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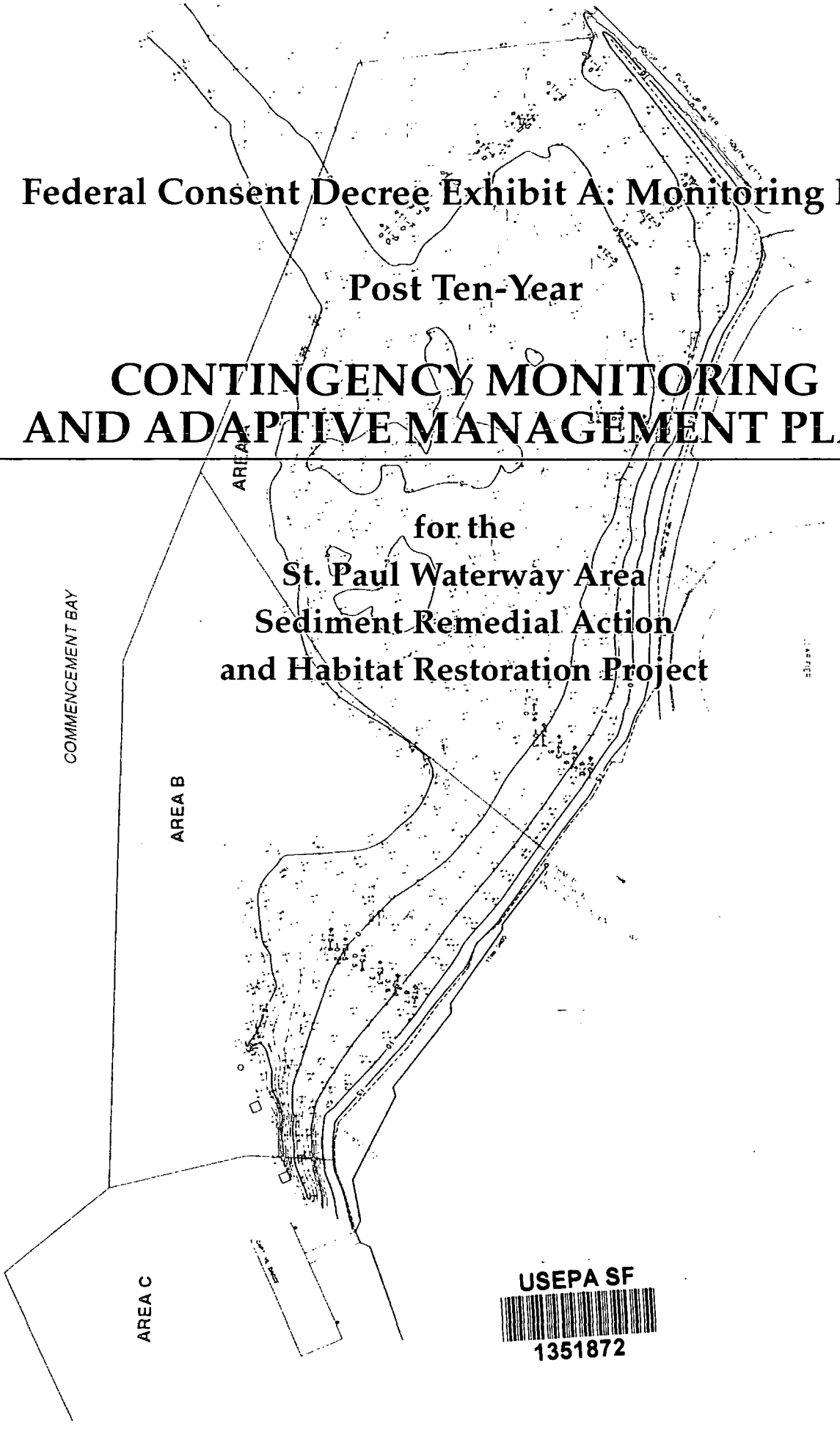
Federal Consent Decree Exhibit A: Monitoring Plan

Post Ten-Year

CONTINGENCY MONITORING AND ADAPTIVE MANAGEMENT PLAN

for the
St. Paul Waterway Area
Sediment Remedial Action
and Habitat Restoration Project



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for the St. Paul Waterway Area Sediment Remedial Action and Habitat Restoration Project

Prepared for Simpson Tacoma Kraft Company
and Champion International Corporation by
Parametrix, Inc.

October 1999

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Table 1. Contingency screening monitoring activities and reporting summary.

Activity	Sample Method	Frequency	Report Due Dates Draft	Report Due Dates Final
Intertidal Transects	Ground surveying during extreme low tide	Biannually[a], May-June 2000, 2002; and 2004; emergency monitoring (see footnote a) thereafter.	July 15[b]	Oct 15[b]
Visual Inspection	Ground inspections, photos, and field notes	If the intertidal transects survey indicates the cap thickness in a particular location may not meet the Consent Decree performance standard of three feet, a visual inspection will be conducted in the area exhibiting the loss of material to further assess cap thickness and integrity.[a]	Per contingency planning procedures	
Bathymetry	Ground surveying during extreme low tide	May-June 2004 (full survey-all portions of Areas A and B). In addition, if the intertidal transects survey indicates the cap thickness in a particular location may not meet the Consent Decree performance standard of three feet, a bathymetry survey will be conducted in the area exhibiting the loss of material to further assess cap thickness and integrity.	July 15	Oct 15
Surface Chemistry Subsurface Chemistry	Sample surface sediment Core sample subsurface sediment	If the intertidal transects survey indicates the cap thickness in a particular location may not meet the Consent Decree performance standard of three feet, surface and subsurface chemistry sampling may be conducted in the area exhibiting the loss of material to further assess cap thickness and integrity. EPA will make this determination upon preliminary notification by and consultation with Simpson.	Per contingency planning procedures	

[a] Should any major storm (with winds from the north or southeast at 30 miles-per-hour or greater, which persists for more than four hours) or earthquake of significance occur, an intertidal transects survey coupled with a visual inspection will be conducted as soon as possible after the event.

[b] EPA will be notified of proposed surveying date and locations 30 days prior to surveying. Data reporting will include a table and figure showing cumulative (1988 through most recent) transects survey data. If an intertidal transects survey indicates loss of cap material equal or greater than one foot (12 inches) in one year or 1.67 feet (20 inches) over two years at one station, or indicates the Consent Decree cap thickness performance standard of three feet might not be met at a station (or stations) then Simpson will provide written and verbal notification to EPA within seven days of receipt of the transects survey data and will not wait until submitting a data report.

1. INTRODUCTION

The St. Paul Waterway Area Remedial Action and Habitat Restoration Project (Project) was constructed from 1987-88 by Simpson Tacoma Kraft Company (Simpson) and Champion International Corporation (Champion), the current and previous owners of the Tacoma Kraft Mill, respectively. Both the U.S. Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) issued completion certificates for the remedial work and have delisted the St. Paul Waterway area (Project site) from the federal Superfund National Priorities List (NPL) and the Washington State Hazardous Sites list.

The Project is designed to provide: (1) permanent isolation from the environment of chemical contamination found in marine sediments, and (2) restoration of intertidal and shallow water habitat (state and federal Consent Decrees 1987 and 1991; Ecology 1990; Weiner 1991). Because of the restoration component, these consent decrees also include resolution of natural resource damage claims. The federal Consent Decree (paragraph 46) specifies the applicable performance standards, which are:

- The physical performance standard requires a minimum of three feet of clean sediment be maintained over Areas A and B.

- The biological performance standard consists of not finding an adverse effect for benthic infaunal abundance (i.e., mean total abundance of any of the following major taxa—crustaceans, polychaetes, and molluscs—being statistically different and less than 50 percent of the reference sample mean total abundance; amphipod mean mortality being greater than 25 percent [absolute] and statistically different from reference sample mean mortality; and larval mean abnormality being greater than 20 percent [absolute] and statistically different from reference sample mean abnormality). An interim chemical standard was used until 1994, when the biological performance standard (biological indicators approach) went into effect (Parametrix 1994a).

Project approvals under the federal and state Consent Decrees included a long-term monitoring, reporting, and contingency plan to ensure the effectiveness of the remedy. This Exhibit A to the federal Consent Decree specifies the current monitoring plan for the Project. As explained below, this plan updates and replaces the prior monitoring plan. A key component is the contingency planning process, which includes early notice, contingency planning, and contingency response procedures. After the original plan was adopted, the term "adaptive management" has come into use regarding the type of process established by the contingency planning procedures. This term has therefore been included in the title of the current plan.

The original monitoring plan specified: (1) a detailed intensive physical, chemical, and biological monitoring program for ten years following Project construction; and (2) that requirements after this period were to be determined based on the first ten years' results. Page 4 stated:

> The five- and ten-year reviews will provide a basis for evaluating the monitoring program and making any adjustments that may be necessary. The early warning process described in the contingency planning section provides a basis for revising the monitoring program, as

necessary, based on monitoring results. Should refinement of this plan be necessary, the Consent Decree provides for appropriate revisions in the monitoring plan by mutual agreement, without formally amending the decree itself.

EPA has independently reviewed and approved each annual monitoring report for the past ten years (Parametrix 1990 through 1999), including the five- and ten-year reviews in the 1993 and 1998 annual reports, after circulation of the draft report to consulted agencies and interested members of the public and an annual agency and public low tide site inspection.

The five- and ten-year reviews of the long-term physical, chemical, and biological monitoring have confirmed that the remedy is protective of human health and the environment, that performance standards are being met, and that a biological community similar to a typical healthy back-bay mudflat in Puget Sound now inhabits the Project site (Parametrix 1994b, 1999). These conclusions are also reflected in documents by other agencies (e.g., Commencement Bay Natural Resource Damage Assessment: Restoration Plan and Final Programmatic Environmental Impact Statement, USFWS et al. 1997, e.g., p. 2-10).

The ten-year review, as approved by EPA (EPA 1999), found the following with respect to overall project performance and the physical, chemical, and biological results (Parametrix 1999):

- *Overall.* "In general, 1998 monitoring results indicate that the Project and new habitat are both functioning as planned. The Project provides habitat for diverse biological communities of benthic and epibenthic organism, as well as algae. Shorebirds and salmon use the site for feeding and rearing, and tide pools observed at low tide are abundant with invertebrates. Productive shoreline habitat now exists at the Project site where essentially no productive habitat existed prior to Project construction." (p 1-5)

- *Physical.* "Comparison of elevation changes with core thickness (taken for chemical monitoring) has shown that the cap continues to meet performance standards and continues to range from approximately five to 20 feet in Areas A and B." (p 1-10)

- *Chemical.* "Overall, chemical monitoring over the past ten years indicates: (1) that no substantial levels of chemical from off-site sources are being deposited on the cap; (2) chemicals in the underlying sediments are remaining in-place; and (3) the Project cap is functioning as designed." (p. 1-12)

- *Biological.* "Abundance and diversity observed at the Project site have generally been similar to those found at the various background stations sampled and indicate a community similar to a typical healthy back-bay mudflat in Puget Sound." (p. 1-15)

The findings of both the five-year and ten-year reviews were similar to each other, indicating sustained Project performance (see Appendix A to this plan).

Because the long-term confirmational monitoring results indicate that Project goals and monitoring objectives have consistently been met, it is appropriate to focus any ongoing monitoring on the implementation of the contingency planning procedures and adaptive management, rather than on routine data collection. The full title of the monitoring plan has been updated to Post Ten-Year

Contingency Monitoring and Adaptive Management Plan for the St. Paul Waterway Area Sediment Remedial Action and Habitat Restoration Project (referenced to in this document simply as the Plan or Contingency Monitoring Plan). In addition, the monitoring plan has been updated to include refinements in monitoring methods and protocols over the past ten years approved by EPA.

This updated Plan:

- specifies a monitoring schedule for screening whether the contingency planning process needs to be initiated, and updates the screening levels;
- updates the monitoring methods and protocols for physical, chemical, and biological monitoring based on approved revisions by EPA in these protocols during ten years of confirmational monitoring; and
- provides for a final bathymetric survey for all of Areas A and B prior to moving to emergency monitoring, which is expected to occur after the next five-year review in 2004.

Simpson will continue the monitoring and adaptive management of the Project site as necessary through the updated contingency planning procedures. These activities are summarized on the above "Table 1 - Contingency screening monitoring activities and reporting summary."

This Plan contains the following sections: project background, monitoring objectives, contingency monitoring activities, contingency planning procedures, monitoring methods and quality assurance/quality control (QA/QC), and reporting.

2. PROJECT BACKGROUND

2.1 INTRODUCTION

This section provides background information on the sediment remediation and habitat restoration at the St. Paul Waterway area adjacent to the Tacoma Kraft Mill.

The Project, which is the first cleanup at the Commencement Bay Nearshore Tideflats Superfund Site, was initiated in 1987 by Simpson and Champion. Project approvals under federal and state consent decrees included a monitoring plan to ensure the effectiveness of the remedy and to provide an annual report on the monitoring results.

The remedial work was completed and approved by Ecology in September 1988. In January 1991, EPA approved the Commencement Bay Nearshore Tideflats Superfund Completion Report for St. Paul Waterway Sediment Remedial Action (Weiner 1991). EPA had previously approved the Commencement Bay Nearshore Tideflats Source Control Completion Report for the St. Paul Waterway (Ecology 1990). Ecology is responsible for administering source control monitoring requirements for the Tacoma Kraft Mill.

Monitoring at the St. Paul Waterway area occurred before, during, and after Project construction. Monitoring before construction helped not only with Project design but also with establishing baseline conditions for evaluating future monitoring results. Monitoring during and immediately after construction ensured pollution control and verified that the remedial work conformed to the remedial design (this monitoring is sometimes referred to as "protection" and "performance" monitoring).

Confirmational monitoring occurred at the Project for a ten-year period (1988 through 1998) following Project construction. The Project is now in the contingency screening monitoring phase, which is similar to an institutional control or post-confirmational monitoring O & M.

This Plan was revised in conjunction with the December 1991 approval of the federal Consent Decree and an amendment to the 1987 state Consent Decree (both decrees then contained the same monitoring program). As described below, the monitoring protocols have been revised to incorporate biological indicators and to take into consideration previous monitoring results. These revisions were anticipated by the consent decrees, and the Plan was updated in 1993 to reflect these changes (i.e., the modifications were filed with the court in August 1993).

The fifth year of monitoring was completed in 1993 and a five-year data review was conducted (Parametrix 1994b). The five-year review confirmed that the Project was attaining performance standards and was providing a healthy environment for marine organisms (Parametrix 1994b). The Commencement Bay Restoration Plan and Programmatic EIS likewise noted the habitat value of the Project and states that this restoration project will be a significant component of the Trustee's bay-wide restoration plan (USFWS et al. 1997).

Because habitat restoration and re-establishment of healthy biological communities is a fundamental long-term goal of the Project, the Consent Decree and monitoring plan anticipated that biological

monitoring of benthic communities (marine life living in the sediments) would assume a primary role in the evaluation of Project performance.

As specified in the monitoring plan, a biological indicators approach was developed jointly by Simpson, Champion, and EPA in 1994, in consultation with the public and consulted agencies (Parametrix 1994a and Appendix B to this Plan). This approach has been used to evaluate the natural habitat at the Project and evaluate biological health and productivity.

Biological indicators are intended to provide early evidence of changes in biological communities at the Project habitat. If statistically significant changes are present, a review process ("second tier analysis") is initiated to evaluate the causes and ecological importance of these changes. The biological indicators approach has been incorporated into the contingency procedures, which provide early notice of potential problems so that a contingency plan and monitoring can be considered and implemented as necessary. If the second tier analysis shows ecologically important differences are due to human causes (a biological screening level), an early notice is sent to EPA, as is the case for the other contingency screening indicators.

Consistent with the adaptive management approach to the Project, which includes adjusting the monitoring protocols as appropriate based on actual results, the chemical monitoring program was modified in 1994 (Parametrix 1993b) and 1998 (Parametrix 1998b) following review by the consulted agencies and EPA approval. The modifications to monitoring were made because several years of detailed chemical data indicated that the Project was functioning as designed and because the biological indicators approach had been put in place. EPA determined that these modifications were consistent with the objectives of the monitoring plan to ensure an appropriate chemical monitoring component to characterize Project performance.

Also consistent with the adaptive management approach to the Project, the biological monitoring program was modified in 1996 following review by the consulted agencies and EPA approval (USEPA 1996a). The primary modification to biological monitoring was the discontinuation of annual epibenthic monitoring. Review of seven years of epibenthic data indicated that the Project was providing extensive epibenthic habitat as planned and that this habitat was not changing substantially from year to year. Further more, epibenthic monitoring is not a part of the biological indicators approach because epibenthic populations tend to be highly variable from year to year, depending on weather and other natural variations. Thus, epibenthic monitoring was neither necessary nor appropriate for determining the proper functioning of the Project habitat through the approved biological indicators approach.

The adaptive management approach and updated Plan uses the terms contingency screening process and contingency screening level (rather than early warning) to reflect the current phase of the Project.

2.2 THE PROJECT

After analyzing many technologies, as well as their effectiveness in—and impact on—marine waters, capping of the contaminated sediments "in place" in the shallow water offshore of the Tacoma Kraft Mill was selected as the environmentally preferred alternative (Weiner 1991). The 16-acre area was capped with clean sediment in July and August of 1988. The cleanup action was

integrated with natural resource restoration to produce new intertidal and shallow-water habitat in Commencement Bay, an area that had lost about 90% of such habitat over the previous 100 years. More than six acres of new intertidal habitat were reconstructed over the portion of the cap along the shoreline. Clean, shallow-water habitat was provided over the remaining 11 acres (Figure 1).

To promote biological recovery and enhance the ability of the bay habitat to re-establish itself, sediment from the nearby Puyallup River was used for the cap material (Parametrix 1987). The capping sediments consisted of black sand collected near the mouth of the Puyallup River. Intensive testing of the Puyallup River borrow area showed the sediments to be among the cleanest in Puget Sound. Natural forces normally deposit Puyallup River sediments in the Commencement Bay shallows. These sands were suitable for both physically isolating contaminated sediments and providing a desirable substrate for new marine habitat.

To understand the monitoring plan and analyze the results, it is helpful to understand the pre-Project conditions and the variation in cap thickness. The cap ranges from approximately five to 20 feet thick, reflecting differences in the sediment contamination over the 17-acre area. Area A, closest to the former mill outfall, had the most chemical contamination (Figure 1). Levels of concern decrease as the distance from the former outfall increases. Area B contained a mixture of chemical and organic woody material, while Area C was largely composed of woodchips on natural sediments.

Most of Area A was to receive a cap of at least four feet, plus four to eight feet for habitat enhancement, with the most contaminated area to be filled above the high tide line. Much of Area A actually received 12 feet or more of sediment, while some areas received up to 20 feet. Area B, which was to have at least four feet (as a design criteria), received a cap about 12 feet thick. Area C, which did not contain chemical contamination requiring isolation of sediment from marine life, was to receive a cap of two feet to provide a new substrate; it received up to four feet of clean material. In addition, varied topography was constructed in Areas A and B to allow pools and ridges for diverse habitat, with the expectation that natural forces would continue to redistribute the sediments and shape the areas (Weiner 1991).

As part of the Project's adaptive management approach, clean material was placed at Transect 5 in the summer of 1995 as a preventive maintenance measure, after consultation with agencies and the public, and EPA approval (Parametrix 1995b). Prior to and following Project construction, natural accretion from deposition of Puyallup River sediments had been and continues to occur on the north side of the Project site. Over time, the generally clockwise movement of the currents where the river enters the bay is expected to cause accretion along the entire beach. Although the depth of the cap in Area B has always met performance standards, previous years' monitoring and early warning results showed that some of the middle stations on Transect 5 were two to four feet lower because of sediment redistribution in the early years of the Project (the 1994-95 monitoring results indicated small changes, actually showing an increase at two of these stations). There was consensus on the desirability of nourishing the beach with additional material along some of the middle stations on Transect 5, to add an additional margin of safety against erosion and allow more time for natural accretion to reach the south end of the beach. Irregularly shaped gravelly material was selected both for habitat and armoring value.

