species or group. Any station exhibiting a significant enhancement of one taxonomic group in association with a significant depression for another taxonomic group was always defined as "impacted". Hence, the conclusions drawn from the ARTHUR analysis are not expected to be affected by the phenomena described in the comment.

It should also be noted that as a further check on the ARTHUR results reported, scatterplots of data distributions were produced and evaluated to prevent blind acceptance of apparent positive or negative trends between two variables based on summary statistical results.

7. If half of the stations with significant amphipod bioassay responses showed no benthic depression in Commencement Bay, how can the report claim a high degree of concordance among bioassay results and benthic depressions? (see p. 28, para. 2-3 of draft report).

The amphipod bioassay results for Commencement Bay did show the least agreement in comparison with the benthic infaunal results. There was neither a significant depression in the abundance of a major taxonomic group nor a significant response in the oyster larvae bioassay at 7 of the 16 stations that exhibited a significant amphipod bioassay response. As discussed in the report, a possible (but not conclusive) explanation may be that the high percentages of fine-grained material at these stations contributes to the amphipod bioassay response (e.g., Ott 1985; Tetra Tech 1985a). However, a high concordance between combined bioassay results (i.e., oyster larvae and amphipod discussed in the report) and benthic infaunal results in general was indicated by the following items:

- "Impact" vs. "no impact" designations made by benthic and bioassay indicators agreed at 67-79 percent of the 48 stations in the Commencement Bay Remedial Investigation (and at 83-100 percent of the 6 stations in a separate dredging study conducted concurrently with identical methods in Blair Waterway and included in the ARTHUR analyses)

- A significant depression in the abundance of at least one major taxonomic group was observed in 6 of 7 cases (86 percent) that also exhibited significant toxicity in both the amphipod and oyster larvae bioassays

- Eighty-nine percent of the cases exhibiting a significant depression in the abundance of at least two major taxonomic groups occurred in a single similarity cluster (assigned on the basis of species-level benthic data). This similarity cluster also contained 75 percent of the cases exhibiting significant toxicity in both amphipod and oyster larvae bioassays

- All six of the cases exhibiting a significant depression in the abundance of at least three major taxonomic groups occurred in this same similarity cluster; 83 percent of these cases exhibited toxicity in oyster larvae bioassay, 50 percent exhibited toxicity in the amphipod bioassay.

The final report stresses that the high concordance between bioassay and benthic infauna results is best supported by the oyster larvae bioassay. Overall, a significant depression in the abundance of at least one major taxonomic group was observed in 79 percent of the cases (11 of 14) that exhibited significant toxicity in the oyster larvae bioassay. However, in sediments containing <70 percent fine-grained material, significant benthic depressions were also observed in 100 percent of the cases (6 of 6) of the sediments exhibiting a toxic response in the amphipod bioassay (no benthic data were available for a seventh station). As discussed in the response for comment #24/19, impacted or nonimpacted designations made by benthic and either of the bioassay indicators agreed at 67-79 percent of the 48 Commencement Bay stations evaluated. This level of agreement is significant ($P<0.05$, binomial test), and suggests that benthic comparisons based on higher taxa were as sensitive in the Commencement Bay study as the bioassays in identifying problem sediments, although different organisms may differ widely in their sensitivity to individual chemicals present as a complex mixture of chemicals in contaminated sediments.

[see Appendix D for discussion relevant to comment #7]

8. The report was confusing as to whether the interpretation of biological/chemical relationships was based on data that included habitats in which certain taxa are not commonly found.

The data set comprised the 64 numerically dominant species in the Commencement Bay and Carr Inlet samples. Sediments that exhibited low abundances of organisms and high concentrations of certain chemicals exhibited a range of grain size. Because the abundance of organisms depends on grain size and water depth, these samples could not all be compared with the same reference samples (a similar problem does not exist for dry-weight chemical measurements; see Tetra Tech 1985a). Major habitat features were taken into account before determining the significance of benthic effects in these samples relative to reference conditions by matching groups of

reference and study site stations of similar depth and grain size. Hence, the relationships observed between certain chemicals and benthic effects did not appear to be explained solely by habitat. These procedures were also used in the development of sediment quality values from benthic data in Task 4 of the project so that the effect of natural habitat factors would be minimized.

9. Several reviewers requested clarification regarding the statistical assumptions used in analysis (e.g., normality of variables distributions). Was data transformed to induce normality and if so, in what way?

It is true that the choice of data transformations and knowledge of the data distributions are critically important to multivariate hypothesis testing. However, multivariate hypothesis testing was not the purpose of the analyses conducted. The exploratory analyses conducted using ARTHUR required no statistical assumptions about variable distributions (i.e., pattern recognition analysis as applied is useful regardless of the underlying distribution of the data). Specifically, the factor analyses conducted as part of the ARTHUR analysis does not require variables to be normally distributed, especially where the approach is being applied for information compression (i.e., a Karhunen-Loeve transformation; see for example Watanabe 1973) as was done in this project.

In the pattern recognition analysis, the chemical data were first autoscaled (i.e., by a transformation similar to the z-score transformation). Autoscaling is a one-to-one mapping of the values of a variable from one reference system to another. The mapping preserves the shape of the variable distribution (regardless of the specific distribution), by simply zero-centering the distribution, and uniformly scaling the variance. This transformation makes some aspects of the analysis (e.g., data display) easier, but results in a data set that yields the same information as before the transformation.

[see Appendix D and comments #11 and #12 for discussion relevant to comment #9]

10. It is unclear as to why and how the data were "normalized" with respect to total organic carbon (TOC) content, and why TOC may not have been used as a factor in the analysis.

To normalize chemical data to total organic carbon (TOC) content, the dry-weight concentration in a sample is divided by the decimal percent TOC. As one means of interpreting environmental trends, concentrations are normalized in this manner because many chemicals tend to be concentrated in organically-enriched fractions of bulk sediments. Hence, normalization of dry-weight concentrations to TOC content can help to dampen variations caused by patchiness or other depositional factors that could mask trends among samples of dissimilar texture. Theoretical and some experimental evidence also suggests that the chemical-TOC association may affect the bioavailability of certain chemicals (see discussion for comment #22).

Total organic carbon (TOC) was used as an independent variable in the analysis of dry-weight normalized chemical data (see last paragraph on p. 7; Tables 2 and 3, and Figure 5 of the draft report). Statistical

analyses using TOC-normalized data did not include TOC as a variable because its contribution had already been analyzed in the dry-weight analyses.

TOC normalization of the data resulted in few additional trends that were not already evident based upon dry-weight normalized data. As noted in the draft report (p. 30), all data sets should continue to be analyzed with and without normalization to "master" variables such as TOC to confirm the results seen in this project, because the actual mechanism of chemical-organism interactions have not been firmly established in laboratory studies.

[see Appendix G and Section 8.8 for discussion relevant to comment #10]

11. When one autoscales data, one is essentially rendering all variables equally important (i.e., very rare taxa have equal importance to those that numerically dominate the community). To what extent could the influence of autoscaling the ARTHUR analyses have affected the interpretation of analyses results or led to misinterpretation of results?

The process indicated in the comment is incorrect. Autoscaling does not affect the shape of the variable distribution, and retains all of the variable-variable relationships represented by the original data (Green 1979). Therefore, this transformation has no effect on the interpretation of results. See additional discussion in comment #9.

[see Appendix D for discussion relevant to comment #11]

12. In autoscaling the data, the authors have used a standard z-score transformation. This transformation is only appropriate when the data are normally distributed. Most of the biological data used was in the form of abundance estimates, which are notoriously Poisson-distributed. What effect could the skewed distribution of many of the biological, and probably some of the chemical, data have on the results of the factor analysis?

The autoscaling technique is similar to a standard Z-score transformation because it generates a zero-centered distribution with uniformly scaled variance. This kind of transformation simplifies data processing and review (e.g., see SPSS 1975), but does not by itself affect the data distribution (see comment #11). When this tranformation is applied to data that are normally distributed, the resulting value (i.e., the Z-score) can then, and only then, also be interpreted according to certain statistical criteria (i.e., the distribution defines a characteristic probability density function of the normal distribution; see for example Crow et al. 1960). Such interpretations were not made and were not necessary for pattern recognition analyses. As noted in the response to comment #9, the exploratory analyses conducted for this project required no assumptions or corrections for data distributions in order to yield useful results.

[see Appendix D for discussion relevant to comment #12]

13. At least one reviewer was concerned that canonical correlation analysis is the only multivariate technique appropriate for comparing major

trends in several different data sets, and that factor analysis is a technique that is only appropriate for deriving trends in a single data set. What is the rationale for selecting factor analysis as an appropriate technique for use in this study? To what extent did the use of multiple databases collected at different locations and times and the use of the analytical procedure employed influence the results of the factor analysis and possibly limit the validity of the inferences drawn?

This comment suggests a highly restrictive approach that is similar to biological/social modeling problems. The pattern recognition approach used in this project views the chemical, toxicity, and biological variables as descriptors of the sediment stations. These data for an individual station were collected simultaneously during the Commencement Bay study (i.e., chemical and toxicity data were from the same sediment homogenate, and benthic data were from replicate grab samples collected at the same location and time as the chemistry/toxicity samples). While it certainly can be appropriate to analyze these data sets separately, it is also appropriate to analyze the combined data in an exploratory mode to determine if interpretable results can be derived. Canonical correlation is a subset of path modeling that was recommended in this report for potential future analyses.

[see Appendix D for discussion relevant to comment #13]

14. Are there "generally accepted" rules regarding the number of samples required for given numbers of variables? If so, were they followed in the factor analysis presented in the report? If not, why and how will this affect the results?

A general rule of having three to four times as many samples as variables is important before applying many analytical techniques (e.g., especially regression analysis). This rule is not applicable when factor analysis is being used as a Karhunen-Loeve transformation for information compression (i.e., to reduce the number of dimensions that represent the data set; see Watanabe 1973). The value of this application of factor analysis was in identifying key variables from a large list of variables that were most useful in describing trends within the data set.

TASK 3 REPORT: EVALUATION OF APPROACHES FOR THE DEVELOPMENT OF SEDIMENT QUALITY VALUES FOR PUGET SOUND

15. Different approaches or sediment quality values may be needed for application in different situations (i.e., sediment quality values for dredged material may need to be different than sediment quality values for problem identification. Discuss the different potential uses of sediment quality values and whether different sets of values could be appropriate for different uses.

Potential uses of sediment quality values were addressed in the Task 4 and 5a report (p. 48-55; Recommended Uses of Sediment Quality Values).

Different sets of values could be appropriate for different uses but likely will require project-specific interpretation. A comment given at a joint PSDDA/PSEP sediment criteria workshop on Jaunary 8, 1986 highlighted the need to provide sediment quality values for more than one approach to enable program managers some latitude in determining appropriate values for individual programs based on administrative and technical factors. In response to this comment, sediment quality values were summarized in the draft report for three approaches (and several indicators for the empirical approaches). Also percentile data for the distribution of chemical values in approximately 200 Puget Sound sediment samples were summarized for comparison with the range of sediment quality values (see Table 10 in Section 6.3 of the final report).

Decisions concerning the appropriate use of different sediment quality values (e.g., use specific values, a combination of values, or values modified by some "safety factor") are policy decisions of management agencies, and are outside of the scope of this report.

16. **What criteria/rationale was used for not including other methods (i.e., bioassay approach, reference area approach, etc.) in the discussion and evaluation of approaches to setting recommended sediment quality values? Concern was expressed that the bioassay approach (spiking sediments in the lab with known concentrations of contaminants and measuring toxicity) wasn't given fair consideration. The reviewers claim that while the bioassay approach has the benefit of the ability to allow identification and experimental control of physical, chemical, and biological variables, the AET approach cannot distinguish patterns of natural variability from those indicating pollution impacts. Given its merits, why was the bioassay approach eliminated from further consideration?**

The reasons for excluding the water quality and bioassay approaches from the discussion and evaluation section are noted in Section 3.0 of the final report (and p. 34 of the Task 3 draft report). The reference area approach was not excluded from the discussion and evaluation section (see Section 3.1.1 of the final report).

The treatment of the spiked bioassay approach requires further discussion. An important (albeit not clearly stated) criterion for detailed evaluation of approaches in the Task 3 report was that they be able to provide chemical-specific sediment quality values for testing at the present time. The spiked bioassay approach is a powerful and systematic way to establish dose-response relationships for benthic organisms, but it has thus far been used to generate data for very few chemicals and for a few different organisms. A considerable amount of time and effort would be required to generate sediment quality values for a wide range of chemicals (as can be addressed by the AET and SLC approaches using Puget Sound data) and for a wide range of organisms (to account for possible effects on more sensitive organisms). The spiked bioassay approach, unlike other approaches considered, can quantitatively assess additive, synergistic, and antagonistic effects, but this would be a formidable task considering all possible combinations of contaminants and their relative concentrations.

The possible role of spiked bioassays in establishing and verifying sediment quality values was discussed in the Task 4 and 5a report ("Prioritization of Laboratory Cause-Effect Studies" section, p. 53). Spiked bioassays are distinguished from (and treated separately from) field bioassays in the final report. This modification should alleviate confusion regarding the treatment of bioassays in this project.

Finally, the AET approach attempts to distinguish patterns of natural variability from those indicating pollution impacts by statistically comparing sample responses to reference benthic and bioassay samples that have similar grain size distributions and are collected at similar water depths. This statistical comparison reduces the potential for habitat-related factors to confound the results or mask apparent relationships (see response to comment #8).

17. Why is the Screening Level Concentration (toxicity endpoint) approach limited to nonpolar organic contaminants?

The developers of the screening level concentration (toxicity endpoint) approach have suggested that it be used for screening nonpolar organic compounds. The restriction to this class of compounds is related to organic carbon normalization theory, which assumes that interstitial water is the primary biological uptake route for sedimentary contaminants and that sedimentary organic matter is the predominant factor controlling compound distribution in sediment-interstitial water systems (e.g., Battelle 1986). Because of this assumption, organic carbon normalization is not appropriate for metals and polar organic compounds (see pp. 13-14 of Task 3 draft).