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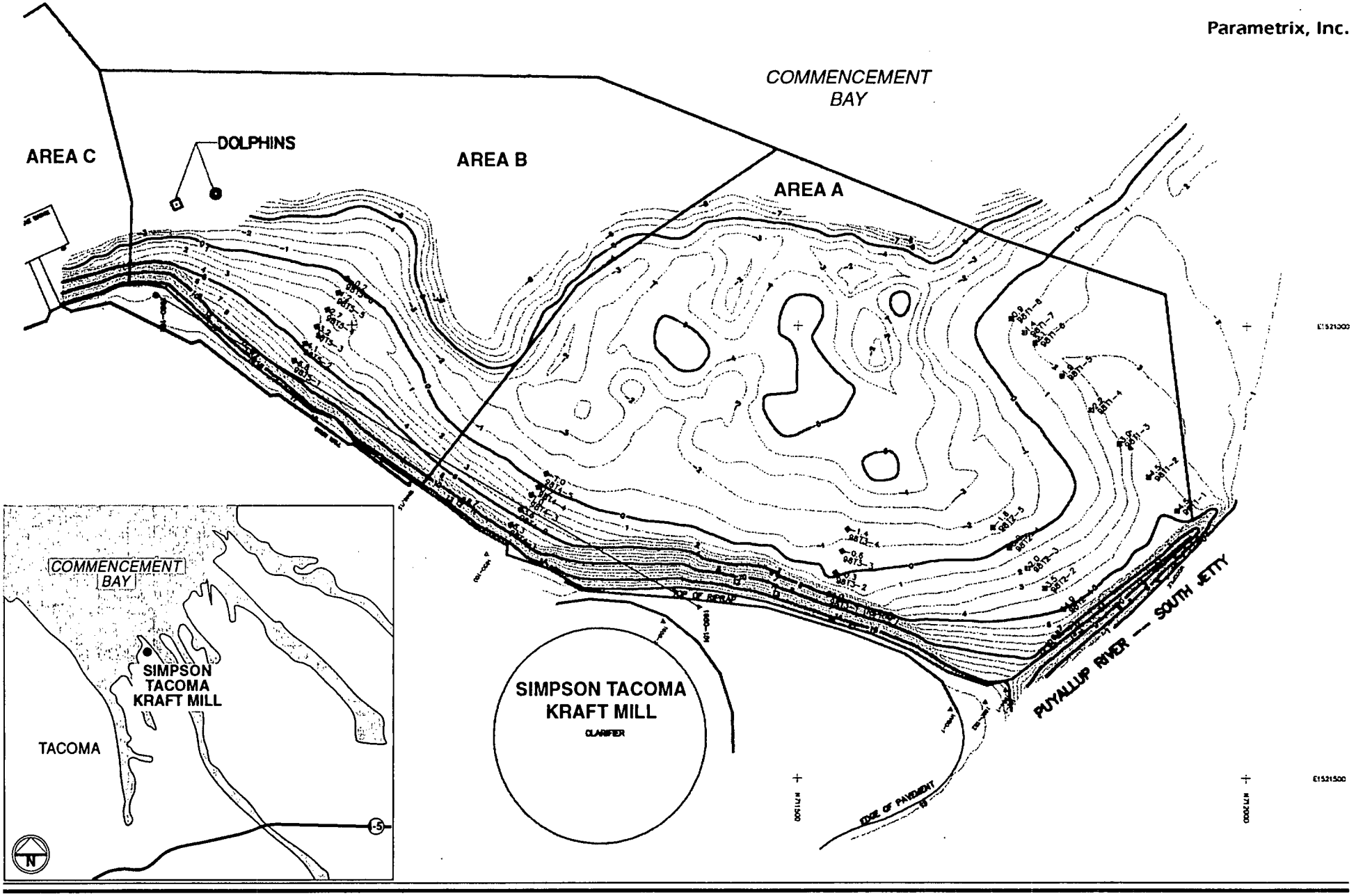

Simpson Tacoma Kraft Co./St. Paul Waterway/55-1650-57(01) 3/99

SCALE IN FEET

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Figure 1. Project Location and Areas

The maintenance construction involved placement of gravel material with some larger cobble to provide protection from wave action in the area of Transect 5. The total area of gravel placed was approximately 0.75 acres in a 300- by 100-ft area between three feet mean lower low water (MLLW) and –3 feet MLLW. The maintenance construction took place July 12 through July 16, 1995. Physical monitoring of this area in 1998 indicated that the material was in place, with only minor redistribution since 1995.

2.3 REGULATORY BACKGROUND

Simpson, the Washington Department of Natural Resources (WDNR), and Champion entered into a state court Consent Decree with Ecology in 1987 to undertake sediment remedial action and habitat restoration. The remedial actions were conducted in 1988 in the problem area at the mouth of St. Paul Waterway prior to completion of the Commencement Bay Nearshore/Tideflats Superfund study. The record of decision (ROD) for the Commencement Bay Nearshore/Tideflats Superfund site was signed September 30, 1989 by the EPA, and it confirmed the capping/restoration methodology, source control through the NPDES program, and comprehensive long-term monitoring as the selected remedy in the St. Paul Waterway Area.

The ROD designated Ecology as the lead agency for source control, and EPA as the lead agency for sediment remedial actions. Therefore, EPA provides oversight of the Simpson sediment remedial action and Ecology oversees source control activities. A separate plan to monitor the wastewater outfall is governed by a state waste discharge and National Pollutant Discharge Elimination System (NPDES) permit. Should source control not prove effective, Ecology will require Simpson to take corrective action. Should the sediment remedial action not perform as expected, EPA will require the potentially responsible parties (PRPs) to implement contingency actions. Where appropriate, EPA will review monitoring data under the NPDES permit for the Mills' outfall and other data on potential sources of contamination in accordance with the Contingency Planning Process before determining the source of recontamination of the cap surface. If Simpson disagrees with EPA's conclusion regarding the monitoring data under the NPDES permit and the source of the recontamination, the dispute will be resolved under the dispute resolution proceedings of the federal Consent Decree.

The consulted agencies for the project are the: Washington State Department of Fish and Wildlife (WDFW), Ocean Assessments Division of the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of the Interior (DOI), U.S. Fish & Wildlife Service (FWS), Ecology, WDNR, Puyallup Tribe, and the Muckleshoot Tribe.

EPA's Remedial Project Manger (RPM) is responsible for oversight of this Plan, and Simpson's Project Coordinator is responsible for implementation of the Plan. The RPM and Project Coordinator can designate other representatives to represent them and carry out specific tasks. However, their designation of any representations to participate in any meetings or conferences on the contingency planning process and the Table 1 update in this plan shall be done with prior and mutual consent.

This Plan is incorporated by reference as an exhibit to the federal and state Consent Decrees and is an enforceable part of the Decrees. Therefore, the terms and conditions of the Consent Decree apply to the implementation of the Plan, as further specified in the decree. Nothing in the Consent

Decree or the Plan regulates or limits Simpson from voluntarily conducting additional monitoring, sampling, or contingency planning at its own expense beyond the requirements of the Plan. These actions do not require consultations with EPA or other agencies or entities under the Plan or Consent Decree.

3. MONITORING OBJECTIVES

The goals of the sediment remedial action completed by Simpson and Champion are to ensure that:

- Toxic concentrations of previously identified chemicals of concern in the sediments are isolated from marine biota.
- Cap sediments are not recontaminated with chemicals of concern from underlying sediments or the mill.
- Contaminated sediments remain isolated for a sufficient period of time to allow the concentrations of chemicals of concern to decrease to an acceptable level (i.e., chemical and microbial activity modify chemical composition of buried sediments over time).
- The natural habitat has been restored to support a productive biological community comparable in species composition and abundance to other relatively noncontaminated estuarine habitats in urban areas.

The integrity of the sediment cap and source control are fundamental to the achievement of these goals. Cap integrity depends upon maintenance of the designed cap thickness to avoid contaminants' contact with biota and the continued attainment of the performance standards in paragraph 46 of the federal Consent Decree. To ensure cap integrity, post ten-year monitoring will focus as necessary on the following:

- **Physical erosion to assure cap depth is sufficient to isolate marine organisms from contaminated sediments**. Transect surveys as supplemented by bathymetric surveys and chemical monitoring can detect these changes.
- **Upward diffusion to assure contaminants are not moving through the cap and pose a threat to cap integrity**. Chemical monitoring can detect this type of change.
- **Surface contamination to assure seeps and vents are not vehicles for recontamination**. Chemical monitoring can detect this type of change.
- **Surface contamination from other sources**. For example, potential off-site contaminant sources could impact the remediation site and deposit chemicals of concern. Chemical monitoring can detect this process.

The objectives of this Plan are to detect any loss of cap integrity and screen whether the contingency planning process needs to be initiated, and, if so, to implement that process. To meet these objectives, physical monitoring is required, and chemical or biological monitoring may be required. Contingency monitoring activities are discussed in the following section.

4. CONTINGENCY MONITORING ACTIVITIES

The specific monitoring and reporting components of the Plan are listed in Table 1 (page *iv*). The contingency screening process, monitoring methods, and associated QA/QC procedures are described in the following sections. Thirty days prior to any sampling effort, EPA will be provided a copy of the proposed station locations for review, comments, and final approval. This will include a map and associated coordinates (i.e., latitude, longitude, or Washington state plane coordinates) for each station.

The Project Coordinator will notify the EPA RPM when a complete data set specific to each monitoring component is received. The federal and state Consent Decrees contain provisions governing the availability of these data. EPA has the authority to obtain a subsample (field split) from any chemistry or biological sample collected by Simpson.

Simpson and the regulatory agencies have used the results of the first ten years of monitoring to define the appropriate sampling type and frequency for subsequent years. As part of the five-year review, the Project Coordinator may provide information and analysis to EPA for consideration.

The Post Ten-Year Contingency Monitoring and Adaptive Management Plan includes a full bathymetric survey of all portions of Areas A and B in 2004. The purpose of this survey is to provide a picture of the site at the time the program changes to emergency monitoring (see Table 1). This survey will facilitate future evaluations of any monitoring or contingency actions resulting from emergency monitoring. The next five-year review is therefore planned for 2004, one year later than usual to allow for this final survey. It is the expectation of EPA, Simpson, and Champion that the five-year review scheduled for 2004 will be the final five-year review for the Project. Unless the monitoring data show there are serious problems and the remedy is no longer being protective, the program will consist of emergency monitoring as indicated in footnote a on Table 1 (and the contingency process), and this plan will be considered an institutional control. It should be noted that this approach includes any future routine maintenance or contingency actions that are implemented to enhance the remedy (such as the Transect 5 beach nourishment).

The five- and ten-year reviews provided a basis for evaluating the monitoring program and making necessary adjustments. The contingency screening process described in the contingency planning section provides a basis for revising the monitoring program, as necessary, based on monitoring results. Should refinement of this Plan be necessary, the federal Consent Decree provides for appropriate revisions in the monitoring and contingency plans by mutual agreement, without formally amending the decree itself.

Any contractor or subcontractor performing more than $100,000 worth of monitoring work is required to obtain a copy of the Consent Decree and Contingency Monitoring Plan from Simpson.

5. CONTINGENCY PLANNING PROCEDURES

5.1 OVERALL PROCESS

The contingency planning procedures consist of four parts: (1) contingency screening, (2) contingency planning, (3) contingency response, and (4) expedited review. Each is briefly summarized below and shown in Figure 2. A more detailed description of these procedures is presented in Sections 5.2 through 5.5.

Contingency Screening Process

The purpose of the contingency screening process is to identify potential problems early enough to conduct a rational and deliberate process to determine whether there is in fact a problem and, if so, how serious the problem may be.

Because laboratory measurements are based on analysis of small quantities of sediments and expected concentrations of some chemicals are near the analytical detection limit, there is a possibility of problems arising in the laboratory testing of these samples. Therefore, the first step following receipt of chemistry information that suggests a problem may exist will usually involve confirming the accuracy of the sampling results (verification).

The contingency screening process will enable the agencies and Simpson to determine what kind of data verification or response is appropriate, so that contingency planning or response actions are based on proper assumptions.

Contingency Planning Process

The purpose of the contingency planning process is to develop plans for contingency actions that may become necessary, depending on future monitoring results. As monitoring data are collected, they will be examined and interpreted relative to possible failure of cap performance. The four types of processes that could potentially contribute to failure of cap performance are:

- Physical erosion of the cap;
- Diffusion of contaminants through the cap;
- Surface contamination from seeps, vent, or other sources; and
- Other specific, but currently undefined, processes.

The monitoring plan was designed to detect these processes as well as the biological recovery of the cap area. If the monitoring data indicate(s) that a potential problem exists, then a plan, developed per the contingency planning process, must be prepared to correct or mitigate or otherwise address the situation.

The contingency planning process could result in an approved contingency response action to be implemented in accordance with an approved schedule. It could also result in agreement on a conceptual approach or a set of criteria for taking further action, pending the results of future monitoring. The process incorporates applicable permit requirements, interagency consultation, and public review of contingency plans prior to approval.

Contingency Response Process

The purpose of the contingency response process is to implement approved plans for contingency actions. This includes agreement on a final schedule, any amendments to the Consent Decree if necessary, and completion and monitoring of the response action.

Expedited Review Process

The purpose of the expedited review process is to allow the parties to shorten the timeframe of the standard process or to implement one or more of the above steps simultaneously when reliable contingency screening data indicate that a problem warrants immediate action.

Notes on the Overall Contingency Planning and Decisionmaking Process

The contingency planning procedures set forth below are described in terms of *tasks* and *steps*. The steps are numbered consecutively rather than being renumbered under each task. Figure 2 summarizes the contingency planning process. However, these tasks and steps may not occur in strict chronological order, since certain actions may occur simultaneously or more than once in the planning process.

Two items should be noted with respect to those situations where final decisions are required on potential contingency actions:

1) A number of agencies have expressed a desire to be involved in such decisions because of their role in the permitting and approval processes for this remedial action. These agencies are collectively referred to below as consulted agencies and include Ecology, WDNR, WDFW, NOAA/NMFS, DOI (FWS), the Puyallup Tribe, and the Muckelshoot Tribe. This Plan is a condition of several of these agencies' permits or approvals for the remedial action in 1987, and these agencies have agreed to use the procedures in this plan in the event that contingency planning is needed.

2) Because of the need for a coordinated decision-making process and a focus on responsibility, EPA will make final decisions under the terms of the accompanying Consent Decree. These decisions will be subject to the consultation process set forth below. In the event of dispute, a judge will review and make the ultimate decision. EPA will also be responsible for convening meetings and sending notices of major decision points. Simpson will send reports and data packages to the consulted agencies. EPA and Simpson may invite other entities to participate in the contingency planning procedures and may update the consulted agency list in response to agency requests.

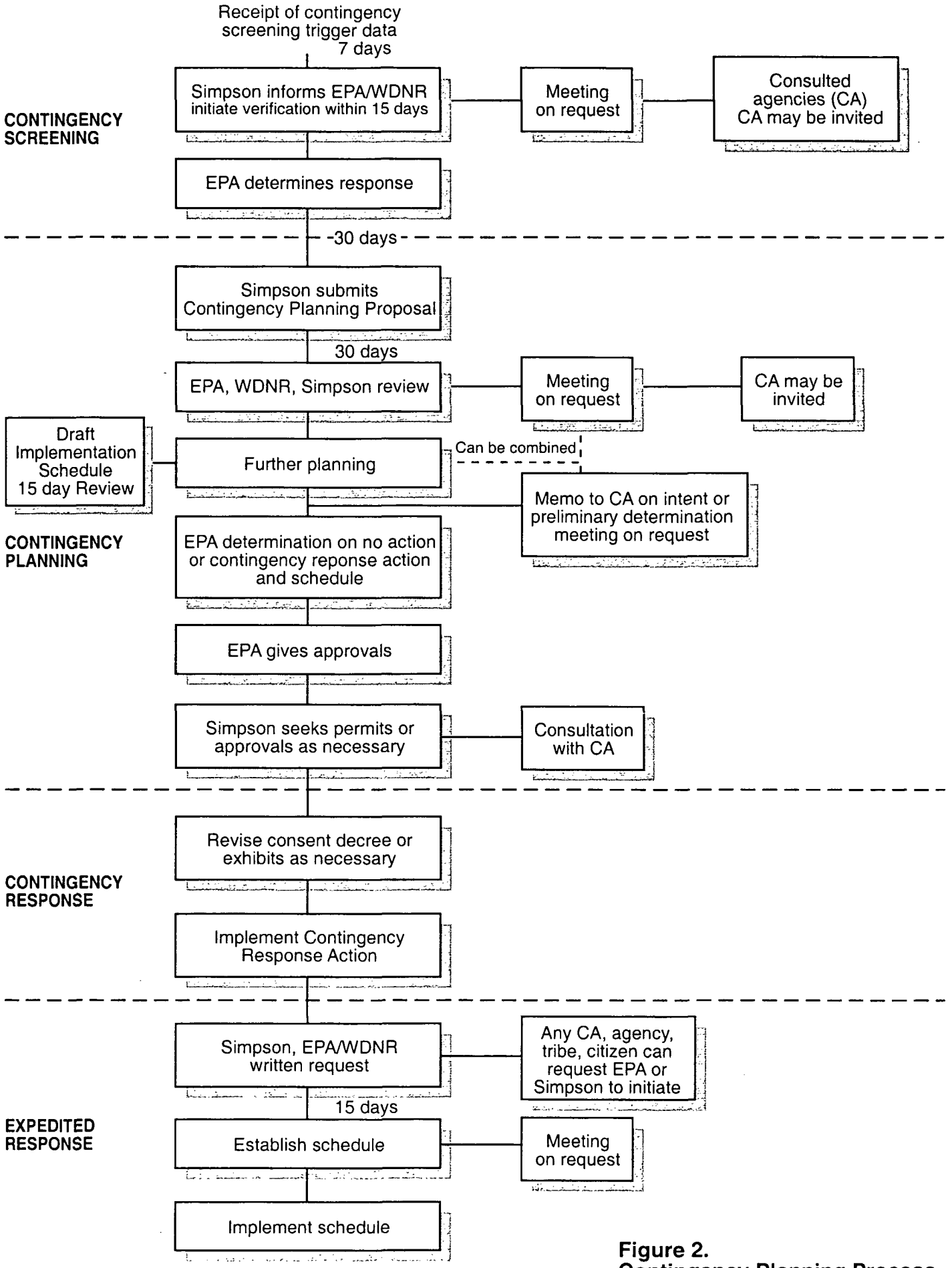

Figure 2.
Contingency Planning Process

Notes on the Performance Standards

The federal Consent Decree specifies that physical and biological performance standards be met:

- The physical standard requires a minimum of three feet of clean sediment be maintained over Areas A and B.

- The biological standard consists of not finding an adverse effect for benthic infaunal abundance (i.e., mean total abundance of any of the following major taxa—crustaceans, polychaetes, and molluscs—being statistically different and less than 50 percent of the reference sample mean total abundance; amphipod mean mortality being greater than 25 percent [absolute] and statistically different from reference sample mean mortality; and larval mean abnormality being greater than 20 percent [absolute] and statistically different from reference sample mean abnormality). An interim chemical standard was used until 1994 when the biological performance standard (biological indicators approach) went into effect (Parametrix 1994a). Chemical analyses are no longer used for performance standards but as analytical tools for contingency screening and, if necessary, interpretation of biological results.

These performance standards are to be used in conjunction with one another to evaluate Project effectiveness. The performance standards are based on sediment quality objectives in the ROD, specific human health risk assessments, environmental effects tests, and associated interpretative guidelines, including the Puget Sound Estuary Program (PSEP) protocols.

Monitoring conducted under the Plan will provide the information necessary to assess conformance with the performance standards. Performance standards should not be confused with contingency screening values and indicators, which focus on early identification of potential problems at individual Project stations rather than overall Project performance. As described above, the Plan uses physical and chemical indicators to initiate an early "screening" process for determining whether a problem might be occurring in terms of the ability of the Project to meet performance standards. For example, the contingency screening process is used to ensure the physical integrity of the cap. Screening levels have been established for transect stations that change 12 inches (1 foot) or more in one year, or 20 inches (1.67 feet) or more over two years. If the results are at or above these levels, the Plan provides a process for analyzing whether a problem really exists and; if so, how to best respond.

5.2 CONTINGENCY SCREENING PROCESS

The Plan's contingency screening process identifies potential problems early enough that a rational and deliberate study can be conducted to determine whether a problem really exists and, if so, how serious it may be and how to best respond.

Table 1 specifies when contingency screening monitoring activities occur. Screening levels are specified in Task 1 below.

Task 1. Screening levels (any one of which initiates Tasks 2 – 4 below)

Step 1: Physical—Simpson receives surveying results under Table 1 that show cap thickness in Regions A or B has decreased by one foot (12 inches) or greater in one year or 1.67 feet (20 inches) or greater over two years, or indicates the Consent Decree cap thickness performance standard of three feet might not be met. Unusual information pertaining to cap integrity obtained from the visual inspection or post-storm inspections (e.g., methane vents or surface erosion) may also trigger contingency action.

Step 2: Chemical—Simpson receives sampling results under Table 1 that indicate contamination levels for the chemicals of concern equal to or greater than 80 percent of the lowest established apparent effects threshold (AET) for benthic organisms, oyster larvae, or amphipods, based on samples collected within 25-105 cm above the contaminated sediments or at the sediment surface. The applicable chemicals of concern and their corresponding AET levels are listed in Table 2. No AETs currently exist for some chemicals (e.g., resin acids, and chlorinated guaiacols). The detection of resin acids or chlorinated guaiacols will be evaluated on a case-by-case basis by EPA, Simpson, and the consulted agencies with a decision made on the need for additional action. Because the resin acids have no AETs, the relatively arbitrary value of 1,000 µg/kg (ppb) dry weight is used in this monitoring program as a screening level. This level is used only as a conservative way to trigger the contingency screening process since there are no established AETs. No existing evidence indicates the relative importance of 1,000 µg/kg concentrations of these various chemicals, and it is unknown whether levels in excess of 1,000 µg/kg of these chemicals are environmentally significant. In addition, a 5-times increase in the concentration of a non-AET chemical measured in the subsurface migration samples relative to baseline will initiate the contingency planning process.

Task 2. Notice and Verification

Step 3—Simpson will provide written and verbal notification to EPA and the consulted agencies within seven days of the receipt of this information and will not wait until submitting a data report. Consulted agencies should provide their comments to EPA within seven days of receipt of the information.

Step 4—Any involved party may decide to undertake verification (e.g., checking laboratory procedures, evaluating split samples, resampling) or EPA may direct Simpson to undertake verification sampling. Simpson will set up a meeting with EPA prior to undertaking verification actions, unless EPA determines a meeting is necessary. Simpson will initiate mutually agreed-upon verification sampling within 15 days unless EPA authorizes more time.

Step 5—Simpson is committed to verifying the sample results in question, as long as the verification procedure is reasonable under the circumstances. If there is disagreement after following the procedures set forth in this section, the signatories to the Consent Decree will use the dispute resolution procedure in the Consent Decree to resolve the issue.

Table 2. Apparent Effects Threshold sediment quality values (µg/kg dry weight for organics; mg/kg dry weight for metals).