In the present evaluation of SLC values, dry-weight normalization was tested along with organic carbon normalization and demonstrated consistently better "efficiency" in correctly identifying only stations with biological impacts for the 3 chemicals evaluated. Similar results were observed in the AET accuracy evaluation based on a larger number of chemicals. Dry-weight normalization enables one to establish SSLC (species screening level concentrations) for a wide range of compounds, including metals and polar organic compounds. Thus, if dry-weight normalization is considered appropriate (e.g., if the mass loading of a contaminant in sediment is considered to be a more important influence on toxicity than the attenuating effects of organic carbon), then the SLC approach need not be limited to nonpolar organic compounds. The accuracy of SLC for additional chemicals must be evaluated before a final recommendation can be made on this issue.

[see Section 2.6.3 and comment #10 for discussion relevant to comment #17]

18. A reviewer commented that an incorrect statement was made that samples in which organisms were not identified were or should be included in calculations of screening level concentrations (toxicity endpoint values). According to a representative of Battelle, the firm developing the method, the stations should not be included. Were such samples included in the Tetra Tech analyses, and if so, do the sediment quality values change if these stations are removed?

Samples in which organisms of a given species were not present were not included in the calculations of screening level concentrations (see Section 5.4.2 of the final report). The term "presence/absence" in the Task 3 draft referred to the initial data selection process used in the approach (i.e., chemical data at stations would be included if a given species of interest were present or disregarded if the species were absent). The term "presence/absence" was used to highlight the contrast between the toxicity endpoint approach, which uses benthic infaunal data but does not rely on absolute abundance, and other approaches that rely on assessments based on absolute infaunal abundances (e.g., AET).

19. Several readers expressed concern that the report's claim that the AET approach does not require normalization to organic carbon content goes against all that has been learned from experimental sediment bioassays. What hypothesis can be forwarded to explain the weaker showing of organic carbon normalization relative to dry weight? Could this be an artifact of the particular database used?

Simply stated, organic carbon normalization theory assumes that interstitial water in the primary source of nonpolar organic contaminants to biota, and that, under equilibrium conditions, the distribution of nonpolar contaminants between sedimentary organic matter and water (K_{OC}) is constant (and predictable). Organic carbon tends to act as a sink for nonpolar contaminants (i.e., organic carbon content and sediment toxicity should be inversely related). Hence, as sediment organic carbon content increases, toxicity "threshold" values expressed per gram of bulk sediment should decrease. If contaminant concentrations are normalized to organic carbon content, threshold values should be constant for that contaminant in all sediments.

Dry-weight normalization simply assumes that mass loading of a contaminant in sediment is a predominant factor influencing toxicity to benthic organisms (although organic carbon interactions may be a secondary factor). The (empirical) AET approach does not favor one of these mechanistic explanations over the other, but can operate whether one, a combination of the two, or alternative assumptions are appropriate. The results from this approach suggest that further research is required to confirm the underlying mechanism, but that dry-weight normalization is the most accurate of the three normalizations tested.

For contaminated sediments in the environment, organic carbon normalization could be less predictive than dry-weight normalization if sediment/interstitial water systems are not at equilibrium (a key assumption of the organic carbon

normalization model), if all sediment organic matter does not have uniform affinity for hydrophobic pollutants, or if interstitial water is not the predominant route of contaminant uptake. For example, it is quite plausible that the equilibrium assumption could be violated in the environment by kinetic aspects of sorption/desorption processes. Equilibrium requires fairly rapid transfer of a contaminant between various phases in a system. Studies of sorption/desorption kinetics have demonstrated that equilibration of a nonpolar organic compound between sediment and aqueous phases could take days to months, or longer (Karickhoff and Morris 1985a,b). In part, slow rates of equilibration could be caused by entrainment or trapping of contaminants within refractory (stable) organic matter (e.g., humic substances or fecal pellets) (Freeman and Cheung 1981; Karickhoff and Morris 1985a). Prahl and Carpenter (1983) observed that PAH were disproportionately concentrated in certain fractions of refractory sedimentary organic matter (e.g., charcoal fragments and vascular plant detritus, such as lignin). This disproportionality indicates that PAH may not have been at equilibrium in the sediment phase or, alternatively, that different kinds of organic matter may have different affinities for PAH. This latter possibility is supported by studies of dissolved and solid humic materials and their associations with hydrophobic organic pollutants (Carter and Suffet 1985; Diachenko 1981).

If sediment-water equilibrium is not often attained in the environment, or various types of sediment organic matter have differing affinities for hydrophobic pollutants, or interstitial water is not the primary route of exposure for organisms, then the relationship between sediment organic carbon content and bioavailable portions of nonpolar organic compound loadings in sediment may not be consistent in environmental samples. Yet a consistent, quantitative relationship is the basis for organic carbon normalization theory.

To our knowledge, only two studies in the open literature address the relationship between sediment bioassay results and sediment organic carbon content [Adams et al. (1984) and Swartz et al. (1986)]. The study by Adams et al. (1984) argues for organic carbon normalization of nonpolar organic compounds. Adams et al. (1984) conducted a series of bioassays in which freshwater midges (Chironomus tentans) were exposed to water, sediments (with various levels of organic carbon content), and food contaminated with Kepone (a relatively nonpolar ketone insecticide). No-effect concentrations based on total sediment Kepone concentrations increased in proportion to total organic carbon content of sediments, whereas no-effect levels based on interstitial water Kepone concentrations were fairly constant regardless of sediment concentration. The authors suggested that no-effect concentrations should be based on sediment organic carbon content, not on bulk sediment weight.

One possible reason for the success of organic carbon normalization in the Adams et al. (1984) study is that sediments were spiked in the laboratory with a carrier solvent containing Kepone. It is plausible that such spiking procedures will promote homogeneous distribution of target compounds in sediments and will preclude some factors that could impede equilibrium

in the environment (e.g., incorporation into fecal pellets and other refractory organic matter).

Swartz et al. (1986), in a study involving amphipod bioassays, found that slight enhancement of total volatile solids content of sediment (resulting from addition of small amounts of sewage sludge or fine particles enriched in organic matter) reduced the toxicity of cadmium spiked into sediment. These results do not provide a strong argument for organic carbon normalization because the experiment did not distinguish between the effects of organic matter "binding" of cadmium vs. the effects of fine particle "binding" of cadmium. For example, it is possible that addition of fine iron oxide particles (not enriched with organic matter) could have reduced toxicity as well. In general, the applicability of organic carbon normalization to metals and polar, ionizable organic compounds is limited because of the variety of environmental factors other than TOC (e.g., pH, redox potential, presence of Fe/Mn oxides and hydroxides) that could strongly influence the sedimentary associations of these chemicals (see Task 3 draft, pp. 13-14).

It is unlikely that the database used for evaluation of AET influenced the success of organic carbon versus dry weight AET (see response to comment #10). The amphipod bioassay and benthic infaunal stations were compiled from numerous studies and study areas. The oyster larvae and Microtox bioassay samples were taken from the Commencement Bay study only. However, evidence of the better predictive success of dry-weight AET relative to organic carbon AET does not consist solely of oyster larvae and Microtox bioassay AET (although they support the trends observed for amphipod bioassay and benthic AET).

[This discussion for comment #19 is also presented in Section 8.6]

20. Concern was expressed that none of the approaches considered may adequately address interactive effects. How would chemical interactiveness affect uncertainty associated with sediment quality values developed using different approaches? Discussion should include factors that could overestimate or underestimate possible adverse effects and the general likelihood/frequency/probability of these effects occurring.

The frequency that interactive effects occur in environmental settings cannot be confidently determined using existing data. Additive, synergistic (i.e., supra-additive), and antagonistic effects of contaminants are not well understood but can be expected to have variable effects on the uncertainty of sediment quality values generated by different approaches. If interactive effects occurred on a major scale and the effects were not accounted for by one of the approaches, the ability of the approach to correctly identify problem sediments should be reduced. For all approaches based on field data, collection of representative samples over a wide concentration range and sediment type should help in addressing these concerns.

The only systematic approach to identifying and quantifying interactive effects is the spiked laboratory bioassay (see paragraph 2, p. 23, Task 3 draft). This approach allows for control of contaminant mixtures, type of

test organism, and various other test conditions. It should be noted that while such tests are feasible, they would require considerable effort (i.e., years or decades) to be applicable to the numerous possible contaminant mixtures in the environment. Interim measures are needed to address the expressed need by agencies for application of sediment quality values as a regulatory or investigative tool.

The equilibrium partitioning sediment-water approach and the related Water Quality Criteria approach are based on toxicological data for chemicals tested individually. Thus, the approaches are not designed to address interactive effects of contaminants (a safety factor is built into the water quality criteria used in the approaches, but this factor is not based upon knowledge of interactive effects of contaminants). To the extent that interactive effects occur in the environment and to the extent that they alter the absolute threshold concentrations of individual contaminants, these effects will increase the uncertainty of equilibrium partitioning values.

The uncertainty of the screening level concentration (SLC) approach is potentially increased by the existence of interactive effects; the increase in uncertainty will be less pronounced when large data sets collected from diverse areas are used to generate sediment quality values with this approach. Additivity and synergism can produce a comparatively low SSLC (species screening level concentration) for a given chemical by causing species absence at concentrations that would not eliminate a species in the absence of these interactive effects. This would reduce the pool of "non-impacted" stations used to generate an SSLC. If a large database is used such that chemicals occur over a wide range of concentrations at stations where additivity and synergism are not operative, then the SSLC will be not be biased by these effects. Antagonism could potentially increase sediment quality values set by the SLC approach by allowing a species to survive in a sample at a concentration (of a given chemical) that would normally eliminate the species. With a large database and the 90-percent safety factor in SSLC values, such cases would probably have little effect.

Similar to the SLC approach, the uncertainty of the AET approach is increased by the possibility of interactive effects; the increase in uncertainty will be less pronounced when large data sets collected from diverse areas are used to generate AET. Additivity and synergism can produce a comparatively low AET for a given chemical by causing impacts at concentrations that would not cause impacts in the absence of these interactive effects. This would effectively reduce the pool of nonimpacted stations used to generate AET. This effect is reduced if a large database is used such that chemicals occur over a wide range of concentrations at stations where additivity and synergism are not operative. Anatagonism will produce comparatively high AET if the AET is established at a station where antagonism occurs. A large database could not rectify this elevation of AET because the station at which antagonism occurred would tend to be the non-impacted station with the highest concentration.

[see Sections 2.6.4, 2.7.4 for discussion relevant to comment #20]

21. Concern was expressed that the Apparent Effects Threshold (AET) approach is limited to the number of species for which testing information is available. National water quality criteria are based on eight families of organisms, while sediment quality values developed using the AET approach may not necessarily account for effects of some contaminants on other aquatic animals. Can AET really tell us anything other than how one species responds to a given test? What confidence do we have that sediment quality values based on AET developed using one species will be appropriate (and protective) for use in making decisions that could affect other species?

AET were generated for four biological indicators in this project [i.e., amphipod bioassays, oyster larvae bioassays, Microtox bioassays, and benthic infaunal abundances (at the major taxon rather than species level)]. Other AET would have been generated if synoptic data had been available because the AET approach is not inherently limited to any specific indicators. The AET approach itself is simply a procedure for classifying and ranking synoptic biological and chemical data and could be applied to biological effects data (e.g., bioassays) for as many diverse species as were used to develop U.S. EPA water quality criteria. Also, AET derived from benthic infaunal abundance data take the responses of a variety of benthic species into account. Benthic AET at the major taxon level (as presented in this report) do not provide the "resolution" that a species-level benthic AET could provide. Development of species-level AET was beyond the scope of this work, but is recommended in the final report for future work.

Contaminant concentrations below the AET developed for the four indicators used in this project could potentially be harmful to untested aquatic species (and in some cases to the species tested). The same could be true for U.S. EPA water quality criteria, as toxicological data for all aquatic species have not been incorporated into these criteria. Because the species (and life stages) of bioassay organisms used in the present project are thought to be relatively sensitive, there is reason to believe that sediment quality values based on AET from these bioassays are representative of a wide range of organisms. Greater confidence would result from application of the potential effects threshold (i.e., the concentration of a contaminant below which no statistically significant effects were observed in any sample) as a sediment quality value, but this concentration is often below reference conditions and is not recommended (see Section 2.7.2 discussion of the AET approach). Considering the limited availability of field toxicological data for various species, the best approaches to ensuring protection of a wide range of species with AET are as follows:

- Develop AET based on species-specific benthic infaunal abundance data (and as an environmentally protective measure, use the most apparently sensitive of these could be used for decision-making)
- Rely on bioassay data for species known to be sensitive to contaminants.

Development of AET for a wide range of species should help to better define the sensitivity of individual species. This analysis could ultimately enable AET to be used in a modified SLC approach, in which sediment quality values are set to protect some percentage of species as indicated by the lowest AET for a range of species. In such an approach, the AET would not by themselves be considered "protective".

22. **Concern was expressed that selection of study sites can greatly affect AET because thresholds may depend on each specific mix of contaminants. What evidence/confidence do we have that AET generated using one database can adequately and consistently identify known or suspected impacted stations from another database?**

An additional accuracy analysis has been included in the final report to address two issues: the applicability of AET generated from one study area to another, and the potential bias that could result from using the same data for establishing and then evaluating AET. AET (dry-weight normalized) generated from the 56 Commencement Bay Remedial Investigation samples were evaluated for accuracy with the remaining data in the compiled Puget Sound database (134 samples, excluding Commencement Bay samples). The analysis was carried out as before:

- The chemical database (from the 134 non-Commencement Bay samples) was subdivided into groups of stations tested for the same biological indicators (either amphipod bioassay or benthic infaunal analysis; Microtox and oyster larvae bioassays were not performed for these samples)

- The stations of each group were classified as "impacted" (and "severely impacted") or "non-impacted" (i.e., without significant effects relative to reference conditions)

- Using only Commencement Bay data, AET were generated for all appropriate chemicals and were used to predict problem stations from independent chemical concentration data for the non-Commencement Bay stations (the predicted problem stations were non-Commencement Bay stations with one or more chemicals exceeding the Commencement Bay AET, i.e., those stations predicted to have biological effects)

- Measurements of accuracy ("sensitivity" and "efficiency," as defined in the final report) were calculated for each subgroup of stations as:

$$\text{sensitivity (impacted)} = \frac{\text{predicted problem stations with impacts}}{\text{all stations with impacts}}$$

$$\text{sensitivity (severely impacted)} = \frac{\text{predicted problem stations with severe impacts}}{\text{all stations with severe impacts}}$$

$$\text{efficiency} = \frac{\text{predicted problem stations with impacts}}{\text{all potential problem stations}}$$

The results are tabulated below:

	Sensitivity ("Impacted")	Sensitivity ("Severely Impacted")	Efficiency
Amphipod	72 (18/25)	100 (8/8)	37 (18/49)
Benthic	90 (9/10)	100 (4/4)	31 (9/29)

Thus, AET based on the chemical mixtures represented by a range of stations in one study area (Commencement Bay) appear to be fairly successful at predicting biological impacts in diverse areas of Puget Sound. Furthermore, these accuracy results support (and even slightly exceed) results obtained by generating and evaluating AET with the same database (see Table 10 in the Task 4 and 5a draft). However, the efficiency of Commencement Bay AET for both biological indicators (31 and 37 percent) is a more reliable estimate of true performance than the 100-percent efficiency reported in Table 10 (as footnoted in Table 10, the 100-percent values were a result of the way in which AET are generated). Efficiency may be better if two larger, independent databases are used in such analyses.