Chemical	Amphipod AET	Oyster AET	Benthic AET
Lower molecular weight PAHs[a]	24,000	5,200	13,000
Naphthalene	2,400	2,100	2,700
Acenaphthylene	1,300	560G[b]	1,300
Acenaphthene	2,000	500	730
Fluorene	3,600	540	1,000
Phenanthrene	6,900	1,500	5,400
Anthracene	13,000	960	4,400
2-Methylnapthalene	1,900	670	1,400
High molecular weight PAHs	69,000	17,000	69,000
Fluoranthene	30,000	2,500	24,000
Pyrene	16,000	3,300	16,000
Benzo(a)pyrene	3,000	1,600	3,600
Indeno(1,2,3-c,d)pyrene	1,800	690	2,600
Dibenzo(a,h)anthracene	540	230	970
Benzo(g,h,i)perylene	1,400	720	2,600
Total chlorinated benzenes	680	400	400
1,3-Dichlorobenzene	170G	170G	170G
1,4-Dichlorobenzene	120	120	110G
1,2-Dichlorobenzene	110G	50	50
1,2,4-Trichlorobenzene	51	64	—
Hexachlorobenzene	130	230	22
Total PCBs[c]	3,100	1,000	1,100
Phenols			
Phenol	1,200	420	1,200
2-Methylphenol	63	63	72
4-Methylphenol	3,600	670	1,800
2,4-Dimethylphenol	72	29	210
Pentachlorophenol	360	140G	690
2-Methoxyphenol	930	930	580
Miscellaneous extractables			
Retene	1,700	2,000G	2,000
Metals			
Arsenic	93	700	57
Cadmium	6.7	9.6	5.1
Copper	1,300	390	530
Lead	660	660	450
Mercury	2.1	0.59	2.1
Zinc	960	1,600	410

Source: Federal Consent Decree

[a] PAH = polycyclic aromatic hydrocarbon.

[b] G = indicates that a definite AET could not be established because there were *no effects* stations with chemical concentrations above the highest concentration among *no effects* stations.

[c] PCB = polychlorinated biphenyls.

Task 3. Meeting and Consultation

Step 6—Consulted agencies or other entities identified by EPA and Simpson may be invited to attend the meeting or meetings discussed in Step 4. Meeting notices and agendas will specify that the meeting is part of a contingency screening review to determine what kind of verification or response to the data is appropriate. EPA and the consulted agencies reserve the right to meet and consult throughout the contingency planning process and prior to final contingency planning decisions (see Task 3 of the contingency planning process below).

Task 4. Response to Contingency Screening

Step 7—EPA will make a final determination of the most appropriate response based on all available information. Potentially appropriate responses to contingency screening data include, but are not limited to, one or more of the following actions:

- Concluding the situation does not require further action at this time;
- Verifying the data;
- Seeking expert advice on the interpretation of monitoring data;
- Initiating the biological indicators approach (Parametrix 1994a, Appendix B to this Plan, and benthic monitoring methods described in this Plan) to evaluate the ecological importance of the contingency screening data or compliance with the biological performance standards in the Consent Decree;
- Preparing a report of analyses needed to define or describe the problem or situation in terms of potential threat to human health and the environment;
- Developing more specific criteria to evaluate the data or future sampling;
- Revising the sampling plan for the specific area, media, or chemical of concern (e.g., more frequent sampling, additional stations, groundwater monitoring, testing for additional parameters) on a temporary or ongoing basis;
- Conducting sediment bioassays;
- Initiating the contingency planning process (see below); and
- Initiating expedited review and planning response actions (see below).

5.3 CONTINGENCY PLANNING PROCESS

Task 1. Initiation

Step 1—The contingency planning process may be initiated after the contingency screening process.

Task 2. Contingency Planning Proposal

Step 2—Within 21 days (or within any timeframe on which the signatories to the Consent Decree mutually agree), Simpson will propose contingency response actions that will be taken if necessary to address the problems identified in the contingency screening process (i.e., a contingency planning proposal). The proposal will include the type of action to be initiated and a proposed schedule for implementation.

Step 3—EPA will review the contingency planning proposal within 21 days (or within the timeframe on which they mutually agree). EPA may decide to (1) refrain from further action at this time, (2) require further planning, or (3) proceed with implementation (see contingency response process below). A meeting will be held prior to the conclusion of this review period if requested by any one party.

Task 3. Meeting, Consultation, and Further Planning

Step 4—Consulted agencies or other entities identified by EPA and Simpson may be invited to attend contingency planning process meetings. Consulted agencies will be sent a memorandum by EPA summarizing the preliminary decision and requesting comments. A meeting will be held prior to a final decision if a consulted agency so requests.

Step 5—Meeting notices and agendas will specify that the meeting is part of the contingency planning process to determine the nature and timing of appropriate response actions necessary to address potential problems identified in the contingency screening process.

Step 6—The contingency planning proposal identified in Step 2 may be conceptual in nature. The precise technology, cost, timing, and other matters may be refined through a series of revisions, consultations, and meetings as part of further planning. The signatories of the Consent Decree may establish a schedule for completing the planning of a contingency response action under Step 3; however, Simpson must provide a detailed plan to EPA within 30 days of approval of the contingency planning proposal (Task 2, Step 3). Disagreement on the schedule will be handled through the dispute resolution process in the Consent Decree.

Task 4. Approvals for Contingency Planning Proposal

Step 7—Prior to the conclusion of the contingency planning process, EPA will issue a final determination as to the necessity and type of further remedial action required to be implemented by Simpson. EPA will also determine, after consultation with Simpson, whether permits, other approvals, or public participation are needed to implement the contingency planning proposal. Consulted agencies will be given an opportunity to review such decisions before EPA makes its final determination.

Step 8—If EPA deems it necessary, the PRPs will develop a more detailed implementation schedule for the contingency planning proposal, including reasonable time periods for any permits, approvals, public participation, or amendments to the Consent Decree. Simpson will draft the implementation schedule.

Step 9—EPA has 30 days to review the draft implementation schedule. EPA will not make a determination on a final schedule without prior consultation with Simpson and the consulted agencies, although EPA is the final decision-maker for accepting the schedule.

Step 10—Unless specifically prohibited by law, EPA will approve all facets of a contingency response action over which it has jurisdiction prior to requesting or requiring Simpson to seek any permits or other approvals.

Step 11—EPA and Simpson will initiate permit or approval processes in accordance with the implementation schedule. EPA will assist in obtaining any federal, state, or local permits or approvals. This process may occur prior to the contingency response process (below) if obtaining prior approvals is necessary or desirable to facilitate prompt contingency response action.

5.4 CONTINGENCY RESPONSE PROCESS

Task 1. Initiation

Step 1—The contingency response process will be initiated after the contingency planning process.

Task 2. Implementation

Step 2—Upon approval of the contingency response proposal, the resulting action may be reported in the next contingency monitoring report, or, if the action is extensive in duration and scope, the signatories to the Consent Decree will revise the Consent Decree by adding a description of the work to be performed and a schedule for implementing the approved proposal (contingency response action). The Consent Decree may be amended if appropriate under the schedules agreed to in previous tasks, while the amendment is being drafted and signed by the agency and signatories.

Step 3—The contingency response plans, and implementation schedule and actions, will become an enforceable part of the Consent Decree, except as the decree may be amended under Step 2, above.

5.5 EXPEDITED REVIEW PROCESS

Task 1. Initiation

Step 1—The expedited review process may be initiated at any time in the contingency planning procedures. EPA will inform or notify the consulted agencies when this occurs.

Step 2—The signatories to the Consent Decree may initiate the expedited review process by submitting a written request to the other parties if a party reasonably believes that (1) the contingency screening process is unnecessary to commence contingency planning, (2) discovery of a release or threatened release of hazardous substances at much higher levels than the contingency screening levels, (3) a previously unknown threat to human health or the environment is discovered, or (4) there is cause for concern about the adequate performance of the remedial action that the normal contingency planning procedures may not sufficiently address.

Step 3—In addition, any consulted agency; federal, state, or local agency with jurisdiction; Indian tribe, or citizen may request that EPA or Simpson consider initiating expedited review. EPA, in cooperation with Simpson, will establish a mailing list and inform persons on the list of the availability of any data reports submitted under this plan. If mutually agreed upon, this list may be concerned with notification systems for other Commencement Bay or EPA program activities. EPA or Simpson may hold informal discussions with the requester to learn about or respond to the requester's concern. The request may be withdrawn at any time. Prior to initiating the expedited review process, EPA or Simpson will convene a meeting to discuss the request with the requester, EPA, Simpson, and any other agencies or entities identified by EPA and Simpson to discuss the request.

Task 2. Expedited Procedures and Planning Schedule

Step 4—In consultation with PRPs, EPA will determine whether to conduct an expedited contingency screening process (see Step 5, below) or whether to proceed directly to the contingency planning or contingency response procedures.

Step 5—Within 15 days of initiation of the expedited review process, the signatories to this decree will establish a schedule for accomplishing the steps set forth in the normal contingency planning procedures (expedited planning schedule). They may add or omit steps, or shorten the time periods associated with particular steps. The schedule will allow reasonable time for Simpson to meet with EPA and WDNR and review any contingency response actions recommended by either agency. EPA will not approve an expedited planning schedule without prior consultation with Simpson and WDNR, including a meeting (if requested) and an opportunity to resort to the dispute resolution process in the Consent Decree.

Potentially appropriate responses include, but are not limited to, the actions noted above in response to contingency screening and detailed analyses, such as a focused remedial investigation or feasibility study.

Step 6—Disagreements will be resolved under the dispute resolution procedures, however, EPA may revoke the endangerment or other applicable provisions of the Consent Decree in order to take action to protect human health and welfare or the environment.

6. MONITORING METHODS AND QUALITY ASSURANCE/QUALITY CONTROL

This section describes the standard procedures and techniques used to collect samples at the Project site, as well as to generate and analyze data. Physical, chemical, and biological monitoring methods have been used at the Project site over the course of the ten-year confirmational monitoring. Some types of monitoring are no longer scheduled but are still described here.

6.1 PHYSICAL MONITORING METHODS

Data Collection

Cap Elevation Monitoring

To determine possible changes in cap elevation, two types of surveys have been conducted at the Project site. The first type, a bathymetric survey, generates elevation contours. The second type involves surveying transect elevations at known stations on predetermined transects. All surveys will be conducted using standard land-based theodolite/EDM equipment.

The intertidal portion of the bathymetric survey will be conducted from land during a spring low tide lower than -2 feet MLLW. Elevations throughout the Project area from approximately +6 to -7 feet MLLW will be spot surveyed using a marker stick with a prism device on top. Because surveys are conducted using land-based techniques, some lower elevations will be surveyed by having personnel wade into the water and placing the survey rod on the bottom. Areas have been surveyed this way in up to approximately three feet of water. The subtidal portion of the bathymetric survey (below approximately –7 feet MLLW) will be conducted by boat.

The transect survey will be conducted along five transect lines established in 1988 (see Figure A-1 in Appendix A). Each transect contains four to eight monitoring stations. Elevations of -4 to +6 feet MLLW will be surveyed at each transect station with standard theodolite equipment using a permanent shoreline benchmark. Concurrent with the transects survey, the Simpson Project Coordinator (or other designated representative as identified in Section 2.3) will conduct a visual examination noting special or unusual features.

Visual Inspection and Aerial Photograph

Visual inspections will consist of walking the Project site during an extreme low-tide and noting and photographing physical and biological features. Details to be noted include general contours and topography of the site; the color, texture, and odor of surface sediments; the presence of observable biological communities and all organisms and indication of organisms; and the presence and locations of special, unusual, or abnormal features. These inspections will be conducted jointly by EPA and Simpson representatives; consulted agencies will be invited to attend. Simpson will notify EPA and the consulted agencies at least three weeks prior to the planned inspection date. This requirement does not preclude any of the parties listed from conducting additional inspections.

A low-altitude color aerial photo of the Project site will be taken during a low tide (lower than -1.8 feet MLLW) using a standard 9 x 9 inch aerial camera (or equivalent). Kodak 2448 Aerochrome

MS film (or equivalent) will be used and altitude will be low enough to yield a scale of 1 inch = 100 feet.

QA/QC and Laboratory Analysis

No laboratory analysis will be conducted as a part of the physical monitoring; therefore, discussion of laboratory analysis methods is not applicable to this section.

Cap Elevation Monitoring

Quality assurance for all cap elevation monitoring will consist of noting all procedures of the survey which deviate from normally accepted practices using standard theodolite/EDM equipment. Estimates on survey accuracy will be made based on type and severity of deviations from normal survey procedures. Standard theodolite/EDM equipment is normally accurate well within the plus or minus four inches required by this Monitoring Plan.

Visual Inspection and Aerial Photograph

Aerial photo scale of 1 inch = 100 feet and the use of the proper type of color film will be verified with the aerial survey crew before and after the photograph is taken.

Data Analysis

Cap Elevation Monitoring

Topography and transect profiles will be generated from raw elevation data using a computer-aided drafting (CAD) system. Transect data will be entered into tables for comparisons to previous years' data and the contingency screening levels specified in this Plan. A summary of the Simpson Project Coordinator's visual examination will be prepared.

Visual Inspection and Aerial Photograph

The aerial photograph will be viewed and compared to the previous years' aerial photographs. Any substantial changes in the Project appearance will be noted. General physical and biological characteristics and any unusual features will also be noted.

6.2 CHEMICAL MONITORING METHODS

Data Collection

Chemical monitoring at the Project site has included surface and subsurface sediment sampling and analysis. The subsurface data has been used to confirm the integrity of the cap over a broad area, determine the degree to which the sediment at the bottom of the cap may have been mixed with underlying contaminated sediments, and provide a frame of reference for past and subsequent comparisons with monitoring data. Subsurface samples have been used to detect possible migration of contaminants into the cap from the underlying contaminated sediments. Subsurface samples also have been used to verify the thickness of the cap at each boring location. Surface sediment sampling has been conducted to assess if contaminants from off-site have affected the surface

sediment quality at the site. The contingency planning procedures section describes how chemical monitoring data will be evaluated and what contaminant levels will initiate additional action.

Surface Sediment Samples

The surface sediment samples will be collected in accordance with all applicable Puget Sound Estuary Program (PSEP) protocols (USEPA 1996b). (The current version of PSEP protocols in effect at the time of sampling and analysis will be used). A land-based surveyor will position a boat over the surface sediment stations, and when the exact position of the vessel is determined using a hand-held prism device on the boat, a buoy marker will be dropped at that location. Locations of buoys at the correct location will be verified by a final survey shot over the location while holding the buoy line taut directly over the anchor. Location of the grab within plus or minus two meters of the buoy anchor will be verified by examining the angle of the grab line (correlated with depth in relation to the buoy anchor).

Surface sediments will be collected at the surveyed stations using a $0.1m^2$ van Veen grab. The surface sediment stations that were sampled in July 1998 (SS1, SS2, and SS4) are shown in Figure A-2 (Appendix A). The grab will be cast off the vessel and retrieved. On successful grabs, two cm of surface sediment will be collected using a decontaminated stainless steel spatula or spoon. After sediment collection, the sampling, mixing, transportation, and archiving will be completed consistent with the techniques and procedures described in the sample collection and transport section below.

Subsurface Sediment Sampling

The subsurface sediment samples will be collected in accordance with all applicable PSEP guidelines (USEPA 1996b). (The current version of PSEP protocols in effect at the time of sampling and analysis will be used). The locations will be fixed in the field through a land-based survey similar to that described for surface sediment sampling. As with surface sampling, locations of buoys will be verified with a final survey over the buoy anchor while holding the line taut.

The subsurface corings will be collected at the surveyed stations using a portable (truck type) drill rig placed over a drill hole on a barge. The subsurface sediment stations that were sampled in July 1998 (C1, C2, C3, and C10) are shown in Figure A-2 (Appendix A). The barge will utilize three or more anchors set at various locations around the Project site to hold the barge on station, and anchor winches will be used to move the barge around the Project site. This technique will allow for accurate and stable placement over the station. The barge will be positioned over the coring station using the anchor winches and the location of the marker buoys as a reference. The angle of the buoy line will be used to determine the actual location of the buoy anchor beneath the barge.

The angle of the line will be visually correlated with depth at the location and the amount of slack on the buoy line. Although the exact distance will not be calculated in the field, the angle and length of line will be compared to known distances on the barge. For example, if the distance between the barge drill hole and the edge of the barge is three meters, and it is observed that the anchor lies parallel to the barge hole approximately one to two meters under the barge, it will be inferred that the sampling location is within ± two meters of the required site. Sampling at the location will proceed once the barge is stable over the location.

The drill rig will use shelby tubes to recover the sediment core. The previously decontaminated tubes will be driven by water pressure into the undisturbed sediment ahead of the tip of the drill bit. The tubes will then be retrieved and capped to prevent sediment spillage. Excess water will be decanted out of the tops of the tubes and the tubes will be taped with duct tape and labeled. The entire core (in 2-foot sections in the tubes) will then be transported on ice to the lab for extrusion and sampling. If the shelby tube is rejected by rocks or wood pieces in the cap, standard procedure will be to drill past this section and retry the tube lower down. If two full tubes are not obtained before encountering the contaminated sediment, then the core hole will be rejected due to an incomplete core. In addition, if the retrieved tubes are only partially filled prior to encountering the contaminated sediment, the core hole will be rejected. When core holes are rejected, the barge will be moved slightly and the location will be resampled.

Once the full shelby tubes are at the laboratory, the cores will be extruded using a hand-cranked device which pushes a stainless steel plug down the length of the tube. The core will be extruded onto a decontaminated tray. The distance from either the contaminated sediment boundary or the surface of the cap will be used to measure the correct distance up or down the core to the sampling location. Samples will be taken 25 to 45 cm above the contaminated sediment boundary for stations C1, C3, and C10 (samples will be designated by core number and distance such as C1 2545), and 85 to 105 cm above the contaminated sediment boundary at station C2 (example designation, C2 85105). Archives will be taken from the core in 10 cm sections from the contaminated sediment boundary to 120 cm above the boundary and 25 to 45 cm below the surface of the cap. The remainder of each core will be discarded. Sample and archive intervals for cores proposed at stations other than those listed above will be provided to EPA for review, comment, and final approval 30 days prior to any sampling effort.

Once the sediment is taken from the core, the mixing, sampling, transportation, and archiving will be conducted consistent with the techniques and procedures described below.

Sample Collection and Transport

Once sediment samples are taken, they will be placed in a stainless steel bowl and mixed thoroughly with a stainless steel spoon or spatula. All utensils coming in contact with the samples will have been previously decontaminated. The mixed samples will then be placed in the sample container which will be immediately labeled. For subsurface sulfide analyses, sediment samples will be collected from areas all along the extruded core prior to any additional disturbance and placed in a jar with two ml of zinc acetate.

For surface samples of sulfides and volatile organics, samples will be collected directly from the grab prior to any disturbance of the sediment surface.

Decontamination procedures for all utensils, which will be decontaminated in the laboratory prior to sampling, include the following: scrub with alconox in tap water, rinse with deionized water, rinse with 10 percent hydrochloric acid, rinse with methanol, rinse with acetone, rinse with deionized water several times. Next utensils will be allowed to air dry and then covered in aluminum foil wrap.

Decontamination procedures for utensils which will be decontaminated in the field include the following steps: scrub with alconox in deionized or marine water, rinse with deionized water, rinse

with 10 percent hydrochloric acid, rinse with methanol, rinse with acetone, rinse with deionized water several times, and loosely cover in aluminum foil wrap.

When possible, samples will be transported to the laboratory on ice on the same day that sampling takes place. Chain-of-custody seals will be placed on coolers prior to transport. If the samples cannot be transported to the laboratory on the same day sampling occurred, then the samples will be stored in refrigerators at 4°C (for not more than two days) prior to transport to the laboratory. Chain-of-custody forms will be filled out at the end of each day of sampling. Once the samples are transported to the laboratory, the delivery contents will be verified and the chain-of-custody forms signed by the laboratory representative.

All sample containers used for sample collection will be consistent with the requirements listed in Table 3.

QA/QC and Laboratory Analysis

The chemical analysis required and methods for surface and subsurface sediments are presented in Table 4. The analysis requirements for surface sediments were revised in 1998 to include only phenol compounds, phthalate compounds, resin acids, guaiacol, and conventionals (Parametrix 1998b). Six chemicals called "indicator chemicals" (4-methylphenol, guaiacol, and four chlorinated guaiacols) and conventionals are analyzed for subsurface sediments. All chemical concentrations will be reported as bulk sediment concentrations on a dry weight basis.

Field quality control will consist of verifying that all sampling stations were sampled within plus or minus two meters. Any field procedure which introduces location error will be noted and reported.

The quality control and analysis procedures in the laboratory will be conducted consistent with the procedures recommended under each specific analysis protocol and the PSEP guidelines (U.S. EPA 1996b). (The version of PSEP protocols in effect at the time of analysis will be used). PSEP guidelines will be used where they are more stringent, more specific, or where they address a quality control procedure not specified in an analysis protocol. In addition, detection limits attained in most cases will be lower than those specified in analysis protocols or PSEP guidelines for semivolatiles. The laboratory will provide a U.S. EPA Contract Laboratory Program (CLP) data package for all analyses. Recommended frequencies and control limits for semivolatile chemical quality assurance (QA) samples are summarized in Table 5.

The validation of laboratory data will be conducted according to CLP National Functional Guidelines for Organic and Inorganic Data Review (U.S. EPA 1994a,b). (The version of CLP guidelines in effect at the time of analysis will be used). These guidelines include quality control limits and specify data qualifiers that are attached to sample results, in addition to qualifiers designated by the laboratory. Additional guidance for data validation will come from the PSEP recommended guidelines (U.S. EPA 1996b), the isotope dilution Method 1625C and EPA SW-846 Methods (U.S. EPA 1990).

Table 3. Chemical sample handling techniques.