23. Concern was expressed that the AET approach optimistically dismisses the possibility of effects being caused by non-quantified (covarying) chemicals. Several reviewers were of the opinion that a range of concentrations must be tested empirically in the lab on a compound-by-compound basis before criteria can be established. Is it possible that the AET approach really only has utility in establishing for later lab testing possible ranges of contamination that induce biological effects, and not for setting recommended sediment quality values?

Unmeasured, covarying chemicals would not be expected to substantially decrease the ability of AET to predict biologically impacted stations (excluding interactive effects; see response #8). If an unmeasured chemical (or group of chemicals) varies consistently in the environment with a measured chemical (e.g., concentrations of certain alkylated PAH often correlate well with those of their unalkylated priority pollutant counterparts), then the AET established for the measured contaminant will (indirectly) apply to, or result in management of, the unmeasured contaminant. In such cases, a measured contaminant would be used as an "indicator" for an unmeasured contaminant (or group of unmeasured contaminants). Because all potential contaminants cannot be measured routinely, management schemes must rely to some extent on "indicator" chemicals.

If an unmeasured chemical (or group of chemicals) covaries with a measured chemical in some cases but not in others (e.g., if a certain industrial process releases an unusual mixture of contaminants), the effect should be discerned if a sufficiently large data set is used to establish AET.

Use of a large data set comprising samples from a variety of areas with wide-ranging chemical concentrations would decrease the likelihood that an unrealistically low AET would be set. Because AET are set by the highest concentrations in samples without observed biological impacts, AET will not be affected by less contaminated samples in which unmeasured contaminants cause impacts.

If an unmeasured toxic chemical does not co-occur with any measured chemicals, it is likely that the AET approach will not predict impacts at stations where the chemical is inducing toxic effects. This was one of the sources of uncertainty addressed by the accuracy (sensitivity) evaluation. In that evaluation, AET proved fairly successful at predicting impacted stations (e.g., 54-94 percent accuracy in predicting impacted stations depending on the biological indicator, and 92-100 percent accurate in predicting "severely" impacted stations based on the same indicators). Note that, like the AET approach, the spiked bioassay approach cannot be expected to predict impacts in environmental samples in which unmeasured toxic chemicals do not co-occur with measured chemicals. For this reason, chemical-specific sediment quality values are recommended as one tool that can be used with other tools (e.g., direct biological testing) for the management of sediments.

Nonetheless, the use of laboratory (e.g., spiked bioassay) studies for confirming or "fine-tuning" AET values is desirable and will better define the uncertainty of AET. This recommendation is discussed in the "Prioritization of Laboratory Cause-Effect Studies" section in the Task 4 and 5a draft report.

24. What was the rationale for using the total number of individuals in a class or phylum as opposed to finer levels of classification as the measure of community disturbance?

Higher level taxa were used to set AET values for two major reasons. First, because the AET approach is based on pair-wise statistical comparisons with reference conditions, the benthic taxa must either be abundant enough or have a low enough variance to allow major depressions to be discriminated statistically. If these criteria are not met, it may be very difficult to discriminate a depression and, in some cases, complete absence of a taxon may not be indicated statistically as a significant impact. Therefore, use of taxa that are either rare or highly variable may not result in a useful indicator of environmental impact.

In developing the AET approach for the Commencement Bay Superfund Study, it was found that almost all species, except the four or five most abundant ones, were either too rare or too variable to be used as sensitive indicators of impacts. By contrast, higher level taxa such as total taxa, Polychaeta, Mollusca, and Crustacea were found to be variable, but abundant enough to statistically discriminate major depressions in numbers of individuals. Echinodermata, a fifth higher taxon, was found to be both rare and variable, so that depressions rarely could be discriminated. It therefore was decided that total taxa, Polychaeta, Mollusca, and Crustacea were the best available taxa for pair-wise statistical comparisons with reference conditions. An alternate strategy might have been to use the four to five

most abundant species, but it was decided that an index based on a greater number of species considered as an aggregate might be more representative. It should be noted, however, that the four to five most abundant species dominated most of the higher taxa, and therefore exerted considerable influence as to whether or not a depression was discriminated.

The second major reason for using higher taxa was that comparisons with bioassay results (i.e., amphipod mortality and oyster larvae abnormality) as part of the Commencement Bay Superfund Study showed that impacted or non-impacted designations made by benthic and bioassay indicators agreed at 67-79 percent of the 48 stations evaluated. This level of agreement is significant ($P<0.05$, binomial test), and suggests that benthic comparisons based on higher taxa were as sensitive in the Commencement Bay study as the bioassays in identifying problem sediments, although different organisms may differ widely in their sensitivity to individual chemicals present as a complex mixture of chemicals in contaminated sediments. This independent corroboration of the use of higher level taxa contributed to its acceptance for setting benthic AET in Commencement Bay.

TASK 4 AND 5a REPORT: APPLICATION OF SELECTED SEDIMENT QUALITY VALUE APPROACHES TO PUGET SOUND DATA

25. Concern was expressed that reliance on acute responses may generate sediment quality values that are not protective of human health or of chronic impacts on aquatic organisms, such as demersal fishes. In order to be protective, one reviewer was of the opinion that sediment quality values should be generated based on sediment concentrations necessary to maintain contaminant levels in edible seafoods below proposed tissue criterion.

Reliance on acute responses (i.e., acute toxicity bioassays) may indeed generate sediment quality values that are not protective of human health or against chronic health impacts to aquatic organisms (e.g., demersal fishes). Some of the sediment quality values generated in this project incorporated chronic effects data [e.g., equilibrium partitioning values based on chronic water quality criteria, or AET based on benthic infaunal abundances (the latter analyses would incorporate chronic toxicity, for example, if samples were not taken during or shortly after a large contaminant influx)]. However, these criteria do not directly address human health or health of benthic biota and demersal fishes.

If human health (with regard to seafood consumption) or health of demersal fishes are primary management objectives, both the equilibrium partitioning or AET approaches could be oriented toward those objectives. The sediment-biota equilibrium partitioning approach (discussed in Task 3) would be applicable for nonpolar organic compounds in shellfish if appropriate tissue criteria and bioaccumulation factors were available, and if various assumptions were not violated (see Task 3). The approach would involve greater uncertainty for bioaccumulation in demersal fishes than for shellfish because of the more complex equilibrium relationships and

bioaccumulation factors that apply to fish-sediment systems relative to systems consisting of relatively immobile benthic infauna and sediments.

The AET approach could also be used to focus on human health and chronic effects in fish. AET could be based on shellfish bioaccumulation ("impacted" stations would be defined by shellfish tissue concentrations above an established human dietary criterion), fish bioaccumulation ("impacted" areas or groups of stations within a trawl area would be defined by fish tissue concentrations above an established human dietary criterion), or fish histopathology ("impacted" areas or groups of stations within a trawl area would be defined by the frequency of certain histopathological conditions in fish). The mobility of fish relative to shellfish or other benthic organisms would preclude synoptic collection of chemical and biological data, thus increasing the uncertainty of AET developed for mobile species. A fish trawl (unlike a benthic infaunal sample or a sediment sample used for bioassays) cannot be related to a single sediment chemistry sample. Instead, chemical concentrations for multiple sediment samples in a trawl area must be averaged, which will incorporate environmental variability of contamination into AET.

AET could be developed based on results of chronic laboratory tests. Any sediment quality value could be modified (e.g., using a safety factor) in an attempt to protect against chronic effects. Such sediment quality values could be used in conjunction with direct bioassessments in a two-part decision-making approach.

26. Concern was expressed regarding an apparent apples/oranges comparison of sediment quality values generated by different approaches. Reviewers were concerned that numbers were not directly comparable because sediment quality values were generated by different approaches using different databases and types of calculations and normalizations. Are these concerns warranted? If the comparisons included in the report are appropriate, discuss why.

Because the generation of sediment quality values by different approaches (inherently involving different kinds of data and calculations) was one of the major objectives of this project, it is assumed that this comment refers to comparisons made in the accuracy section. The accuracy measurements in Table 10 (based on comparison of potential problem stations and truly impacted stations) were calculated identically for the equilibrium partitioning and AET approaches. Direct comparisons of the predictive success (accuracy) of both approaches were considered appropriate as a simulation of their relative performance when applied in Puget Sound. The evaluation process consisted of the following steps (pp. 25-26):

- "The chemical database was subdivided into groups of stations that were tested for the same biological effects indicators" (this was necessary because all stations were not tested for all indicators)
- "The stations of each group were classified as 'impacted' or 'nonimpacted' based on the appropriate statistical criteria..."

- "For each approach, sediment quality values for all applicable chemicals... were compared with the corresponding chemical data for each station."

- Sediment quality values normalized to a given variable (e.g., to organic carbon content, as for equilibrium partitioning values) were compared to chemical data from the Puget Sound database that were normalized to the same variable. "When one or more chemicals exceeded the appropriate sediment quality values at a given station, that station was considered to be indicated as a potential problem station." (In essence, potential problem stations are predicted to have biological impacts.)

Accuracy of the toxicity endpoint approach was evaluated less thoroughly than for the equilibrium partitioning and AET approaches for reasons explained in the first paragraph of the draft section entitled "Preliminary Evaluation of the Toxicity Endpoint Approach": "The evaluation of the toxicity endpoint approach could not be conducted as thoroughly as that of the equilibrium partitioning and AET approaches because PNEL [SLC] values were not developed for all appropriate chemicals and did not incorporate data from a large number of stations." These accuracy results were presented in a different section than "Evaluation of Equilibrium Partitioning and AET Sediment Quality Values" to preclude direct comparisons of the more thorough (equilibrium partitioning and AET) and less thorough (toxicity endpoint) accuracy evaluations.

It was considered unreasonable to calculate the accuracy of toxicity endpoint values in predicting problem stations because the values were generated for only three chemicals (or chemical groups): naphthalene, high molecular weight PAH (HPAH), and mercury. These three chemicals (or chemical groups) could not be expected to account for all biological impacts in Puget Sound that could be associated with other chemicals. Therefore, the following measure of efficiency was used:

$$\text{efficiency} = \frac{\text{predicted problem stations (based on chemical x) with impacts}}{\text{all predicted problem stations (based on chemical x)}}$$

where:

chemical x = naphthalene, HPAH, or mercury.

This measure of efficiency is described in Section 7.1 and Figure 13 of the final report.

27. Comment on the appropriateness of quantitatively comparing the sediment quality values (Table 3 in the draft report) based on different normalization factors if assumptions regarding these factors are required for comparison (i.e., assuming 1-percent organic carbon content).

Equilibrium partitioning values were presented on a dry-weight basis in Table 3 (Table 6 of the final report) because this is the form of data

typically reported in environmental studies and is familiar to most readers. The equilibrium partitioning dry weight values were not used in the accuracy evaluation of the equilibrium partitioning approach; however, they were considered useful for giving readers an idea of the magnitude of the values relative to other sediment quality values (e.g., Fourmile Rock Interim Sediment Criteria), which are reported as dry-weight concentrations.

As footnoted in Table 3, a 1-percent organic carbon content is assumed for equilibrium partitioning values, but "to adjust the value for a different organic carbon content, multiply by the percent organic carbon." Thus, the dry-weight equilibrium partitioning values can be easily adjusted for any organic carbon content. Because the mean and median organic carbon content of the compiled Puget Sound data set are 2.0 and 1.3 respectively, it might be most representative to increase equilibrium partitioning values by these factors.

Use of any of the organic carbon values in the Puget Sound database would not invalidate the general observations made about relative magnitudes of AET and equilibrium partitioning values in the Task 4 and 5a draft. These observations are further supported by Table 4, which is an unqualified comparison of equilibrium partitioning and AET values based on organic carbon normalization.

28. Criteria should be presented to show how the 66 chemicals were selected. Were the data screened, and if so, how? Basis for selection of normalization parameters should also be presented.

Because AET can be established for any chemical, there was no selection scheme based on chemical type used to pare down the chemicals in the compiled Puget Sound database. However, as noted in the draft Task 4 and 5a report (p. 9), "the frequency of occurrence and range of detected concentrations of chemicals limit their appropriateness for establishing AET. Chemicals seldom detected in the Puget Sound data set (e.g., hexachloroethane, heptachlor) were not used because they did not cover a wide range of concentrations." Beryllium and chromium are initially discussed and then dismissed in the final report (Section 5.3.2) because their range of concentrations do not exceed those found in nine different Puget Sound reference areas [as summarized in Tetra Tech (1985a)].

The normalization variables were discussed in the draft Task 3 report (Ancillary Sediment Variables; see Appendix G of the final report) and are commonly used by environmental scientists. Organic carbon normalization also enabled a direct comparison of AET and equilibrium partitioning sediment quality values (Table 4 of the draft Task 4a and 5 report; Table 7 of the final report).

29. To what extent do AET address other compounds not identified or measured in sediment samples?

See discussion for comment #23. Aside from expanding the chemical database to include unusual compounds that do not co-occur with measured chemicals, direct biological testing is the only means to provide additional

information beyond what can be provided by sediment quality values based on AET or other available approaches.

30. Discuss the appropriateness (or lack thereof) of comparing AET generated by using liquid (i.e., oyster larvae, Microtox) and non-liquid tests (i.e., benthic community, amphipod bioassay).

A broadly based toxicity index that is based on multiple indicators and encompasses a wider range of sediment toxicity than would be evident from a single testing procedure is desirable for the development of sediment quality values. The Apparent Effects Threshold (AET) is an example of such an index because it identifies, for each data set and kind of bioassay, the sediment concentration above which significant toxic responses were always observed. Thus, the range of AET values for the different bioassay (and benthic infaunal) indicators provides an index of the range of biological variability (e.g., differences in organism sensitivity and route of exposure) normally encountered in multiple species toxicity testing.