Analyte Group	Container	Preparation	Preservation
Extractable organic compounds	250-mL glass jar TFE-lined lid	Detergent wash, distilled water rinse, kiln fired at 450° C for > 1 hour	Ice (4° C)
Conventional parameters (except sulfide)	125-mL glass jar	Detergent wash, distilled water rinse	Ice (4° C)
Grain size	Glass or plastic jar	None	Ice (4° C)
Sulfide	Glass or plastic jar	Detergent wash, distilled water rinse	5-mL 2N zinc acetate solution per 30-gram sample, mix and seal, ice (4° C)

Table 4. Chemical analysis requirements and methods for surface and subsurface sediments.

Chemical	100% AET[a]	80% AET[a] [b]	Analysis Method
SURFACE SEDIMENTS			
Phenols (µg/kg)			EPA SW-846 (1625C)
Phenol	420	336	
2-Chlorophenol	--	--	
2-Methylphenol	63	50	
4-Methylphenol	670	536	
2-Nitrophenol	--	--	
2,4-Dimethylphenol	29	23	
2,4-Dichlorophenol	--	--	
4-Chloro-3-methylphenol	--	--	
2,4,6-Trichlorophenol	--	--	
2,4,5-Trichlorophenol	--	--	
2,4-Dinitrophenol	--	--	
4-Nitrophenol	--	--	
4,6-Dinitro-2-methylphenol	--	--	
Pentachlorophenol	360	288	
Phthalates (µg/kg)			EPA-SW-846 (1625C)
Di-n-Butylphthalate	--	--	
Butylbenzylphthalate	--	--	

Table 4. Chemical analysis requirements and methods for surface and subsurface sediments (continued).

Chemical	100% AET[a]	80%[b] AET[a]	Analysis Method
bis (2-Ethylhexyl) phthalate	--	--	
Di-n-Octyl phthalate	--	--	
Diethylphthalate	--	--	
Dimethylphthalate	--	--	
Resin Acids and Guaiacol (µg/kg)			EPA SW-846 (8270)
Pimaric Acid	--	--	
Sandocopimaric Acid	--	--	
Isopimaric Acid	--	--	
Palustric Acid	--	--	
Dehydroabietic Acid	--	--	
Abietic Acid	--	--	
Neoabietic Acid	--	--	
14-Chlorodehydroabietic Acid	--	--	
12-Chlorodehydroabietic Acid	--	--	
Dichlorodehydroabietic Acid	--	--	
Guaiacol	--	--	
Conventionals			EPA SW-846 (9071) and PSEP
Total Solids (%)	--	--	
Preserved Total Solids (%)	--	--	
Total Volatile Solids (mg/kg)	--	--	
Sulfide (mg/kg)	--	--	
Total Organic Carbon (%)	--	--	
Total Oil and Grease (mg/kg)	--	--	
Grain Size (%)	--	--	
SUBSURFACE SEDIMENTS			
Organics (µg/kg)			EPA SW-846 (8270)
4-Methylphenol	670	536	
Guaiacol	--	--	
4,5-Dichloro-2-methoxyphenol	--	--	
4,5,6-Trichloroguaiacol	--	--	
3,4,5-Trichloroguaiacol	--	--	
Tetrachloroguaiacol	--	--	

Table 4. Chemical analysis requirements and methods for surface and subsurface sediments (continued).

Chemical	100% AET[a]	80%[b] AET[a]	Analysis Method
Conventionals			EPA SW-846 (9071) and PSEP
Total Solids (%)	--	--	
Preserved Total Solids (%)	--	--	
Total Volatile Solids (mg/kg)	--	--	
Sulfide (mg/kg)	--	--	
Total Organic Carbon (%)	--	--	
Total Oil and Grease (mg/kg)	--	--	
Grain Size (%)	--	--	

[a] Source: Federal Consent Decree
[b] Represents 80% of the Apparent Effects Thresholds (AET) for the most sensitive test organism.

Table 5. Recommended frequencies and control limits for semivolatile chemical quality assurance samples.

Analysis Type	Frequency of Analysis[a]	Control Limit
Method blanks	One per extraction batch[b] or one per 12-hour shift (whichever is most frequent)	Phthalates: 5 ug total or <50% of analyte concentration in samples Other organic compounds: 2.5 µg total or <5% of analyte concentration in samples
Certified reference materials[c]	<50 samples: one per set of samples submitted to laboratory >50 samples: one per 50 samples analyzed	95% confidence interval for certified reference material (±1.96SD)
Matrix spikes	Not required if complete isotope dilution used <20 samples: one per set of samples submitted to the laboratory ≥ 20 samples: 5% of total number of samples	≥50% recovery; ≤100%
Field and analytical replicates	<20 samples: one per set of samples submitted to laboratory ≥20 samples: one triplicate and additional duplicates for a minimum of 5% total replication	± 100% coefficient of variation (for >2 replicates) or ± RPD (for duplicates)
Surrogate spikes	Every sample	≥50% recovery (10% if isotope dilution is used)

Table 5. Recommended frequencies and control limits for semivolatile chemical quality assurance samples (continued).

Analysis Type	Frequency of Analysis[a]	Control Limit
Initial calibration	Before any samples are analyzed, after each major disruption of equipment, and when ongoing calibration fails to meet criteria. Initial calibration includes 5% calibration.	≤20% coefficient of variation; ≤30% for highly polar compounds or other analytes at the discretion of the QA reviewer
Ongoing calibration	At the start of each work shift, every 10-12 samples, or every 12 hours (whichever is more frequent), and at the end of each shift for gas chromatography/mass spectrometry (GC/MS) and gas chromatography/flame ionization detection (GC/FID).	≤25% of initial calibration for GC/MS; ≤15% of initial calibration for GC/ECD; ≤15% of initial calibration for GC/FID
	At the start of each work shift, every six samples, or every six hours (whichever is less frequent), and at the end of each shift for gas chromatography/electron captive detection (GC/ECD).	

[a] Frequencies listed are minimums; some programs may require more control samples.
[b] A batch is ≤ 20 samples.
[c] As available.

All laboratory data will be reviewed for quality using checklists to document quality control checks and to document qualifiers attached to data points. Checklists will include the following major categories: holding times, GC/MS tuning, calibration (initial and continuing), blanks, surrogate recovery, matrix spike and matrix spike duplicate, field duplicates, internal standards, TCL compound identification, compound quantification and reported detection limits, tentatively identified compounds, system performance and overall data assessment, ICP interference check samples, reference sample, laboratory duplicate analysis, and furnace AA and ICP controls. (Note that some categories are only applicable to some analyses.) All summary tables generated from laboratory data will be checked for transcription errors.

Data Analysis

All results will be compiled with quality assurance review qualifiers into summary tables. Summary tables will also contain 80 percent AET levels (contingency screening levels) for each chemical. Any exceedances of 80 percent AET or 1,000 µg/kg (contingency screening level for resin acids) will be highlighted in summary tables. The results section will discuss each exceedance of contingency screening levels or 1,000 µg/kg, as well as any other chemical detections substantially above detection limits. Any detections of non-AET chemicals in subsurface samples which are five times above baseline values for clean sediment exceed contingency screening levels and will also be reported in the results section.

Grain-size data will be reported for each type of chemical monitoring based on ranges of percentages of particle sizes found. Any apparent correlations between grain-size and chemical results will be also noted in the results section. No grain-size plots will be generated from the grain-size data, and full grain-size results will be reported in a data appendix.

Project performance is evaluated in the discussion section based on the chemical results. Non-statistical correlations of chemical results among types of compound detected, location of detections, and timing of detections will be discussed. The effects of data qualifiers on data usefulness will also be discussed.

6.3 BENTHIC MONITORING METHODS

Scheduled benthic monitoring was completed in 1998. The benthic monitoring methods described in the 1998 annual monitoring report Methods Appendix (Parametrix 1999) are presented in this section in the event they are needed under the contingency planning procedures.

Data Collection

Sampling

To monitor the progressive changes in the Project benthic infauna, samples will be collected during high tides from six Project sampling stations (four in Region A and two in Region B) (see Figure A-3 in Appendix A). Two additional sites to be used as background stations will also be sampled (see Figure A-3 in Appendix A).

All stations will be sampled using benthic sampling procedures specified in PSEP protocols (U.S. EPA 1996b). (The version of PSEP protocols in effect at the time of sampling and analysis will be used). Five sample replicates (A - E) will be obtained at each station for benthic community analysis. An additional sample will be taken to provide a sample for sediment particle-size distribution and chemical analysis. Benthic sampling stations will be determined from shore surveys using standard theodolite/EDM equipment and then marked by buoys. Surveyors on shore will verify sampling sites and note anything which might affect the required accuracy of two meters, and the positioning will be monitored during all sampling. Offsets of the EDM reflecting board and wire angle will be noted to determine the relative error caused by these procedures. Samples will be taken subsequent to the determination of all station locations by sampling at the buoy locations.

Before sampling, a file containing the positions of all planned benthic stations will be established. In addition, this file will contain station designations for all sample sites. This will allow sample labels and containers to be made before field operations commence. Such prelabeling will minimize sample labeling errors. One team member will be responsible for sample tracking and logging. Samples will be collected using a 0.1 m^2 van Veen grab. After collection, the grab will be measured to determine adequate penetration. Minimum standards for adequate penetration depth, by sediment type, follow:

Sediment Type	Penetration Depth
Cobbles/pebbles	Unacceptable sediment type
Coarse sand/gravel	4 cm
Medium sand	7 cm
Fine sand	10 cm
Silty sand, sandy silt	15 cm
Silt	15 cm
Clay	15 cm

To verify that the sample was not disrupted during retrieval, the following acceptability criteria will be used:

- The sampler is not overfilled with sample so that the sediment surface is pressed against the top of the sampler
- Overlying water is present (indicates little leakage)
- The overlying water is not excessively turbid (indicates little sample disturbance)
- The sediment surface is relatively flat (indicates little disturbance or winnowing)
- The desired penetration depth is achieved (see above).

If a sample does not meet these criteria, it will be rejected.

Sediment characteristics will be observed and recorded according to a five-character sediment-type code. These notations will include the following sediment properties:

- Odor
- Color
- Substrate type
- Presence of reducing layer
- Presence of large particles or organisms
- Miscellaneous observations.

In addition, a logbook will be maintained. Entries will detail all significant events, including the following information:

- Date and time
- Names of all personnel
- Purpose of sampling
- Identification number, location, and depth of sampling site
- Details of sampling effort and deviations from standard procedures
- Observations and measurements.

These observations will also be entered on printed log sheets for sediment sample characterization.

Sample Tracking

External and internal sample labels will accompany each container. The samples will be labeled upon collection. Labels will include station identification numbers, date, personnel initials, and the number of containers used. Following the completion of each day's sampling, the team member responsible for tracking and logging will prepare a chain-of-custody form that will accompany the samples back to the laboratory.

All samples will be logged into the laboratory before further processing and all subsequent processing steps will be tracked. If the sample is split (for example, when vials of specimens were sent to different taxonomists), such changes will be logged. All transfers of material outside the laboratory will be noted on signed chain-of-custody forms.

Sample Sieving and Preservation of the Benthic Samples

After sample collection, the general characteristics of the sample will be noted and the sample will be labeled. The sample will be placed in a water-tight, sealed bucket and transferred to a sieving station on the sampling vessel. The samples will initially be sieved to retain all materials that will not pass through a 1-mm mesh. The samples will then be preserved in 10 percent borax-buffered seawater formalin, stored in labeled containers, and returned to the laboratory.

Grain-size samples will be placed in labeled jars, which will be placed in coolers. The grain size samples will be transported to the laboratory where they will be maintained at 4°C until analysis.

QA/QC And Laboratory Analysis

Sediment Physical Characteristics

The physical characteristics of the sediment will be analyzed using a dry sieve and pipette method (Buchanan 1984). Although sediment particle-size distribution will be initially recorded in millimeters, it will be converted to the standard Wentworth scale for analysis. According to the Wentworth scale, particle size is indicated in phi (Φ) units, where $\Phi = -\log_2$ of the particle size.

The sieves typically used for sediment analysis have openings that are 2, 1, 0.5, 0.25, 0.125, and 0.063 mm in diameter. The corresponding Φ sizes are -1, 0, 1, 2, 3, and 4, respectively. Smaller particles will be determined by their relative sinking rates in a column of water. Sediment particles from four to 0.63 mm in diameter ($-2 < \Phi < 4$) are sands of varying coarseness. Particles between 0.063 and 0.004 mm in diameter are called "silt." Clay particles are smaller than 0.004 mm in diameter.

The amount of organic material will be estimated by the percentage of the total volatile solids or the weight of the dried sediment that can be evaporated from the sample by heating at 500°C for 24 hours under controlled conditions.

Station-by-station comparisons of sediments or substrates will be done graphically and by using the Proportional Similarity Index, a derivative of the Bray-Curtis (Dis)Similarity Index.

Biotic Characteristics

The samples will be preserved for 24 to 48 hours and then rescreened using low-pressure tap water on a 0.5-millimeter sieve to remove the formalin. Formalin will be rinsed from the samples to minimize decalcification of mollusks or other taxa with calcareous parts. All containers of a single sample will be washed at the same time to ensure consistent handling; all replicates of a single sample will be processed by the same individual.

The residual material will be returned to the container and covered with denatured 70 percent ethanol. To assist in sorting, sufficient rose bengal stain will be added to stain all preserved organisms.

The sample volume will be measured, and samples will be sorted twice to remove all organisms and organism fragments. A small amount of the sample will be placed in a Petri dish and examined under magnification (a minimum of 10X). All organisms observed will be transferred to a second Petri dish divided into quadrants labeled for the following four major organism groups: arthropods, mollusks, annelid worms, and miscellaneous. When the dish is full, it will be surveyed for misplaced animals, and the organisms will be transferred to the appropriate quadrant. The specimens will be removed from these quadrants and placed into the appropriate vial (with fresh alcohol) for that taxon. Sediment and other remaining material will be saved. All sorted sediments will be retained until completion of the entire project.

Quality Control Sort-Checks and Quality Assurance Procedures

QC sort-checks will be conducted on each sample in accordance with procedures in PSEP guidelines (U.S. EPA 1996b). The post-sorting sample will be thoroughly mixed, and a 20 percent aliquot of the sediment removed. This aliquot will be sorted by someone other than the initial sorter. If over one percent more total organisms than originally counted are found in the QC sort-check (indicating that over five percent of the original animals had been missed), the sample will fail, and the entire sample will be re-sorted. If only one or two organisms are found in the re-sort, and if this number is greater than five percent of the total animals sorted, the sample will be re-sorted at the discretion of the quality control technician or laboratory supervisor.

The vials of each major taxon will be checked when the sample sorting is complete to remove any missorted animals. Any missorted animals will be placed into the correct containers. After these vial checks are completed, specimens from each sample will be weighed to provide a wet-weight biomass.

QA will be provided by the laboratory supervisor's routine audits of laboratory procedures. QA forms will track replicates sorted, initial sorter, QC sorter, passage or failure of the sort, number of organisms found in the initial sort, and the number of organisms found in the QC sort.

Wet-Weight Biomass

The wet-weight biomass of each of the major taxa from each sample will be determined by pouring the animals from the sorted sample through a preweighed 0.25-mm screen. This screen will be placed on absorbent paper and either blotted dry from underneath, or allowed to remain on the paper until no more fluid can be removed. The sample will be dried for no more than 30 seconds because small animals, polychaetes in particular, will quickly dry out and rupture or tear. The screen and sample will be weighed. Finally, the animals will be washed back into the vial with 70 percent ethanol, and the wet-weight biomass will be determined by subtracting the container weight. Complete biomass data will be reported in a data appendix.

Traditional Taxonomic Analysis (TTA) Procedures

Verifying that organisms were accurately identified is an important component of the laboratory procedures. Only qualified taxonomic experts will be allowed to identify the organisms. The sorters will separate the organisms into the major taxonomic groups. Each group will be transferred to the appropriate specialist for identification.

Traditional Taxonomic Analysis (TTA) will be conducted on the 1-mm fraction from all the samples. The TTA data will be summarized by station and site.

Data Analysis

Sediment Physical Characteristics

The depth and sediment particle size distribution of each station will be analyzed to determine whether any observed changes might be due to normal ecological shifts resulting from changes in the substrate. Location-by-location comparisons of sediments or substrates will be done graphically and by use of the Proportional Similarity Index (PSI) of which the Bray-Curtis Index is a more general form. Additionally, the quantity of organic material will be estimated based on the percentage of total volatile solids.

Physical characteristics of background and Project stations will be used qualitatively in the evaluation of all results.

Biotic Characteristics

General Descriptions and Ecological Indices

General descriptions of abundances, taxa richness, and assemblages will be developed. From the raw data, mean values and error estimates for each parameter will be derived. Three quantitative ecological indices will be used to measure diversity and dominance: The Shannon-Wiener (H′), Evenness (J), and Simpson's (S) indices (Poole 1974).

Shannon-Wiener Index (H′)

The Shannon-Wiener index is derived from the mathematical discipline of "Information Theory." It ranges upward from zero and gives a quantitative measure of the relative amount of new information contained in each individual specimen collected. Where the sample is dominated by a few taxa, the amount of new information likely to be gained by enumerating any given specimen is small. Where the sample is diverse, new information is more likely to be gained because each new specimen might be a representative of a previously unsampled taxon. Consequently, the index values are low (H′< 2.50) if calculated from areas of relatively few taxa, and high if taxa are numerous.

The following is the formula for the Shannon-Wiener Index:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where:	H'	=	The Shannon-Wiener or information theory index of diversity
	p_i	=	The proportion of taxon "i" in the sample
	s	=	The number of all taxa in the sample

Evenness Index (J)

The Evenness Index (J) ranges from 0 to 1 and measures the dominance of the sample by one or a few taxa. It describes the dispersion of all taxa in a sample as a proportion to the maximum possible dispersion. Samples with J values near 0 are dominated by few species, while samples with values near 1 have approximately equal numbers of individuals in each species.

The following is the formula for the Evenness (J) Index:

$$J = \frac{H'}{\ln s}$$

Where:	J	=	The Eveness Index
	H'	=	the Shannon-Weiner Index
	s	=	The total number of taxa in the sample

Simpson's Index (S)

Simpson's Index (S) ranges from 0 to 1, and measures the probability of randomly drawing two individuals of any given species from the total sample. This index is a measure of the degree the sample is numerically dominated by one or a few taxa. Values near 1 indicate a diverse array (the probability of drawing two individuals of the same taxon is small), while those near 0 reflect dominance by one taxon (the probability of drawing two individuals of the same species is large). The formula for the Simpson's Index given here is the standard unmodified form (Poole 1974).

$$C = \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N-1)}$$

Where:	n_i	=	The number of individuals in species "i"
	N	=	The total number of individuals in the sample
	s	=	The number of all taxa in the sample

This form is then expressed and reported as "S" (or 1-C) so that high diversity will be indicated by high numbers, consistent with the other indices.

Power of the Tests

Power analysis is used to determine the statistical validity of field or experimental data for any given analysis. Two kinds of errors are inherent in statistical analysis: Type I or α error, the error of rejecting a true null hypothesis; and type II or β error, the error of incorrectly specifying the hypotheses. For a given number of sample replicates, the value of α is related inversely to β (Sokal and Rohlf 1981; Zar 1984). Alpha error is commonly set at 0.05. Beta error is often set at 0.1 or 0.2. The "power" of a test is defined as $1 - \beta$, and is commonly referred to as a percentage; thus, a test with $\beta = 0.2$ can be considered to have a power of 80 percent.

The power of the test depends on the error variance of the population being sampled. This can be estimated by the error mean square of an ANOVA comparing the given taxon across the sampled stations (Zar 1984; C. Hogue, personal communication). This latter value is inversely proportional to the number of samples, consequently the power of a test can be related to the number of replicates. To assure consistency in the analyses, all data will be ln(x+1) transformed prior to the analyses of variance.

Power tables will be computed using methods presented in Zar (1984) to calculate minimum detectable differences (MDDs). The MDDs will then be reported as percent of reference station mean to determine whether each test can detect a reduction of 50 percent of reference mean with 80 percent of power.

The following constants will be held constant for the station-by-station comparisons: k=8, v_1=6, n=harmonic mean of station sample sizes (B1, B2, ..., B6, R1, R3), and v_2=28. A series of values for δ, the MDDs, will be obtained using formula 11.28 of Zar (1984).

For benthic two-sample analyses, equation 9.25 in Zar (1984) will be used to calculate MDDs (given below). The values for n, $t\alpha$, and t_β differ depending on the sizes of the samples being compared in each statistical test. If the sample sizes are equal, n is equal to that sample size; otherwise, n is the harmonic mean of the sample sizes.

$$\phi = \sqrt{\frac{n\delta^2}{2ks^2}}$$

Where:	n	=	The number of replicates
	δ	=	The mean detectable difference
	k	=	The number of samples
	s^2	=	The error mean square from a one-way analysis of variance for the given taxon done across all samples from the cap (Zar 1984)

The MDDs can be viewed as the limits on how similar two samples can be and still be discernible, both above and below the sampled mean. Thus, with an α of 0.5, a power of 0.8 implies the hypothesis that two means differing by at least the MDD will be correctly discriminated 95 percent of the time and that 80 percent of the time the difference between the two means can be correctly estimated (Zar 1984).

Note: All references in this section to significance or significant differences refer to statistical significance and not to biological or ecological significance.

Tier One, Level One Analyses

Analysis 1.1: Analyses of Numerical Abundance

Statistical comparisons between Project and background stations will be conducted for several meristic factors. Station mean abundances will be statistically compared to determine whether there is no significant difference between the Project and background stations (null hypothesis), or whether there is a significant difference between the Project and background stations (alternative hypothesis).

Comparisons will be conducted between the following groups:

- All Project stations (pooled) versus all background stations (pooled); and
- Comparisons among all individual stations through an 8-sample ANOVA (or appropriate non-parametric test).

Two null hypotheses will be tested: (1) there is no difference in mean abundance between the pooled background stations and the pooled Project stations; and (2) there is no difference in mean abundance between the individual stations (background and Project).