Comparability of the Microtox, oyster embryo, and amphipod bioassys used to characterize toxicity of Commencement Bay sediments is evaluated by Williams et al. (1986). Correlation analyses indicated a high level of agreement among the three bioassays (Kendall's coefficient of concordance = 0.64, $P<0.001$). Pair-wise comparisons using Pearson's correlation also indicated a high level of agreement:

- Oyster embryo vs. amphipod ($R = 0.86$, $P<0.001$)
- Oyster embryo vs. Microtox ($R = 0.62$, $P<0.001$)
- Amphipod vs. Microtox ($R = 0.48$, $P<0.001$).

The magnitude of individual correlations suggests considerable variability among the three bioassays, which may be partially attributable to differences in exposure routes inherent in the experimental design of each bioassay. An additional source of variability is interspecific differences in sensitivity to the kinds of contaminants in the various sediment samples.

Differences among the bioassays in duration of exposure (i.e., 15 min vs. 48 h vs. 10 day), and exposure medium (i.e., saline extract vs. sediment slurry vs. whole sediments) may affect comparability of results. Most importantly, differences in sediment manipulation and exposure medium may affect the relative proportions of polar, nonpolar, and sediment-bound contaminants in each experimental system. It is not surprising that the Microtox and amphipod bioassay results showed the lowest level of agreement, although the agreement was still significant. These two bioassays are at opposite ends of the aqueous-whole sediment exposure spectrum. Nevertheless, the three bioassays showed a significant ($P<0.05$) level of concordance that indicates a robustness to withstand much of the variability in bioassay sensitivity, sediment heterogeneity, and experimental exposure bias. Sediment bioassays results showed significant agreement (67-79 percent; $P<0.05$) with the presence or absence of benthic infaunal depressions in Commencement Bay (Tetra Tech 1985a).

31. What do we know about the relative sensitivity of AET species compared to screening level concentration species? Discuss the extent to which species sensitivity is or is not addressed by the AET approach.

By the design of the screening level concentration (SLC) approach, the most sensitive species of those evaluated are species that establish the critical concentrations of chemical contaminants. The AET approach, by contrast, can establish values for any single species, regardless of its sensitivity. As currently applied, the AET approach applied to benthic infauna data is based on higher level taxa. As such, current benthic AET values probably are high estimates (i.e., not protective of all sensitive species) of critical concentrations of chemical contaminants because less sensitive species may be included in the analyses. However, to generate lower (i.e., presumably more protective) estimates, the AET approach can be applied to sensitive species alone. (see additional discussion for comment #25).

32. Provide scientific reasoning for selection of 80-percent depression as indication of sensitivity for use in the Screening Level Concentration (toxicity endpoint) approach. Is this truly a sensitive indicator?

Use of an 80-percent depression is as arbitrary as using P=0.05 as the critical level of statistical significance. There is no scientific basis for either. Instead, each should be set by a consensus of knowledgeable parties. A critical level of 80 percent was used as a first-cut test level for the screening level concentration (SLC) approach because 33 of 37 stations exhibiting statistically significant ($P<0.05$) depressions in higher-level benthic taxa in the Commencement Bay Superfund Study also exhibited a >80-percent depression in abundance relative to reference conditions. If the SLC approach is to be evaluated further in the future, it is highly desirable to determine how different (higher and lower) critical depression levels influence the results. Only then can a more informed decision be made as to what critical depression level provides results that are "adequately" sensitive. Based on the limited comparison made in this project (see Section 6.2.1 of the final report), SLC values based on absence/presence exceeded those based on an 80 percent depression criterion by 12-56 percent. Hence, SLC based on the 80 percent depression criterion are potentially more sensitive indicators of contamination.

33. Circularity - Concern was expressed that use of the same data to define and then evaluate the accuracy of AET and toxicity endpoint-generated sediment quality values will bias the results.

The reason for using the entire Puget Sound database to generate AET (Tables 3-5 of the Task 4 and 5a draft report; Tables 6-8 of the final report) was that the reliability of AET is expected to be greater when larger databases are used. This in turn necessitated that accuracy of the AET was assessed with the same database from which AET were generated.

This issue is also addressed in response #22. As discussed in that response, the accuracy of AET established from one database (Commencement Bay/Carr Inlet) and evaluated with an independent database supported (and

even slightly exceeded) the results presented in Table 10 of the draft report (Table 13 of the final report, in which AET were evaluated with the same data that were used to generate the AET). The results of the two accuracy evaluations (tabulated below) indicate that the original accuracy analysis was not biased. However, the efficiency of AET can only be realistically evaluated with independent databases.

AET Tested	Sensitivity ("Impacted")	Sensitivity ("Severely Impacted")	Efficiency
Amphipod (DW)[a]	54	92	100[b]
Benthic (DW)[a]	82	92	100[b]
Amphipod (DW)[c]	72	100	37
Benthic (DW)[c]	90	100	31

[a] From Table 13 of the final report (Table 10 of the draft Task 4 report), AET generated and evaluated with the same data set.

[b] As noted in Table 13, efficiency is 100 percent by definition.

[c] AET generated with data from one data set (Commencement Bay, 56 samples) and evaluated with data from several independent studies (Puget Sound data in the compiled database, excluding Commencement Bay; 134 samples).

There is no reason to suspect circularity in the preliminary accuracy evaluation of toxicity endpoint values because these values were generated with a subset of the Commencement Bay database but were evaluated with the entire compiled Puget Sound database.

34. There is more to uncertainty than technical variance. The weight of evidence supporting certain numbers or the number of assumptions/steps removed from the observation directly affects the "confidence" in the use of the numbers. How does the report deal with this aspect of uncertainty in evaluating the sediment quality values developed from the different approaches?

Uncertainty was evaluated in this project with estimations of accuracy (success at predicting biological impacts) and precision (an approximation of "technical variance").

The accuracy evaluation was considered the best way to evaluate the overall ability of each approach to predict biological impacts. The accuracy analysis could not quantify various elements of uncertainty in each approach, but instead provided an estimate of how the combined uncertainties of an approach would affect its ultimate predictive success. This estimate was considered particularly useful because numerous factors that affected the uncertainty of the AET and equilibrium partitioning approaches were not quantifiable, including factors that may have resulted in partially offsetting effects.

The precision analysis was an attempt to quantify the expected variability of sediment quality values given the particular constraints in the design and use of an approach. The equilibrium partitioning approach, which is theoretically based, requires a number of estimations and assumptions (e.g., estimation of K_{OC} values from K_{OW} values, assumption of thermodynamic equilibrium) to derive a sediment quality value. Quantifiable and unquantifiable factors relating to the uncertainty of equilibrium partitioning values were discussed in "Estimated Minimum Confidence Limits for Equilibrium Partitioning Values." The precision of equilibrium partitioning values could only be estimated for those chemicals with established chronic water quality criteria; the uncertainty associated with estimated water quality criteria was not possible to quantify.