Testing the two null hypotheses will provide different levels of information. The two-sample tests will be used to compare the mean abundances between the pooled background and pooled Project stations. This test will provide a general assessment of Project performance as a whole.

The comparisons between individual stations (among station tests) will take into account the existence of different community structures and developing habitats at the Project. If significant station differences are indicated by the ANOVAs (parametric or non-parametric), a multiple comparisons technique will be conducted to identify specific pairwise differences between stations.

These statistical comparisons will be conducted at the 0.05 significant level for each of the following analyses:

Analysis 1.1.1 — Total number of taxa at each station
Analysis 1.1.2 — Number of numerically dominant taxa at each station
Analysis 1.1.3 — Number of the non-numerically dominant taxa at each station
Analysis 1.1.4 — Total number of individuals at each station

All of these analyses will be conducted on station means. Numerically dominant taxa will be defined as those taxa which cumulatively comprise 75 percent of the total abundance.

The statistical procedures described above are discussed in more detail in the Biological Indicators Approach (Parametrix 1994a and Appendix B to this Plan). Generally, statistical comparisons will include a preliminary comparison of the data distributions to a normal distribution and a test of homoscedasticity (homogeneity of variance, or HOV). Both of these tests will be necessary to

determine whether the assumptions required for parametric statistical tests are met. Prior to testing the data for normality and HOV, the abundance will be log-transformed (ln[x+1]), since abundance data commonly will include a large number of high values (i.e., the data are skewed). If the assumptions are met, parametric tests will be used due to their greater power. If the assumptions are not met, then non-parametric tests will be used. The following tests will be used: one-way analysis of variance (parametric) and Kruskal-Wallis Mann-Whitney U-tests (non-parametric). If the assumptions for parametric tests are met for most of the groups examined, then parametric tests will be used for the statistical comparisons. Analysis of variance is robust even when the assumptions of normality and homogeneity of variance are not completely met.

Cataloging of specimens and presentation (graphical or tabular) of data will include calculations of station mean abundances. Station mean abundances (number of taxa) will be used in each of the above tests.

Analysis 1.2: Standing Crop Patterns (Wet-Weight Biomass)

Similar analyses will be performed using major taxon wet-weight biomass for whole sediment samples as an indication of standing crop. Significant changes in biomass can indicate either the overabundance of one or a few species or significant changes in all species; either of these changes could be due to substrate contamination or other causes. Biomass patterns are likely to be biased if one or a few large individuals are present. Consequently, in addition to total major taxon wet-weight biomass measurements, a subsequent similar set of measurements will be made excluding large organisms. The excluded organisms will be subjectively chosen to remove those whose weight is a substantial fraction of the total. The weight and the major taxonomic group of any excluded organisms will also be recorded.

Both the total and selective biomass data will be analyzed using traditional statistical analyses as described in the previous section. The traditional analysis will use ANOVA techniques if the data are sufficiently homogeneous in variance, and if they are normally distributed. The appropriate use of parametric or non-parametric tests will be determined using the same methodology as described for Analysis 1.1. If most of the examined groups meet the parametric test criteria, all of the tested groups will be examined using parametric tests. If the data do not meet the criteria, appropriate non-parametric tests will be used to verify the results of the parametric tests.

Statistical comparisons (parametric and/or non-parametric) will be conducted between the following groups:

- All Project stations (pooled) versus all background stations (pooled); and
- Among all individual stations.

Analysis 1.3: Proportional Similarity Index (PSI)

Sample comparisons of taxa abundance will be based on taxa-sample matrices from station replicates. Similarity between stations will be measured with the PSI, which considers the total number of taxa collected from all the samples. This form of the PSI is generally equivalent to the Bray-Curtis index. This analysis will be run on the taxa sample matrices using a nearest-neighbor group clustering algorithm. The data used for these PSIs will be the means of the five replicates for

each station (station means of actual and log-transformed abundances). Results will be displayed as optimally rotated dendrograms.

When completed using proportions of abundances, the PSI is independent of the number of taxa in each sample. This sample size independence is desirable when the basis of sampling is different between samples (e.g., when data from different studies are used). When abundances are used in the computations, the resulting quantity is the Bray-Curtis index, an index influenced by sample size. This influence is reduced, however, when log-transformed abundances are used.

The following is the formula used for the PSI:

$$PS_1 = \frac{2\sum_{i=1}^{s} \min(x_{ij}, x_{ik})}{\sum_{i=1}^{s} (x_{ij} + x_{ik})}$$

Where:	x_{ij}	=	The number of individuals of taxon "i" in sample "j"
	x_{ik}	=	The number of individuals of taxon "i" in sample "k"
	s	=	The number of taxa across all samples

Analysis 1.4: Ordination of the Benthic Infaunal Data: Principal Coordinate Analysis (PCOR)

As approved by EPA in a July 29, 1997 letter to Simpson Tacoma Kraft Company (USEPA 1997), PCOR is no longer required as part of the biological indicators approach.

Tier One, Level Two Analyses

Analysis 1.5: Analyses of Numerical Abundance (Comparison Between Years)

This analysis is similar to Level One analyses of numerical abundance except that comparisons will be made between present year data and the previous year's data. Station mean abundances will be statistically compared to determine whether there is no significant difference between present data and the previous year's data. Comparisons will be conducted between the following groups:

- All present year Project stations (pooled) versus all previous year Project stations (pooled); and
- Two sample comparisons between individual stations (e.g. B1 1994 vs. B1 1993, B2 1994 vs. B2 1993, etc.).

Hypotheses to be tested and the numerical data to be used for each test will be the same as in Analysis 1.1 described above, except that comparisons between years will be conducted.

Analysis 1.6: Ordination of the Benthic Infaunal Data (Comparison Between Years)

This analysis is similar to the ordination methods described in Analysis 1.4 to determine whether the infaunal assemblages sampled annually from each station are significantly different from

samples collected during the previous year. The procedures and methods followed for Analysis 1.6 will be identical to those followed for Analysis 1.4 except the comparisons will be made to the previous year's data.

Tier Two Tests

Tier Two analyses will be conducted only if the statistical evaluations conducted in Tier One analyses indicate significant differences potentially indicative of a decline in Project health.

The enumeration and quantitative description of the benthic infauna conducted under Tier One (Analyses 1.1 through 1.6) of the biological indicators approach will provide insight as to whether an assemblage is normal, interactive, and productive. However, Tier Two, if conducted, will focus on the ecological interactions occurring at the site. An examination of the collected taxa abundance data for ecological interactions may be able to provide significant information within the framework of previous research. In Tier Two, the attempt will be made to provide a synthesis of such data and a functional interpretation of the biological assemblages sampled at the site. Because it is likely that only one or a few stations will show significant differences in the Tier One indicators, Tier Two analyses described here may only include the station or stations which showed significant differences in Tier One indicators.

Tier Two analyses will examine common infaunal taxa which belong to known feeding guilds or to other ecologically functional groups (Parametrix 1994a). As with the Tier One analyses, Tier Two includes qualitative evaluations and statistical tests of these ecological groups. Analyses will be performed using present year data for the Project station compared to the background stations. Tier Two biological indicators will include the following analyses:

Analysis 2.1 — Examination of trophic guilds including statistical and qualitative comparisons of guild abundances and descriptions of food webs where information is available.

Analysis 2.2 — Examination of key species including statistical comparisons if abundances are sufficient across the stations to provide valid statistical results.

Analysis 2.3 — Examination of changes in abundance of pollution-sensitive or -tolerant taxa, including statistical comparisons to background stations if abundances are sufficient across the stations to provide valid statistical results.

Normality and homogeneity of variance will be examined using the same methods described for the Tier One analyses. If most of the groups examined meet the requirements for parametric tests, then parametric tests will be conducted. Although the analysis of variance test is robust, if these requirements are not met for any of the examined groups, then non-parametric tests will also be conducted to verify the results of the parametric tests. The statistical tests used will evaluate the following hypotheses:

Analysis 2.1 — For each trophic guild:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations.

H_a = the mean abundances are significantly different.

Analysis 2.2 — For each key species:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations.

H_a = the mean abundances are significantly different.

Analysis 2.3 — For each pollution-sensitive or -tolerant taxa:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations.

H_a = the mean abundances are significantly different.

The statistical comparisons for each analysis will test two specific null hypotheses: (1) the mean abundance for the pooled Project stations is not different from the mean abundance for the pooled background stations, and (2) the mean abundances for the individual stations, background and Project, are not different. All statistical comparisons will be tested at the 0.05 significance level.

Because these tests focus on a particular group of the benthic community at the site, the abundance of some of these groups may be relatively low. This may result in statistical tests with relatively low power particularly for Analysis 2.3 which involves pollution reactive taxa. The relative power of any test considered will be evaluated so that analyses with wholly insufficient power are not conducted. The power of particular tests will be considered when results of these tests are evaluated. As with other tests, the goal for statistical power will be an MDD of 50 percent of the background mean. If lack of power severely limits the interpretation of one or more indicators, the following types of tests will be considered as alternatives:

- Presence-Absence testing using standard non-parametric statistical techniques as presented in Gibbons (1985)
- Presence-Absence testing using the statistical methods of Hendrickson (1978)
- Pairwise statistical comparison between stations presented by Goodall (1969)
- Coefficient of community (Sorensen's Index) described by Pielou (1977)
- Infaunal Trophic Index described by Word (1990).

Other Data Analysis Procedures

Dendrograms

The programs in the Community Analysis System (Bloom 1992) will be used to construct all dendrograms as well as to calculate or verify all quantitative indices. All dendrograms will be optimally rotated. Dendrograms will be based on Proportional Similarity, as described earlier, and constructed using group average sorting.

Statistical Analyses

Since distributions of abundances (counts) tend to be skewed, data will be log-transformed (ln[x+1]) prior to evaluating the parametric test assumptions. ANOVA tests for two samples will be conducted and the residuals will be recorded. The ANOVA residuals will be evaluated for homogeneity of variance and normality. Homogeneity of variance will be tested using Levene's test in conjunction with box plots of residuals by sample. Other homogeneity of variance tests, such as Cochran's, Bartlett's, or Hartley's will also be considered. Normality will be evaluated using the Shapiro-Wilk test in conjunction with normal probability plots of residuals (U.S. EPA 1989, 1992).

Based on the results of the homogeneity of variance and normality tests, appropriate statistical tests (parametric or non-parametric) will be conducted. For each hypothesis tested, if most of the test groups examined meet the requirements for parametric tests, parametric tests will be conducted. Although the analysis of variance (ANOVA) test is robust, if these requirements are not met for any of the examined groups, non-parametric tests (Kruskal-Wallis or Mann-Whitney U-tests) will also be conducted to verify the results of the parametric tests. These comparisons involving individual stations will be followed by a multiple comparisons test if the initial test indicated significant differences.

This basic statistical testing procedure will be applied to Analyses 1.1, 1.2, and 1.5. For Analyses 1.1 and 1.5, several types of abundance data (described previously) will be examined and each will be individually tested as described here. For Analysis 1.2 tested data will be wet-weight biomass for major taxonomic groups. The several types of abundance data addressed in Analysis 1.5 will be tested individually.

6.4 MACROPHYTE MONITORING METHODS

Scheduled macrophyte monitoring was completed in 1998 and further monitoring is not required. The macrophyte monitoring methods described in the 1998 annual monitoring report (Parametrix 1999) are presented in this section.

Data Collection

To assess the relative abundance, density, and composition of algae that have colonized the Project site, the intertidal areas will be examined by a biologist for macrophytes during a low tide between June and August. The on-site inspections will include notation of extent, density, and general location of all macrophyte beds on the Project. A species list will be generated for each macrophyte bed with the aid of several field guides to marine algae of the region (Kozloff 1973; Scagel 1971;

Waaland 1977). The presence and general extent of hard substrate within each bed will also be noted. Examination of the subtidal areas of the cap will be made during the lowest point of the low tide to visually verify the presence or absence of subtidal macrophytes.

A low-altitude color aerial photograph of the Project will be taken during the low tide. The photograph will be taken using a standard 9 x 9 inch aerial camera (or equivalent) with true color Kodak 2448 Aerochrome MS film (or an equivalent) from a sufficiently low altitude to yield a scale of 1 inch = 100 feet. The photograph will be blown up to approximately 24 x 36 inch size for easier examination. From this photograph, the extent of each macrophyte bed will be mapped.

QA/QC And Laboratory Analysis

No laboratory analysis will take place as a part of the macrophyte monitoring. QA/QC procedures will consist of independent verification by a second biologist of at least one specimen of each macrophyte species identified at the site. Estimates of macrophyte density and substrate composition will be compared to verify that both biologists were noting the same features with similar results. The use of a standard aerial camera and specified color film will be verified with the aerial survey crew before and after the aerial photograph is taken.

Data Analysis

The general composition, type, and extent of each macrophyte bed recorded will be described in the results section of the monitoring report. A map of the macrophyte beds will be generated from the aerial photograph with verification from field notes. The composition of macrophytes on the Project will be compared to previous years' results, and qualitatively observed trends will be reported.

7. REPORTING

Data Management Plan

All data submitted to EPA will be in a format consistent with EPA's GIS for the CB/NT site.

Contingency Monitoring Reports

Contingency monitoring reports will be submitted in accordance with Table 1. Simpson will submit five copies of all reports to EPA on the dates specified in Table 1. Concurrently, Simpson will forward a copy of each report to the consulted agencies.

As indicated in the Consent Decree, all required work plans, reports, and other documents ("documents") shall be subject to review and approval by EPA. Except as otherwise provided by the contingency planning procedures or agreed between EPA and Simpson: (A) EPA shall notify Simpson in writing of approval of disapproval of the document, or any part thereof, within thirty (30) calendar days of receipt of the document. If EPA needs a longer review period, EPA shall notify Simpson of its revised response date within thirty (30) calendar days of receipt of the document. (B) In the event of disapproval, EPA shall specify in writing any deficiencies and modifications to the document. Nothing in this provision shall negate EPA's right to approve or disapprove the submittal should the time periods stated in this paragraph be exceeded by EPA, nor shall such delay by EPA subject Simpson or Champion to any enforcement action. (C) Within thirty (30) calendar days of receipt of any document disapproval or comments for revision, Simpson shall either: (1) submit a revised document to EPA which incorporates EPA's modifications or summarizes and addresses EPA's concerns or (2) provide a notice under the dispute resolution process.

Spill Reporting

This program recognizes that the coordination of governmental notification and response to new spills and similar releases is the responsibility of the National Response Center under CERCLA and OPA, and that the contingency plan is not intended to duplicate other governmental requirements and programs. In order to promote cooperation and enhance coordination, if the Tacoma Kraft Mill has a spill or release of a listed chemical in a reportable quantity onto the Project site, the Simpson Coordinator will—as a courtesy and not as a requirement of this contingency program and consent decree—make an oral or written notification within 15 days of the incident to the EPA RPM and will send the EPA RPM a copy of the report, if any, that was filed with an agency regarding the incident. EPA may initiate consultation with the Simpson Project Coordinator and consulted agencies following the contingency screening or expedited contingency procedures in this plan.

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APPENDIX A

SECOND FIVE-YEAR OVERVIEW AND TEN-YEAR REVIEW

Excerpt from the approved Tenth (1998) Annual Monitoring Report (Parametrix 1999) with minor formatting and editing changes.

SECOND FIVE-YEAR OVERVIEW AND TEN-YEAR REVIEW

Physical, chemical, and biological characteristics of the Project have been monitored consistent with the requirements of the monitoring plan for ten years (Parametrix 1990 through 1999). The 1993 Annual Monitoring Report provided a five-year overview (Parametrix 1994b). This appendix provides a similar overview of the past five years (1994 through 1998) and briefly summarizes the results of the ten years (1988 through 1998) of Project monitoring.

Physical Monitoring

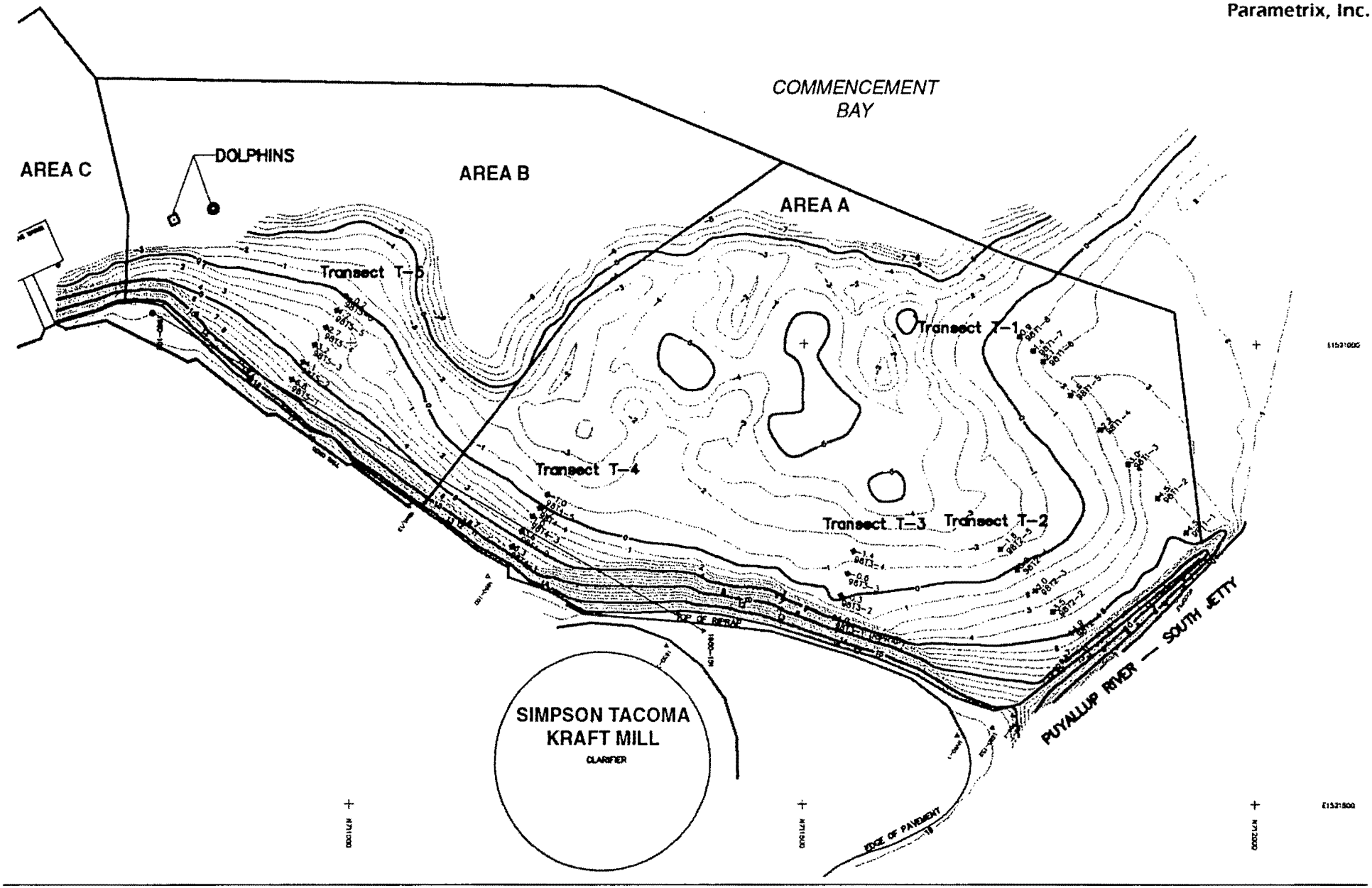
Bathymetric surveys over the five-year period were conducted in 1995 and 1998, and transect surveys were conducted annually 1994 through 1998. (The monitoring plan required transect surveys in 1995 and 1998; Simpson and Champion elected to perform them annually during 1994 through 1998 in-part to provide a complete ten-year data set.) The five intertidal elevation transects that were surveyed each year consisted of four to eight monitoring stations (Figure A-1).

As anticipated, surface features of the Project have changed as cap material has been redistributed over the site. The greatest changes of elevation occurred within two years following Project construction, however, both increases and decreases have continued over time. In general, redistribution of the materials appears to have become less rapid and the magnitude of change has become smaller within the past five-to-eight years (Table A-1).

A comparison of elevations measured 1994 through 1998 at stations on transects 1 through 4 indicates that the extent of changes within the five-year period were less than six inches at the majority of the stations. Transect 5 had new material placed as a preventive measure in 1995. The subsequent three years of monitoring indicated little change in this area at Transect 5 (Table A-1).

There were only two physical monitoring results above applicable early warning criteria in the period 1994 through 1998: (1) 1994, for an increase of 2.8 feet over two years at Station 1-4 (which has since gradually returned to the approximate initial cap elevation); and (2) 1995, for a decrease of one foot at Station 1-5 (the resulting elevation was 2.2 feet higher than the elevation at the time of the initial cap placement, and in 1998 was over one foot higher than in 1988).

In the ten years following project construction, eight stations had net increases, one station was unchanged, and 13 stations had net decreases (excluding stations on Transect 5). As was found in the first five-year review, the redistribution of materials at the site has not affected the integrity or function of the cap in any area measured. Comparison of elevation changes with core thickness (taken for chemical monitoring) indicates the cap continues to exceed the three-foot performance standard in Areas A and B.



Simpson Tacoma Kraft Co./St. Paul Waterway/55-1650-57(01) 6/99

SCALE IN FEET

0 75 150

N

Figure A-1.
Project Site Topography (May 1998) and Location of Benchmark Stations

Table A-1. **Elevation changes (ft MLLW) monitored on the Project site at five intertidal transects between 1988 and 1998.**

Transect/ Station	12/88	6/89	6/90	6/91	6/92	6/93	6/94	6/95	7/96	6/97	5/98	Elevation Changes 6/94 to 5/98	Elevation Changes 12/88 to 5/98
1-1	5.0	6.1	5.8	5.2	5.2	4.9	4.4	4.8	4.8	4.5	4.5	+0.1	- 0.5
1-2	3.6	4.0	5.1	4.7	4.5	4.5	4.1	4.4	4.5	4.5	4.5	+0.4	+0.9
1-3	2.9	2.9	2.7	3.1	2.7	3.7	3.6	4.2	4.4	3.9	3.0	- 0.6	+0.1
1-4	2.4	2.1	1.5	1.4	1.3	4.0	4.1	3.6	2.8	2.5	2.2	- 1.9	- 0.2
1-5	0.1	0.6	1.0	3.5	3.6	3.7	3.3	2.3	2.1	1.9	1.9	- 1.4	+1.8
1-6	1.8	1.7	2.8	3.4	2.8	2.8	2.4	2.3	2.3	2.2	2.1	- 0.3	+0.3
1-7	0.2	0.5	2.1	2.6	2.1	2.1	1.8	1.8	1.7	1.7	1.4	- 0.4	+1.2
1-8	-0.3	-0.1	1.3	1.5	1.0	0.9	0.9	0.8	0.8	0.8	0.9	+0.0	+1.2
2-1	6.9	6.6	7.0	6.7	6.3	5.8	5.6	5.6	5.3	5.2	4.9	- 0.7	- 2.0
2-2	6.0	5.5	5.1	5.0	4.7	4.3	4.1	4.0	3.6	3.6	3.5	- 0.6	- 2.5
2-3	4.6	4.2	3.4	3.1	2.5	2.5	2.1	2.1	2.0	2.0	2.0	- 0.1	- 2.6
2-4	2.7	1.7	1.0	0.7	0.5	0.4	0.2	0.2	0.3	0.3	0.2	+0.0	- 2.5
2-5	-1.9	-1.8	-1.0	-2.0	-2.1	-1.8	-1.8	-1.7	-1.6	-1.6	-1.6	+0.2	+0.3
3-1	5.7	5.3	4.7	4.7	4.8	4.4	4.3	4.2	4.5	4.5	4.0	- 0.3	- 1.7
3-2	2.9	1.9	0.6	0.1	-0.3	-0.4	-0.6	-0.5	-0.4	-0.2	-0.3	+0.3	- 3.2
3-3	-0.2	-0.4	-0.7	-1.2	-1.4	-1.1	-0.9	-0.9	-0.7	-0.5	-0.6	+0.3	- 0.4
3-4	-1.4	-1.6	-1.6	-1.6	-1.8	-1.5	-1.4	-1.3	-1.4	-1.3	-1.4	+0.0	+0.0
4-1	5.2	7.6	8.4	7.6	7.7	7.0	6.7	6.6	6.7	6.7	6.3	- 0.4	+1.1
4-2	6.2	5.7	5.0	4.8	4.7	4.3	4.0	3.9	3.7	3.7	3.6	- 0.4	- 2.6
4-3	4.4	3.6	2.8	2.5	2.2	2.1	1.9	1.5	1.3	1.3	1.0	- 0.9	- 3.4
4-4	1.4	0.9	0.5	0.5	0.3	0.0	-0.2	-0.3	-0.3	-0.3	0.2	+0.4	- 1.2
4-5	-0.9	-0.8	-0.8	-0.7	-1.0	-1.0	-0.9	-1.0	-1.0	-1.0	-1.0	- 0.1	- 0.1
5-1	5.0	6.5	8.5	7.5	8.0	7.0	6.5	6.7	6.7	7.0	6.8	+0.3	+1.8
5-2	5.8	6.1	5.7	5.4	4.8	4.4	3.8	3.6	3.8	4.0	4.1	+0.3	- 1.7
5-3	5.2	5.4	4.0	2.9	2.2	2.0	1.5	1.3	2.4	3.3	3.2	+1.7	- 2.0
5-4	3.7	3.1	1.7	1.1	0.6	0.5	0.4	0.5	2.8	2.5	2.7	+2.3	- 1.0
5-5	1.5	0.7	0.6	-0.3	-0.4	-0.4	-0.3	-0.2	1.6	1.6	1.2	+1.5	- 0.3
5-6	-0.8	-0.8	-0.7	-1.4	-1.4	-1.3	-0.9	-1.1	0.1	0.2	-0.2	+0.7	+0.6

Chemical Monitoring

Chemical monitoring over the five-year period included sampling of surface and subsurface sediments in 1995 and 1998. The analysis reflected a more focused monitoring program than in the first five years (1988 through 1993) for two reasons: (1) the results from the first five years, which showed few detections or early warning results (Parametrix 1994b); and (2) the use of the biological indicators approach required to be developed by the monitoring plan (Parametrix 1994a, 1995c).

Although a wide variety of chemicals were monitored, most of the chemicals were undetected over the period 1994 through 1998, and very few of the chemical detections were above the early warning criteria (Table A-2). Of more than 1,000 possible chemical detections over the period 1994 through 1998, only eight results were above applicable early warning criteria. Seven of the eight early warning results (six in 1995 and one in 1998) were surface sampling results for low levels of resin acids (a surrogate level of 1,000 µg/kg was used in the absence of apparent effects thresholds). The sample analysis protocol used in 1995 for resin acids was deemed to have overestimated resin acid concentrations in sediments and the early warning level exceedances were not significant.

The other early warning level exceedance was in 1995 at subsurface sediment station C2 (Figure A-2). The sample location was deep within the cap (approximately eight feet deep) near the interface of the underlying surface and the bottom of the cap. This result, and similar detections in other years at this location, are believed to reflect mixing at depth of berm sediments and contaminated sediments during Project construction. Consistent with the conclusion in the five-year review (Parametrix 1994b), the sediment chemistry does not indicate any chemical migration upward through the cap.

Overall, chemical monitoring conducted from 1988 through 1998 indicated: (1) no substantial levels of chemical from off-site sources are being deposited on the cap; (2) chemicals in the underlying sediments are remaining in-place; and (3) the Project cap is functioning as designed.

Biological Monitoring

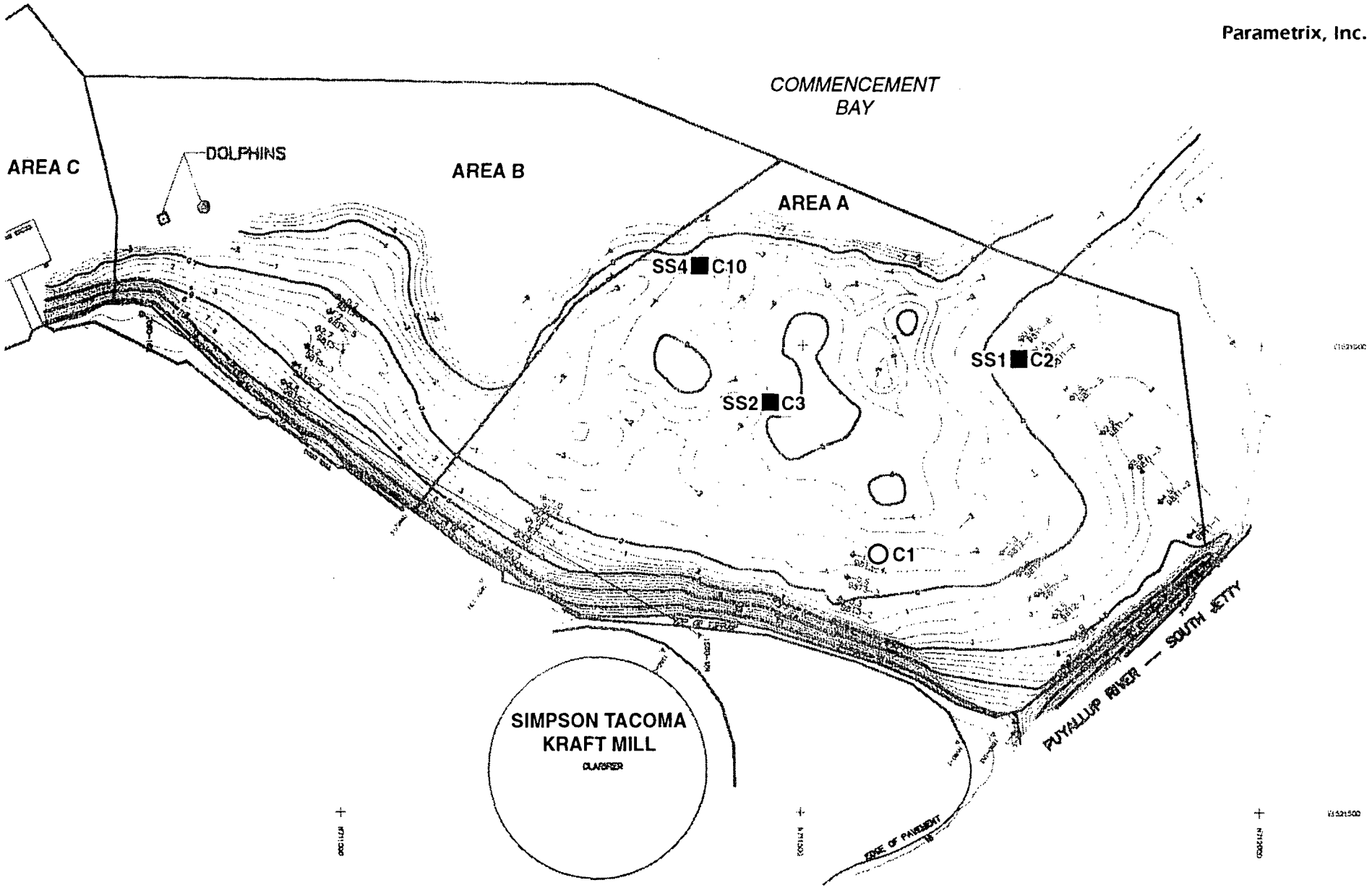
Benthos and macrophytes were examined annually at the site over the period 1994 through 1998; epibenthic sampling was conducted in 1994 and 1995. The monitoring plan implemented the two-tiered biological indicators approach in 1994 (Section 1.4.4 of the 1994 Annual Monitoring Report, Parametrix 1995c). This approach analyzes benthic communities at six sampling stations as the overall indicator of a healthy ecosystem and Project success. Under Tier One, comparisons are made between the six stations and background stations (located elsewhere in Commencement Bay) for the current year and in comparison to the past year's results. If Tier One analyses identify statistically significant differences that warrant further review, a Tier Two analysis is conducted to analyze ecological interactions at the Project and whether changes are due to natural or human causes. If the latter, an early warning notice is sent to EPA. The biological monitoring did not result in either an early warning notice or in the need to conduct a Tier Two analysis in the period 1994 through 1998.

Table A-2. Summary of chemical detections over early warning levels at the Project 1988 through 1998.

	Sediment Sample Type	Total Number of Parameters	Total Number of Samples[a]	Total Number of Possible Detections	Total Number of Detections Above Early Warning Levels[b]
1988	Cores	55	25	1,375	4
1989	Cores	55	19	1,045	1
	Gas Vents	54	3	162	0
1990	Cores	44	13	572	0
1991	Cores	50	36	1,800	31
	Gas Vents	52	8	416	0
	Surface	96	5	480	3
	Seeps	52	4	208	5
1992	Cores	4	36	144	2
	Gas Vents	5	10	50	0
	Surface	153	5	765	0
1993	Cores	6	18	108	0
	Surface	153	5	765	0
	Seeps	49	3	147	0
1995	Cores	6	18	108	1
	Surface	159	5	795	6
1998	Cores	6	4	24	0
	Surface	31	3	93	1
Total		**1,030**	**220**	**9,057**	**54**

[a] Replicate or duplicate samples at a single station are not included in these totals.

[b] Many of the chemicals considered here do not have established early warning levels. However, these chemicals were considered below early warning levels when they were undetected (most cases) or detected at low levels. None of these chemicals were identified by EPA as having concentrations of concern at the Project.



Simpson Tacoma Kraft Co./St. Paul Waterway/55-1650-57(01) 6/99

SCALE IN FEET
0 75 150

N

C1 Subsurface Coring

SS3 C4 Surface and Subsurface Sediments

Figure A-2.
Surface and Subsurface Sediment Sampling Locations (July 1998)

Results for 1994 through 1998 are similar to conclusions from the first five-year review (Parametrix 1994b). The silt and sand fractions composing the outer, exposed beaches have fluctuated annually. The inter lagoon area has become typical of a Puget Sound mudflat, with Stations B1 and B6 (Figure A-3) containing a majority of fines and silty material (also verified by site inspection on the periphery of the lagoon).

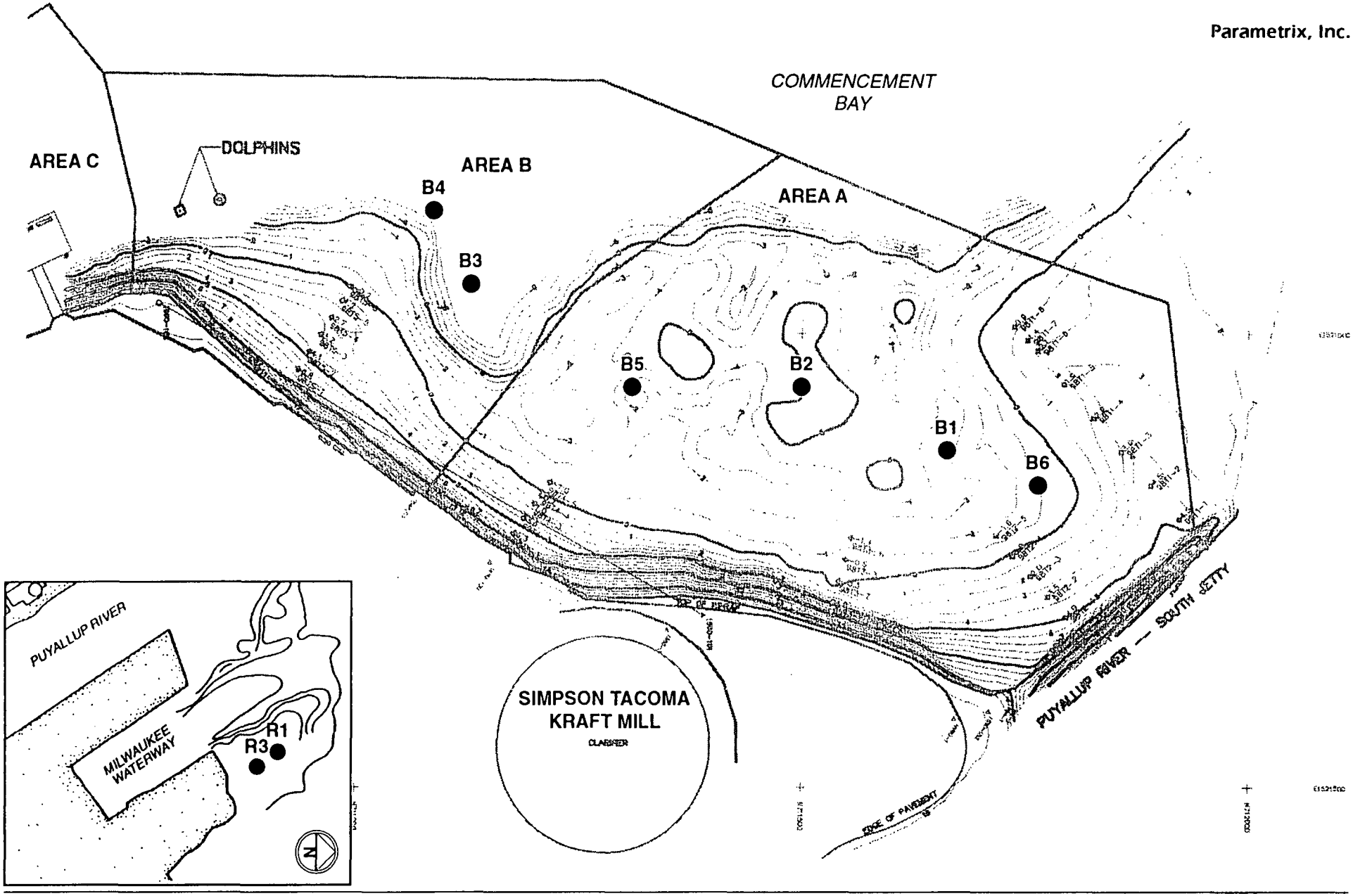
The abundance and complexity of biological systems at the site have been relatively similar for at least seven of the past ten years following initial recolonization (Table A-3). From 1994 through 1998, the number of taxa identified to species at all Project stations ranged from 132 to 167, with variations at individual stations each year (Table A-3). Variations in the total number of taxa were also noted for all Project stations. Although total abundances at Project stations fluctuated over the period 1994 through 1998, the mean total abundance (27,788 organisms) for those years was higher than the mean total abundance (21,110 organisms) recorded in prior years. The variations in abundance that occurred 1994 through 1998 appeared to reflect bay-wide conditions (Parametrix 1995c, 1996, 1997c, 1998a, 1999).

Prior to Project construction, the site was essentially devoid of marine life. The restored intertidal beach and mudflats recolonized rapidly within the first two years (Parametrix 1990, Weiner 1991). Because there has been a change in sampling seasons from summer (in 1989 and 1990) to spring, direct ten-year comparisons of abundance and diversity across all sampling years are not statistically appropriate. However, benthic abundance had increased from essentially zero to between 627 and 5,275 organisms per station by 1991. This increase in abundance from pre-Project conditions has been maintained over the past seven years within a range of 1,172 to 10,361 organisms per station. Abundances ranged from 2,503 to 4,414 organisms per station in 1998.

Over ten years, based on the number of organisms per square meter obtained in the annual monitoring (averaging more than 7,000 organisms per square meter over 69,000 square meters), the site has changed from an area with few benthic organisms to intertidal habitat that has annually sustained a diverse population of approximately one-half billion benthic organisms.

The particular species at each station has generally varied from year-to-year, which appears to reflect the dynamic nature of the delta environment near the mouth of the river. Although a few species dominated a particular station in any given year, a variety of species have inhabited most of the areas sampled. The results indicate ongoing recruitment, biological diversity, and self-sustaining habitat.

As was concluded in the first five-year review, substantial epibenthic populations have been found at the Project site, indicating that these organisms are utilizing the site (Parametrix 1994b). Because epibenthic populations are generally highly variable, as reflected in Project monitoring, the biological indicators approach developed and adopted under the monitoring plan for use in the second five-year period focused on benthic monitoring rather than epibenthic monitoring.



Simpson Tacoma Kraft Co./St. Paul Waterway/55-1650-57(01) 6/99

SCALE IN FEET

0 75 150

N

B Stations = Project Area Stations

R Stations = Background Stations

Figure A-3. Benthic Infaunal Sampling Stations

Table A-3. Abundance of benthic infauna and number of taxa at Project stations, by year, 1991 through 1998.

	Totals							
	1991	1992	1993	1994	1995	1996	1997	1998
A. Abundance								
B1	627	2,693	2,017	3,113	6,117	8,589	2,763	4,414
B2	2,193	3,062	3,341	4,042	3,037	6,268	3,700	3,692
B3	5,275	5,557	5,585	3,806	5,988	8,141	3,768	4,221
B4	3,419	8,303	9,718	4,471	5,247	10,361	2,705	3,129
B5	1,149	2,163	1,172	2,576	1,913	4,911	1,339	2,503
B6	1,262	3,235	2,559	5,703	7,947	3,978	6,681	3,818
Total	13,925	25,013	24,392	23,711	30,249	42,248	20,956	21,777
B. Number of Taxa Identified to Species								
B1	38	56	69	84	74	73	69	67
B2	74	67	69	77	65	68	81	61
B3	85	70	73	87	83	105	99	90
B4	79	82	80	95	96	86	96	89
B5	56	69	60	89	68	86	58	74
B6	59	74	75	79	78	71	68	63
Total	174	216	189	141	148	156	167	132
C. Total Number of Taxa								
B1	56	83	89	104	110	95	86	91
B2	102	101	91	98	99	89	105	87
B3	112	127	120	109	127	140	132	124
B4	111	134	119	112	132	118	120	121
B5	83	94	82	107	94	109	79	106
B6	69	91	79	98	111	111	99	88
Total					211	222	225	190

Epibenthos are common prey organisms for salmonids. A separate sampling effort conducted in 1997 confirmed use of the site by juvenile salmonids during the spring migration, as reported in a separate study and in Section 1.3.3.3 of the 1997 annual monitoring report (Parametrix 1997b and 1998a).

Macrophyte coverage at the site has increased greatly since construction and has been maintained over the period 1994 through 1998. By 1991, macrophytes were growing on almost every stable hard surface available that was protected from substantial wave action or currents. By 1993, it appeared that macrophyte coverage was near the maximum possible given the physical conditions of the site. As material is redistributed on the site, some previously available surfaces are buried or moving around the site, as was anticipated in Project design.

Since 1991, annual variations in coverage by different species have been typical. This annual variation appears to be caused by changes in the availability of hard surfaces for macrophyte attachment, changes in tidal cycles, and weather (sun and growing seasons for each particular year). Some patterns have been observed in the distribution of aquatic macrophytes. A relatively dense kelp bed has formed along the shoal between shallow subtidal and intertidal elevations on the western boundary of the lagoon (where the initial berm was placed for Project construction). This kelp bed provides shelter, food, and detrital biomass for a range of species utilizing the mudflat. Similar functions are provided by beds of kelp and ulva that range in roughly a crescent from the southeastern-to-northeastern shoreline of the lagoon, and a finger of vegetated shallows extending into the center of the lagoon (Parametrix 1994b through 1999).