For AET values, the effect of "weight of evidence" was not addressed directly in the Task 4 and 5a draft, but was incorporated in the approach used in "Estimated Confidence Intervals for AET Values" (see Section 7.2.2 of the final report). Unquestionably, there is less uncertainty for an AET based on many observations than for an AET based on few observations. (That is the reason that larger databases with wide-ranging chemical concentrations are required for generating reliable AET.) Confidence limits for AET were defined as the concentration range from two or three (non-impacted) stations below the AET to one station above the AET (based on statistical classification arguments). The number of stations used to establish an AET (i.e., weight of evidence) would be expected to have a marked effect on these confidence limits, because small data sets would tend to have less continuous distributions of chemical concentrations than large data sets. That is, small data sets would tend to have larger concentration gaps between stations (and correspondingly wider confidence limits) than larger data sets. Discussion of this concept has been reinforced in the final report (Section 7.2.2).

35. Concern was expressed that Microtox data were derived from stored sediments. Is this correct? If so, how might storage have affected the resulting AET? If storage is not a problem, couldn't other data sets which were excluded have been included in the database?

Sediments used for Microtox bioassays in the Commencement Bay Remedial Investigation were stored for less than 3 wk at 4° C in test tubes that were flushed with nitrogen and then sealed. Under these inert atmospheric conditions, the storage time is not expected to have a significant effect on the results. With respect to chemical changes, U.S. EPA Contract Laboratory Program guidelines allow 2 wk storage of refrigerated sediments without any controls on the overlying atmosphere, and 40 day storage of refrigerated sediment extracts. Up to a 4 wk storage period (under nitrogen) has been recommended by the Evaluation Procedures Work Group of the Puget Sound Dredged Disposal Analyis program (PSDDA) for Microtox bioassays; a 2 wk period is recommended by the Puget Sound Estuary Program (PSEP; Tetra Tech 1986d). Synoptic bioassay data were excluded from the Puget Sound database for this project if they were frozen because of concern by some investigators that freezing may alter the toxicity of sediments (Task 1 draft). However, samples that were stored at 4° C (with or without nitrogen) were not excluded.

36. Does the recommendation that detection limits be set at 1/2 AET represent any method difficulties given current protocols? Which AET did the recommendation refer to (amphipod, oyster larvae, microtox, or benthic community)?

The Puget Sound Estuary Program draft protocol for organic compounds recommends detection limits of 1-50 ug/kg (dry weight) for analysis of semi-volatile organic compounds in sediments by gas chromatography/mass spectroscopy (GC/MS) (Tetra Tech 1986b). These detection limits were agreed upon at a workshop of regional experts. Recommended detection limits for gas chromatography/ electron capture detection (GC/ECD) analysis are 0.1-5 ug/kg for pesticides and 5-20 ug/kg for PCBs. Comparison of these values with AET in Table 3 of the final report reveals that detection limits of 1/2 AET levels (e.g., for the lowest AET, usually Microtox) are reasonable. The most serious problems would probably be presented by p,p'-DDT, 2-methylphenol, 2,4-dimethylphenol, N-nitrosodiphenylamine, and benzyl alcohol. Detection limits of 1/2 lowest AET for chlorinated benzenes (1,2-dichloro- and 1,2,4-trichlorobenzene) could also be difficult to attain, but are technically feasible with existing procedures.

Required detection limits of 1/2 AET for volatile organic compounds and metals/metalloids should not present analytical problems.

37. What scientific reasoning can be provided for using the "Criterion Maximum Concentration" value as the final chronic value instead of the "Criterion Continuous Concentration (CCC)?" Wouldn't the longest term CCC be more appropriate for setting a final chronic value?

The procedure that was used in estimating water quality criteria for the equilibrium partitioning application was discussed on pages 7-8 (and noted in Table 1, footnote 2) of the draft Task 4 and 5a report (see Section 5.2.3 and Table 4, footnote 2 of the final report). Criterion Maximum Concentrations were not used as final chronic values instead of Criterion Continuous Concentrations), criteria were selected based on preference and availability. Chronic criteria (now referred to as Criterion Continuous Concentrations by U.S. EPA) were preferred and used when available. In the absence of U.S. EPA determined chronic criteria, chronic criteria were estimated from the lowest concentration observed to induce chronic toxicity in saltwater organisms [based on data in U.S. EPA (1980)]. Acute criteria (Criterion Maximum Concentrations) or estimations of acute criteria were used only if chronic criteria or chronic data were unavailable. Final Chronic Values could not be calculated from acute criteria (or from estimated acute criteria) because Final Acute:Chronic Ratios were unavailable.

Although estimates of water quality criteria add unquantifiable uncertainty to equilibrium partitioning sediment quality values, they were necessary to evaluate the method with the widest possible range of nonpolar organic pollutants. If the equilibrium partitioning application was limited to chemicals with established chronic water quality criteria, only p,p'-DDT, PCBs, chlordane, dieldrin, and heptachlor could have been used. These chemicals alone could not be expected to be useful for predicting biologically

impacted stations in Puget Sound. The predictive success (expressed as "efficiency") of equilibrium partitioning sediment quality values for individual chemicals with established chronic water quality criteria was addressed in the Task 4 and 5a draft (p. 43) and in more detail in the final report (see Section 7.1.1).

38. Discuss/identify evidence of analyses on the underlying distribution of the data, and the basis for the transformations used throughout the report. Parametric statistics implicitly require a normal distribution to be valid. According to several reviewers, if this distribution analysis was not performed prior to the additional statistical analysis, the results could be invalid.

The primary test used to evaluate bioassay and benthic impacts was the t-test, a test that is mathematically equivalent to the single-classification ANOVA based on two groups (Sokal and Rohlf 1981). Although one assumption of ANOVA is that the data are distributed normally, the consequences of non-normality are not too serious and only very skewed distributions have a marked effect on test results (Snedecor and Cochran 1967; Zar 1974; Sokal and Rohlf 1981).

For the bioassay results, there was no reason to expect distributions to be markedly skewed, as the five replicate values for each test were generated from subsamples of a homogeneous composite under carefully controlled conditions. These test conditions suggest that the values of all five replicates should be very similar and that the random error encountered among replicates should be relatively small. Transformation of the bioassay results therefore were not considered necessary.

For the benthic results, there was considerable reason to believe that the abundance data were strongly skewed, as that pattern is typical of benthic infaunal assemblages (Gray 1981). Accordingly, abundances of infauna were $\log_{10}$-transformed before statistical analyses were conducted (see Section 5.3.4).

39. Will the utility of the equilibrium partitioning and/or Screening Concentration Level (toxicity endpoint) approaches increase with a growing Puget Sound database?

As a general rule, approaches based on field data (e.g., the toxicity endpoint approach) are expected to generate more reliable sediment quality values when based on large data sets (e.g., data sets with wide-ranging chemical concentrations including different contamination sources, and including data for a variety of organisms). Hence, addition of more species-specific data (with synoptic chemistry data) to the Puget Sound database will enable the generation of more reliable SLC values than were generated in the limited application in this project (see Section 8.8 of the final report).

Sediment quality values for the equilibrium partitioning approach are not based on field data. Hence, expansion of the Puget Sound database would not affect current values. However, new field data can be used to further evaluate the ability of the approach to predict biological impacts. The

establishment of more chronic saltwater water quality criteria by U.S. EPA may enhance the "precision" of equilibrium partitioning sediment quality values for chemicals for which only estimated criteria could be determined. Thus, an increase in the U.S. EPA toxicological database should increase the utility of the equilibrium partitioning approach for nonpolar organic compounds.

END

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