The overall habitat results for the past five years, and for the first ten years of the Project, are similar to and consistent with the data and assessment made by EPA and the consulted agencies at the conclusion of the first five years of the Project. As stated in the first five-year review, abundance and diversity observed at the Project site have been generally similar to those found at the various background stations sampled and indicate a community similar to a typical healthy back-bay mudflat in Puget Sound.

APPENDIX B

BIOLOGICAL INDICATORS APPROACH
ST. PAUL WATERWAY AREA REMEDIAL ACTION
AND HABITAT RESTORATION PROJECT

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ABSTRACT

A two-tiered biological indicators approach is presented in this document. Later sections of the document describe analytical and statistical methods that are used in this approach. The statistical tests employed were chosen because they have the statistical power to provide valuable information when considering biological indicators.

Within Tier One of the biological indicators approach, there are two levels of analyses. Tier One, Level One, involves assessing similarity of benthic community structure between the Project stations and background stations using several types of factors:

- Total number of taxa for each station
- Numbers of numerically-dominant taxa at each station
- Numbers of non-numerically dominant taxa at each station
- Total number of individuals at each station
- Standing crop analysis (biomass).

These factors will be analyzed using:

- Proportional similarity index (PSI)
- Analysis of Variance (ANOVA).

Tier One, Level Two, includes comparisons of benthic data from the most recent year to that of the previous year for Project and background stations. Such comparisons help confirm differences and similarities observed over time at the Project, and confirm that observed changes are not the result of changes in the background stations as opposed to the Project stations.

If any statistically significant differences are found in any one of the Tier One analyses, EPA will receive a notification letter detailing those differences, and Tier Two biological indicators may be conducted. Tier Two analyses will focus on ecological interactions at the Project, and assess whether any ecologically significant changes are due to natural or anthropogenic causes. The Tier Two indicators will compare Project and background abundances of trophic guild taxa, key species, and pollution-sensitive or -tolerant taxa.

INTRODUCTION

This document describes the biological indicators approach used at the St. Paul Waterway Area Remedial Action and Habitat Restoration Project (Project) constructed adjacent to the Tacoma Kraft Mill along the shoreline of Commencement Bay in 1988. Development of biological indicators by Simpson and Champion and approval by EPA was required by the St. Paul Waterway Consent Decree Exhibit A to the federal Consent Decree. Use of the biological indicators approach ensured that the natural habitat at the Project was restored to support a productive biological community, and allowed evaluation of potential sediment recontamination in the upper layers of the sediment cap. The biological indicators became effective and applied to all biological data collected from 1994 through 1998 at the Project.

As described in Section 5.2 (Task 4, Step 7) of the Contingency Monitoring and Adaptive Management Plan, the biological indicators approach may be initiated in the future to evaluate the ecology importance of the contingency screening data or compliance with the biological performance standards in the Consent Decree.

Biological indicators are intended to provide early evidence of changes in biological communities inhabiting the Project habitat, and if necessary, to prompt a review process that will evaluate the causes of these changes and the consideration of subsequent actions. Biological indicators are incorporated into the response to the contingency screening process.

For the purposes of this document, the term "biological" refers to marine benthic community structure. Monitoring results over the period 1988 through 1993 documented the development of benthic communities on the Project habitat. These monitoring results provided the necessary information for developing meaningful biological indicators.

In order to develop the biological indicators approach, the advice of many experts was sought, and the site-specific benthic infauna data obtained from 1988 to 1993 at the Project were thoroughly reviewed. Several steps were taken to develop the biological indicators approach. First, Parametrix surveyed approximately 60 scientific experts across the United States to identify any previous use of a concept similar to biological indicators (Parametrix 1994a). It was found that although the concept of either a biological indicator or a suite of biological indicators is a simple one, in practice such indicators have seldom been used. Because of the diversity of ecosystems and biota, there was no scientific agreement as to which characteristics of biological communities should be considered, or what levels of change in these characteristics should be considered detrimental.

The second step in developing biological indicators was to examine existing data from the Project. The benthos data from 1988 through 1993 provided a wealth of knowledge on the Project habitat. Consequently, this wide variety of past information was used in building a suite of analytical processes using biological data that allows observations of biological change at the Project.

The third step was to examine existing site-specific data to determine whether there were statistical limitations that might be expected in future data analyses. Quantitative analyses of benthic infauna, as well as other ecological systems, are generally statistical in nature. As a result, when developing biological indicators, some of the assumptions, properties, and limits of the applicable statistical analyses were reviewed to ensure that statistics were properly applied.

This document describes an approach for evaluating benthic infauna data that uses biological indicators. The benthic infaunal data used as indicators and the approach used for their evaluation is presented first. The technical methods of data analyses that are used as a part of the approach are then presented.

BIOLOGICAL INDICATORS APPROACH OVERVIEW

The biological indicators approach begins by compiling the benthic infaunal data that has been collected using the methods described in Section 6.3 of the Contingency Monitoring and Adaptive Management Plan. The benthic data will then be assessed through a two-tiered process (Table B-1).

Tier One Biological Indicators

Tier One biological indicators will use statistical analyses to identify similarities or differences between sampling stations at the Project and the two background stations. Tier One of the biological indicators has two levels. The Tier One, Level One, statistical analyses, which address comparisons with the present year's data, include:

Statistical analyses of Numerical Abundance (each measure will be defined using station means):

- Total number of taxa at each station
- Number of numerically-dominant taxa at each station
- Number of non-numerically dominant taxa at each station
- Total number of all individuals at each station.

Statistical analyses of Standing Crop using:

- Wet-weight biomass of major taxonomic groups.

Quantitative Analysis of Station Similarity using:

- Proportional Similarity Index (PSI) of all taxa
- Analysis of Variance (ANOVA).

All Tier One, Level One, analyses will compare Project station data to those data from the background stations using the specific data listed above. These analyses will include tests for differences between pooled background and pooled Project stations and tests for differences between individual stations (among station differences). The PSI analysis will also be performed using taxon abundances from all Project and background stations. Analysis will involve all taxa collected where appropriate.

Table B-1. **Biological indicators analyses. The taxa in the analyzed data set are all taxa (identified to the lowest practical taxonomic level) except where otherwise defined. For each statistical test the general criterion is: No significant difference between the sample; $\alpha \leq 0.05$; $\beta = 0.2$, MDD = the lowest MDD possible.**

Analysis Type	Data Analyzed	Statistical Test
Tier One, Level One. Analysis of Present Year Data (Project and Background)		
1.1 Analysis of Numerical Abundance	• Pooled Project vs. Pooled Background • Among Station (8-sample ANOVA)	
1.1.1 Total Number of Taxa	• All Taxa	Two-sample test and 8-sample ANOVA
1.1.2 Numerically Dominant Taxa	• Smallest number of taxa which comprise 75% of total abundance	Two-sample test and 8-sample ANOVA
1.1.3 Non-numerically Dominant Taxa	• All taxa minus dominant taxa	Two-sample test and 8-sample ANOVA
1.1.4 Total Number of Individuals at each Station		Two-sample test and 8-sample ANOVA
1.2 Analysis of Biomass (Standing Crop)	• Defined taxonomic groups • Pooled Project vs. Pooled Background • Among station (8-sample ANOVA)	Two-sample test and 8-sample ANOVA
1.3 Analysis of Station Similarity Using Proportional Similarity Index (PSI)	• All station data pooled (all taxa)	PSI
Tier One, Level Two. Comparison to Previous Year Data (Project and Background)		
1.5 Analysis of Numerical Abundance	• Pooled Project vs. Previous Year's Project • Pooled Background vs. Previous Year's Background • Between years for each station	Two-sample tests
1.6 Ordination of the Benthic Infauna Data	• Between years for each station	Ordination analysis
Tier Two. Ecological Analyses of Present Year Data (Project and Background		
2.1 Trophic Guild Analyses	• Pooled Project vs. Pooled Background • Among Station (8-sample ANOVA) • Total number of individuals in each defined trophic guild	Two-sample test and 8-sample ANOVA
2.2 Key Species Abundance	• Total number of individuals in each defined key species	Two-sample test and 8-sample ANOVA
2.3 Pollution Sensitive/Tolerant Species	• Total number of individuals in each defined species	Two-sample test and 8-sample ANOVA

For biological indicators involving numerical abundance, all benthic organisms collected will be identified to the lowest practical taxonomic level and used in the analyses. In some cases, such as standing crop analysis, information will only be available for major taxonomic groups.

Tier One, Level Two analyses will involve statistical evaluations of year-to-year changes in abundance in the overall Project and background station benthos by comparing to the previous year's data. These analyses are necessary to verify that any differences seen are due to changes occurring at the Project stations as opposed to the background stations.

If the Project stations are not significantly different ($p>0.05$) from either the present data for background stations or the previous year's data for the Project stations, no further action will occur under the biological indicators approach (Figure B-1). Background station data for the present year will also be compared to the previous year's background data. If there is a difference between the background stations and the Project stations that is due to significant changes over time at the background stations rather than the Project stations, no further action will occur under the biological indicator process.

The PSI results will be used to evaluate station groupings and determine whether any differences found are based on the station groupings, rather than a decline in station health.

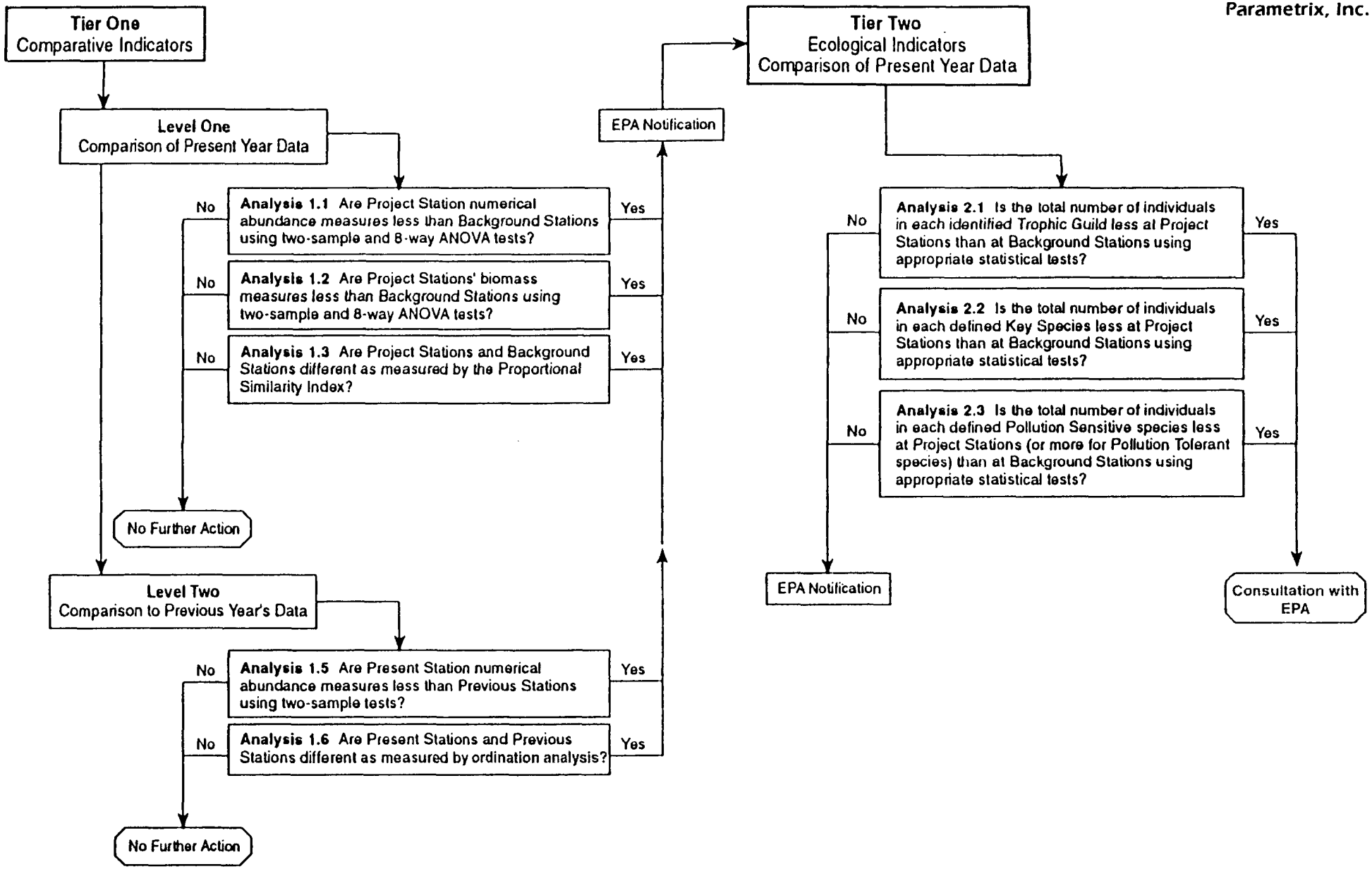
Within seven days of completion of all Tier One, Level One and Level Two analyses, EPA will be notified of these results including identification of any statistically significant differences. If any significant differences are found, a working session will be held including presentation of all applicable data. EPA, with input from Simpson and Champion, will determine whether Tier Two analyses will be required.

Tier Two Biological Indicators

Tier Two biological indicators will evaluate ecological interactions. The Tier Two biological indicators will include qualitative evaluations and statistical analyses comparing present year's data at Project versus background stations. Comparisons will be made for:

- Abundances of trophic guilds
- Abundance of key species
- Abundances of pollution sensitive and/or tolerant taxa.

In Tier Two, statistical differences found in Tier One will be evaluated as they relate to trophic guilds, key species, and pollution sensitive and/or tolerant taxa. Qualitative and statistical comparisons will be conducted for each of the three ecological groups. These analyses will include tests for differences between pooled background and pooled Project samples and tests for differences between individual stations (among station differences). The evaluations will determine whether changes are either a part of natural variation and/or succession or due to anthropogenic causes.



Note: See text for details.

Figure B-1.
Biological Indicators
General Decision Process

BIOLOGICAL INDICATORS APPROACH

This section first describes some general considerations which were made in selecting the biological indicators approach. Later sections describe in detail each of the biological indicators and how they are used.

GENERAL CONSIDERATIONS

Epibenthos

Measures of the epibenthic community at the Project were not proposed as biological indicators. Data collected from 1988 through 1993 at the Project indicated that applying a biological indicators approach to epibenthos would be difficult because of wide variations in abundance and species composition of epibenthic communities in any given year.

In 1992 total epibenthos per sample at station "NEBA" in April were estimated to be 13,017 organisms but the standard deviation among all samples at the same station was 17,333 which is 133 percent of the mean abundance. At the other 1992 stations the standard deviations were 147, 94, and 141 percent of the station means. During these investigations there was no other physical, chemical, or biological parameters that indicated that there was any problem with the health or integrity of the Project. At the same time epibenthos abundances could vary by more than a 100 percent for two replicate samples at a given station.

It is known that epibenthos vary with tidal changes and small changes in substrate (Simenstad et al. 1993). In addition, epibenthos are greatly affected by temperatures, particularly temperature variations in spring. Sampling on the same date each year may result in substantially different results depending on spring weather for that year. It is also known that epibenthic blooms can occur in the spring when conditions are particularly favorable (Parametrix 1993).

Some of these factors that cause interannual variation in epibenthic communities can be partially accounted for by sampling epibenthos at a closely-matched reference station. However, it was difficult to find representative reference stations for the Project from 1988 through 1993. The overall number of variables, including habitat stress, that may cause changes in epibenthos communities make the use of epibenthos as an indicator of stress problematic. Discerning which variables are causing observed differences or changes in populations can be difficult.

A sampling design for epibenthos could be constructed which would attempt to quantify the affects of some of these variables. However, benthic organisms were also studied at the Project from 1988 through 1993. Benthos are also affected by factors other than habitat stress but the number of variables and their affect on abundances may be less dramatic than for epibenthos. For these reasons, benthos were chosen as the biological indicators for the Project.

Benthos

The goal of the biological indicators is to measure the performance of the Project habitat. By measuring performance with a consistent set of indicators from year to year the Project's ability to provide restored habitat can be determined.

Benthic infauna inhabiting the Project have and will continue to change naturally in many different ways, potentially resulting in substantial and rapid shifts in taxa. These natural changes include, but are not limited to:

- Changes in secondary ecological processes, such as the intensity of competition or predation, caused by the colonization of the Project habitat by predators or dominant competitors.

- Changes in the pool of potential larval recruits, which could be caused by changes in the populations whose spawning furnished larvae coming to the Project habitat.

- Changes in the physical regime, such as a slight increase of water temperature (El Niño conditions), that would alter the dynamics of adult-larval or larval-larval interactions.

The biological indicators should be sufficiently diverse to identify these types of changes. Analyses should also allow for determination of the effects of such natural processes on the benthos.

Two tiers of biological indicators have been used to analyze changes in the benthic infauna at the Project and background stations. The Tier One, Level One, analysis concentrates on overall meristic (or discrete) station data and station similarity as compared to background stations. The Tier One, Level Two, analysis consists of statistical analyses of changes in the assemblages from the previous year's data. If significant differences between the Project and background stations or between years at the Project stations are found in any one of the Tier One analyses, and these differences are potentially indicative of a decline in Project health (e.g., an apparent anomaly or due to interannual changes in background stations), the Tier Two analyses will be conducted. The Tier Two analyses will examine ecological interactions of the benthic community.

Additional Considerations for the Biological Indicators Approach

While implementing the biological indicator approach described above, several additional factors will be considered at Tier One and Tier Two. These factors could potentially obscure interpretations of results of the biological indicators approach. These factors include:

- Natural changes of the benthic infaunal population examined and how substantial those natural changes are compared to any potentially undesirable changes observed.

- Natural changes in the substrate at both the background and Project stations and how those natural changes affect the benthic community compared to any potentially undesirable changes observed.

- Adequacy of the statistical power of the methods and tests being used to discern community changes.

- The design of the sampling plan and how it might affect or bias observed results.

Each of these factors will be examined to ensure that the observed changes are not caused by natural variations or inappropriate methodologies.

The appropriateness of the background stations for comparison with Project stations must also be considered. Background stations may change from year to year due to anthropogenic or other causes and become less suitable as background stations. If this occurs, it is proposed that statistical comparisons be made to the previous year of Project data. In the next year of data collection, new background stations will be identified and tested as a part of that year's monitoring.

In addition, each of the biological indicators must be carefully evaluated in relation to the other indicators when considering the significance of observed changes. For example, statistically significant changes in the overall station similarity, as demonstrated by ordination, might be found and may indicate substantial shifts in assemblage or community structure. If this occurs, these shifts will likely be evident in the other biological indicators as well. Conversely, significant changes in, for example, the total number of dominant taxa, may reflect ecological shifts that are normal components of the natural history of the sampled stations and may not be reflected in other analyses.

Finally, while the analysis of ecological interactions is important and can certainly give insight into other changes occurring in the sampled areas, critical data may be lacking for a complete discussion of some of the ecological interactions. These data gaps will be evaluated in relation to the findings of other parameters or factors.

Note: Unless otherwise stated, all references in this appendix to significance or significant difference refer to statistical significance and not to biological or ecological significance.

TIER ONE BIOLOGICAL INDICATORS

Two major factors can describe the relative health or well-being of any biological community. The first is the array of basic numerical data inherent in species-abundance patterns. Although this provides a fundamental method of describing a community, it examines only one aspect of the biotic community found in an area. A second factor is an indication of standing crop or biomass. Although these factors are not independent, neither alone can be used as an adequate indicator of habitat conditions.

Biological indicators of station benthic infaunal community structure require the comparison of assemblage-by-assemblage species abundance patterns to background stations (Tier One, Level One) and a similar comparison from the present year to the previous year (Tier One, Level Two).

In order to conduct these analyses, several other types of data must be collected and initially analyzed. These analyses include basic enumeration and cataloging of specimens as well an examination of the physical characteristics of background and Project stations. Specimens will be identified to the lowest practical taxonomic level. All taxa identified to the lowest practical taxonomic level will be used in each analysis unless otherwise noted. Examinations of physical characteristics include comparisons of station depth, sediment particle size distribution, hydrographic characteristics, and the organic content of sediments. These examinations may include statistical or proportional similarity analyses.

Tier One, Level One Analyses

Analysis 1.1: Analyses of Numerical Abundance

Statistical comparisons between Project and background stations will be conducted for several meristic factors. Station mean abundances will be statistically compared to determine whether there is no significant difference between the Project and background stations (null hypothesis), or whether there is a significant difference between the Project and background stations (alternative hypothesis).

Comparisons will be conducted between the following groups:

- All Project stations (pooled) versus all background stations (pooled); and
- Comparisons among all individual stations through a 8-sample ANOVA (or appropriate non-parametric test).

Two null hypotheses will be tested: (1) there is no difference in mean abundance between the pooled background stations and the pooled Project stations; and (2) there is no difference in mean abundance between the individual stations (background and Project).

Testing the two null hypotheses will provide different levels of information. The two-sample tests will be used to compare the mean abundances between the pooled background and pooled project stations. This test will provide a general assessment of Project performance as a whole.

The comparisons between individual stations (among station tests) will take into account the existence of different community structures and developing habitats at the Project. If significant station differences are indicated by the ANOVAs (parametric or non-parametric), a multiple comparisons technique will be conducted to identify specific pairwise differences between stations.

These statistical comparisons will be conducted at the 0.05 significant level for each of the following analyses:

Analysis 1.1.1—Total number of taxa at each station

Analysis 1.1.2—Number of numerically dominant taxa at each station

Analysis 1.1.3—Number of the non-numerically dominant taxa at each station

Analysis 1.1.4—Total number of individuals at each station

All of these analyses will be conducted on station means. Numerically dominant taxa will be defined as those taxa which cumulatively comprise 75 percent of the total abundance.

The statistical procedures that will be used are discussed in more detail in the methods section. Generally, these statistical comparisons will include a preliminary comparison of the data distributions to a normal distribution and a test of homoscedasticity (homogeneity of variance or HOV). Both of these tests are necessary to determine if the assumptions required for parametric statistical tests are met. Prior to testing the data for normality and HOV, the abundance will be log-transformed (ln[x+1]), since abundance data commonly include a large number of high values (i.e.,

the data are skewed). If the assumptions are met, parametric tests are preferred for their greater power. If the assumptions are not met, then non-parametric tests should be used. The following tests will be used: one-way analysis of variance (parametric), and Kruskal-Wallis and Mann-Whitney U tests (non-parametric). If the assumptions for parametric tests are met for most of the groups examined, then parametric tests will be used for the statistical comparisons. Analysis of variance is robust even when the assumptions of normality and homogeneity of variance are not completely met.

Cataloging of specimens and presentation (graphical or tables) of data will include calculations of station mean abundances. Station mean abundances (number of taxa) will be used in each of the above tests.

Analysis 1.2: Standing Crop Patterns (Wet-weight Biomass)

Similar analyses can be performed using major taxon wet-weight biomass for whole sediment samples as an indication of standing crop. Significant changes in biomass can indicate either the overabundance of one or a few species or significant changes in all species; either of these changes could be due to substrate contamination or other causes. Biomass patterns are likely to be biased if one or a few large individuals are present. Consequently, in addition to total major taxon wet-weight biomass measurements, a subsequent similar set of measurements will be made excluding large organisms. The excluded organisms will be subjectively chosen to remove those individuals whose weight is a substantial fraction of the total. The weight and the major taxonomic group of any excluded organism will also be recorded.

Both the total and selective biomass data will be analyzed using traditional statistical analyses as described in the previous section. The traditional analysis will use ANOVA techniques if the data are sufficiently homogeneous in variance and if they are normally distributed. The appropriate use of parametric or non-parametric tests will be determined using the same methodology as described in Analysis 1.1. If most of the examined groups meet the parametric test criteria, all of the tested groups will be examined using parametric tests. If the data do not meet the criteria, appropriate non-parametric tests will be used to verify the results of the parametric tests.

Statistical comparisons (parametric and/or non-parametric) will be conducted between the following groups:

- All Project stations (pooled) versus all background stations (pooled); and
- Among all individual stations.

Analysis 1.3: Proportional Similarity Index (PSI)

Sample comparisons of taxa abundance will be based on taxa-sample matrices from station replicates. Similarity between stations will be measured with the PSI, which considers the total number of taxa collected from all the samples. This form of the PSI is generally equivalent to the Bray-Curtis index. This analysis will be run on the taxa sample matrices using a nearest-neighbor group clustering algorithm. The data used for these PSIs will be the mean of the 5 replicates for each station (station means of actual and log-transformed abundances). Results will be displayed as optimally rotated dendrograms.

When completed using proportions of abundances, the PSI is independent of the number of taxa in each sample. This sample size independence is desirable when the basis of sampling is different between samples (e.g., when data from different studies are used). When abundances are used in the computations, the resulting quantity is the Bray-Curtis Index, and this index is influenced by sample size. This influence is reduced, however, when log-transformed abundances are used.

The following is the formula used for the PSI:

$$PS_I = \frac{2 \sum_{i=1}^{s} \min(x_{ij}, x_{ik})}{\sum_{i=1}^{s} (x_{ij} + x_{ik})}$$

Where:	x_{ij}	=	The number of individuals of taxon "i" in sample "j"
	x_{ik}	=	The number of individuals of taxon "i" in sample "k"
	s	=	The number of taxa across all samples

Analysis 1.4: Ordination of the Benthic Infaunal Data: Principal Coordinate Analysis (PCOR)

As approved by EPA in a July 29, 1997 letter to Simpson Tacoma Kraft Company (U.S. EPA 1997), PCOR is no longer required as part of the biological indicators approach.

Tier One, Level Two Analyses

Analysis 1.5: Analyses of Numerical Abundance (Comparison Between Years)

This analysis will be similar to Level One analyses of numerical abundance expect comparisons will be made between present year data and the previous year's data. Station mean abundances will be statistically compared to determine whether there is no significant difference between present data and the previous year's data. Comparisons will be conducted between the following groups:

- All present year Project stations (pooled) versus all previous year Project stations (pooled); and
- Two sample comparisons between individual stations (e.g. B1 1994 vs. B1 1993, B2 1994 vs. B2 1993, etc.).

Hypotheses to be tested and the numerical data to be used for each test will be the same as in Analysis 1.1 described above except that comparison between years will be conducted.

Analysis 1.6: Ordination of the Benthic Infaunal Data (Comparison Between Years)

This analysis is similar to the ordination methods described in Analysis 1.4 to determine whether the infaunal assemblages sampled annually from each station are significantly different from samples collected during the previous year. The procedures and methods followed for Analysis 1.6 will be identical to those followed for Analyses 1.4 except the comparisons will be made to the previous year's data.

Practical Considerations of the Tier One Statistical Analyses

Several underlying complicating conditions exist at the Project and in Commencement Bay.

1. At least two marine benthic infaunal assemblages or communities exist on the Project habitat (Parametrix 1993).

2. Those communities are changing temporally, possibly at different rates. Their boundaries may be changing spatially as well (Parametrix 1992, 1993). These changes are likely normal sequential or stochastic changes in the benthic assemblages in the area.

3. Background stations similar to the Project stations may be found during any given sampling period, particularly nearby in the Puyallup River delta (Parametrix 1993). The nature of the estuarine sedimentation processes in the delta or human activity may render these background stations significantly different from year-to-year.

Two different testable combinations of conditions may occur each year.

1. The Project and background stations are the same, or

2. The Project and background stations are different; this condition could be due to significant changes at:

   - the Project stations;

   - the background stations; and/or

   - both the Project and background stations.

These combinations of conditions define the following questions that should be addressed:

Question 1. Are the samples from the Project stations statistically distinguishable from the samples from the background stations?

There are two possible situations where Question 1 could be answered in the positive. The first situation is that both sets of stations are normal (see Table B-1). The second situation is where both sets are abnormal. The assurance that the stations are normal could be done in two ways, first, detailed examination of the fauna from both stations on a taxon-by-taxon basis, and second, by statistically comparing the stations to data taken in the previous year, if those data were determined to be normal.

Regardless of whether both sets of samples were the same in a given year, the Project stations need to be compared to the previous year's Project stations and a judgement must be made as to the condition of the present year's samples. This leads to the next relevant question.

Question 2. Are the samples from the Project stations in a given year statistically distinguishable from the samples from the Project taken in the previous year?

If both years' samples cannot be shown to be different, then presumably the Project biota have reached some temporal equilibrium, which may or may not be normal. The Project samples would be considered normal if they were indistinguishable from samples from the background stations and the background stations were presumed to be normal. The determination of normality would be further strengthened if the data from the Project stations were not distinguishable from the previous year's data from the Project stations.

If the Project station data are distinguishable from the background station data, a comparison with the background station data from previous years would help in the assessment of which of the sets of stations, if any, is abnormal. Over time the background stations may be physically altered to the extent that they no longer serve as adequate background stations. Consequently, the third relevant question is as follows.

Question 3. Are the samples from background stations in a given year statistically distinguishable from samples taken from the background station in previous years, if those previous samples were shown to be "normal"?

For all of these questions the basic statistical process tests the following hypothesis:

H_0: The samples from a given location and year are not distinguishable from the samples from a second given location and year. Type 1 error is set at $\alpha \leq 0.05$; Type 2 error is determined yearly by a power analysis of the collected samples.

H_a: The samples are distinguishable.

These questions can be addressed using traditional statistical analyses, such as ANOVA, which are part of the Tier One analyses.

TIER TWO BIOLOGICAL INDICATORS

As described in the biological indicators overview, Tier Two analyses will be conducted if the statistical evaluations conducted in Tier One analyses indicate significant differences potentially indicative of a decline in Project health.

The enumeration and quantitative description of the benthic infauna conducted under Tier One of the biological indicators approach will provide insight as to whether an assemblage is normal, interactive, and productive. However, Tier Two will focus on the ecological interactions occurring at the site. An examination of the collected taxa abundance data for ecological interactions may be able to provide significant information within the framework of previous research. In Tier Two, the attempt will be made to provide a synthesis of such data and a functional interpretation of the

biological assemblages sampled at the site. Because it is likely that only one or a few stations will show significant differences in the Tier One indicators, Tier Two analyses described here may only include the station or stations which showed significant differences in Tier One indicators.

Tier Two analyses will examine common infaunal taxa which belong to known feeding guilds or to other ecologically functional groups (Parametrix 1994a). As with the Tier One analyses, Tier Two includes qualitative evaluations and statistical tests of these ecological groups. Analyses will be performed using present year data for the Project station compared to the background stations. Tier Two biological indicators will include the following analyses:

Analysis 2.1 - Examination of trophic guilds including statistical and qualitative comparisons of guild abundances and descriptions of food webs where information is available.

Analysis 2.2 - Examination of key species including statistical comparisons if abundances are sufficient across the stations to provide valid statistical results.

Analysis 2.3 - Examination of changes in abundance of pollution-sensitive or -tolerant taxa, including statistical comparisons to background stations if abundances are sufficient across the stations to provide valid statistical results.

Normality and homogeneity of variance will be examined using the same methods described for the Tier One analyses. If most of the groups examined meet the requirements for parametric tests, then parametric tests will be conducted. Although the analysis of variance test is robust, if these requirements are not met for any of the examined groups, then non-parametric tests will also be conducted to verify the results of the parametric tests. The statistical tests used will evaluate the following hypotheses:

Analysis 2.1 - For each trophic guild:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations

H_a = the mean abundances are significantly different

Analysis 2.2 - For each key species:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations

H_a = the mean abundances are significantly different

Analysis 2.3 - For each pollution-sensitive or -tolerant taxa:

H_o = the mean abundance at the Project stations is not significantly different from the mean abundance at the background stations

H_a = the mean abundances are significantly different

The statistical comparisons for each analysis will test two specific null hypotheses: (1) the mean abundance for the pooled Project stations is not different from the mean abundance for the pooled background stations, and (2) the mean abundances for the individual stations, background and Project, are not different. All statistical comparisons will be tested at the 0.05 significance level.

Because these tests focus on a particular group of the benthic community at the site, the abundance of some of these groups may be relatively low. This may result in statistical tests with relatively low power particularly for Analysis 2.3 which involves pollution reactive taxa. The relative power of any test considered will be evaluated so that analyses with wholly insufficient power are not conducted. The power of particular tests will be considered when results of these tests are evaluated. As with other tests, the goal for statistical power will be an MDD of 50 percent of the background mean. If lack of power severely limits the interpretation of one or more indicators, the following types of tests will be considered as alternatives:

- Presence-Absence testing using standard non-parametric statistical techniques as presented in Gibbons (1985)
- Presence-Absence testing using the statistical methods of Hendrickson (1978)
- Pairwise statistical comparisons between stations presented by Goodall (1969)
- Coefficient of community (Sorensen's Index) described by Pielou (1977)
- Infaunal Trophic Index described by Word (1990).

Ongoing natural processes will be examined as both a part of Tier One and Tier Two analyses and will include examinations of the physical environment (as described under methodology) including erosion, siltation, and changes in depth throughout the Project area. In addition, the examination of key species (as described below) in Tier Two will examine species which may have created rapid changes in community structure.

A list of all taxa sampled at the Project site over the period 1988 through 1993 was compiled (Parametrix 1994a). This list was examined and appropriate trophic guilds and pollution reactive designations were defined for each taxa. The methodology for applying these designations and defining key taxa are explained below.

Trophic Guilds

Many unconsolidated sediment taxa collected are sufficiently well-known that either their specific ecological interactions are known or the basic interactions of the whole taxon can be inferred (Parametrix 1994a) (MacGinitie and MacGinitie 1968; Morris et al. 1980). This is particularly true

for intertidal or shallow subtidal taxa (Morris et al. 1980; Kozloff 1983). Within the mollusks, for example, the specific diets and trophic interactions of virtually all predatory gastropod and scaphopod mollusks from the region are known (Robertson 1963; Lloyd 1971; Spight et al. 1974; Abbot and Haderlie 1980; Shimek 1983a,b,c, 1984, 1989, and 1990; Hickman and Lipps 1983). The trophic biology of other mollusks, such as aplacophorans, other gastropods, and bivalves, can be inferred with accuracy (Kohn 1983; Haderlie and Abbott 1980; Stanley 1968; Scheltema 1981; Scheltema et al. 1991).

Similarly, the basic feeding biology of many of the local polychaete annelid groups is sufficiently well known to infer the ecological role for most of the collected taxa (Nichols 1975; Fauchald 1977; Fauchald and Jumars 1979). Arthropods have also been examined in detail, and much information is available (see, for example, Butler 1980; Garth and Abbott 1980; Hart 1982).

Many of the so-called "miscellaneous" taxa are also known sufficiently to determine their trophic or ecological roles (Austin and Hadfield 1980; McEuen 1986). In the Puget Sound region, all common sea-stars and their diets are well-understood (Mauzey et al. 1968; Birkeland 1974; Engstrom 1974; Lambert 1981). Thus, the general diet of any species of sea-star collected and its effect on the benthos can be inferred. Finally, the interactions between epifaunal and infaunal organisms are well-known for many of the common taxa (Birkeland 1974; Robilliard 1970, 1971; Morris et al. 1980).

When taxonomic assemblages are collected and examined, the ecological interactions can be inferred for those taxa with available information. Although taxa are certainly not interchangeable, it is often useful to examine and compare those organisms which have some functional aspect, such as a similar feeding mode, in common (Weinberg 1984). Trophic or feeding interactions are critical to the existence of the organisms. The major broad categories of feeding types will be examined to assess changes in the fauna and the success of the habitat at providing a "functional" ecosystem.

Key Species

Some species are considered to be "keystone" species in their representative communities. These species are so important for the specific community, assemblage, or ecosystem, that the system would likely not exist without them. Keystone species are not restricted to any one taxon or trophic level. The term was first used to describe important predatory sea stars in the rocky intertidal (Paine 1966) but has subsequently has been defined to include sea pens in Puget Sound (Birkeland 1974).

Numerical dominance is not, in and of itself, a condition of keystone status for any species. Nevertheless, very abundant species with characteristic behaviors that act to maintain or increase their numerical dominance can be considered "key" species in the lack of conclusive experimental evidence. At some of the Project stations, the tanaid, *Leptochelia savignyi*, is numerically dominant and has the ecological properties that act to maintain that dominance (Highsmith 1982, 1984). This species certainly can be considered a key species in the context of the biological indicator process. Other key species may be defined as a result of the database for the Project.

The effects of these species on the other fauna will be examined and monitored. The stability of the populations of the key species will likely be predictive of the stability of the community or

assemblage as a whole. Drastic changes in the abundance of such species will likely foretell anthropogenic effects prior to those effects being noticeable in other ways.

Pollution Reactive Taxa

Finally, the Tier Two analyses will examine the relative abundances of those taxa considered to be sensitive to the effects of pollution and those taxa considered to be indicative of the effects of the pollution. These data would intuitively seem to present the best indications of pollution effects. Unfortunately, the placing of taxa into these categories has seldom been done on the basis of their tested and confirmed tolerances or sensitivities to pollutants, but rather their presence, absence, or relative abundances in either polluted or non-polluted areas (Word et al. 1977, 1984; Pearson and Rosenberg 1978; Armstrong et al. 1980; Gray 1982; Pearson et al. 1983). These types of data are correlative, and as such cannot be used to define whether or not the taxa involved truly have the properties attributed to them. Taxa may be present or absent in the areas in question simply due to other correlative factors, such as changes in physical regime (Sanders et al. 1980).

Problems in these analyses may exist even with taxa that have been regularly regarded as pollution tolerant. One of the classic biological indicators of organic pollution is the polychaete *Capitella capitata* (Pearson and Rosenberg 1978). However, *C. capitata* has been shown to be a group of closely-related and difficult to identify, "sibling" species. Some of these species are quite pollution tolerant, while others are found only in pollution-free situations (Grassle and Grassle 1974, 1976).

Probably the best data for the use in these analyses come from the information generated in the development of bioassays. During these investigations, the physical and chemical tolerance of taxa are often well-defined, for example the amphipod *Rhepoxynius abronius*, and the sea urchins *Strongylocentrotus purpuratus* and *Dendraster excentricus* (Oakden 1984; Oaken et al. 1984; Ott 1986; DeWitt et al. 1988; Dinnel and Kocan 1988).

Relatively few taxa, however, have been examined as bioassay organisms, and even fewer of them are likely to be found at any particular sampling site. To a greater or lesser extent, many of the designations of pollution sensitivity or tolerance are based on taxonomic relationships to better known taxa. As an example, amphipods in the families Phoxocephalidae and Ampeliscidae are considered to be sensitive to pollution effects primarily due to their presumed close relationship to the better known members of a few genera within those families. These assumptions may be valid, but should be viewed as preliminary, unconfirmed, and awaiting experimental validation.

Additionally, some of the pollution-sensitive taxa were defined on the basis of published ecological information not directly related to their pollution sensitivity. For example, *Olivella baetica*, a predatory snail, has not been hitherto characterized as either pollution tolerant or intolerant. However, *O. baetica*, buries in sandy sediments and eats foraminiferans (Hickman and Lipps 1983). Foraminiferans are small, shelled, protozoans which, in turn, eat bacteria. As pollution would likely change the bacterial populations and sediment characteristics, it is unlikely that the appropriate bacterial populations and sediment conditions for foraminiferans (such as aerobic sediments) would exist. In turn, *O. baetica*, a specialized predator would also be absent. Thus, the snail is listed as "pollution sensitive." Other taxa have been similarly defined (Parametrix 1994a).

METHODOLOGY

GENERAL METHODOLOGY

All sampling, laboratory, and analytical methods for benthic infaunal and sediment physical parameters will be those previously described in Section 6.3 of the Contingency Monitoring Adaptive Management Plan.

The methods described here are general methods which may be applicable to more than one tier or set of analyses. In addition, some of these methods cover the basic manipulation of physical or biological data which must take place before implementing the biological indicators approach.

Sediment Physical Characteristics

The depth and sediment particle size distribution of each station will be analyzed to determine whether any observed changes might be due to normal ecological shifts resulting from changes in the substrate. Location-by-location comparisons of sediments or substrates will be done graphically and by use of the PSI of which the Bray-Curtis Index is a more general form. Additionally, the quantity of organic material will be estimated based on percentage of the total volatile solids.

Physical characteristics of background and Project stations will be used qualitatively in the evaluation of all results.

Biological Characteristics

Rather than focus only on major taxa, the total array of sampled taxa will be used wherever possible. This is particularly important in the analyses of species abundances. For example, there can be replacement within a single major taxon of a pollution-sensitive taxon by one that is less tolerant. Such changes could not be clearly determined if taxa are pooled to major taxa.

Abundance Data

For any assemblage, population descriptive measures will be calculated from the abundance of all taxa. The descriptive measures, which are averaged over replicates for each station, are:

- Total number of taxa for each station;
- Numbers of numerically dominant taxa at each station;
- Numbers of the non-numerically dominant taxa at each station;
- Total number of individuals at each station; and
- Standing crop analysis (biomass).

For each station, the abundance data will be combined and the taxa ranked in descending abundances until those taxa that constitute 75 percent of the cumulative sampled benthic faunal

abundance are listed. This will result in a relatively small list of taxa. This list, defined as the numerically dominant taxa, probably includes most of the ecologically important taxa in a data set.

Abundance data will be used in Tier One analyses (Analyses 1.1, 1.5, and 1.6) and the proportional similarity analyses (Analysis 1.3). Abundance data of taxa selected based on trophic guilds, key species, and pollution reactive species will be used in all Tier Two analyses (Analyses 2.1 though 2.3).

Ecological Indices

Changes in the Shannon-Wiener Diversity Index, the Evenness Index, and Simpson's Dominance Index will be used to assess changes in the benthic community. These indices will not be used as biological indicators. However, these indices can be used to describe the benthic community and as a basis of comparison to background and the previous year's data. Ecological indices will give another measure to determine if changes observed are detrimental to the Project community. These indices are single measures describing some ecologically important aspect of the assemblage. All of the following indices should be calculated using individuals identified to the same level of taxonomic precision. These indices will be calculated for only those taxa identified to species. This method is more conservative than using all taxa which have been identified to the lowest practical taxonomic level. In addition, it is consistent with previous indices calculated for the Project allowing for direct consistent comparison of indices across all years of data.

The Shannon-Wiener Index (H') is derived from the mathematical discipline of information theory. It ranges upward from zero and gives a quantitative measure of the relative amount of new information contained in each individual specimen collected. Where the sample is dominated by a few taxa, or has few individuals, the amount of new information likely to be gained by enumerating any given specimen is small. Where the sample is diverse or large, new information is more likely to be gained because each new specimen might be a representative of a previously unsampled taxon.

Although this is a standard index used in ecological analyses, its values need to be interpreted with an understanding of the effects of sample size on the index. Samples of significantly differing sizes can give identical index values; consequently, the information inherent in this index is sample-size dependent. For the same index value, larger samples have significantly more dispersion of the sampled individuals throughout the sampled species than do smaller samples.

The following is the formula for the Shannon-Wiener Index:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where:	H'	=	The Shannon-Wiener or information theory index of diversity calculated with natural logarithms ($\log_e = \ln$)
	p_i	=	The proportion of taxon "i" in the sample
	s	=	The number of all taxa in the sample

The Evenness Index (J) ranges from 0 to 1 and measures the dispersion of all taxa in a sample as a proportion to the maximum possible dispersion. Samples with J values near zero are dominated by few species, while samples with values near one have approximately equal numbers of individuals in each species.

The following is the formula for the Evenness (J) Index:

$$J = \frac{H'}{\ln s}$$

Where:	J	=	The Evenness Index
	H′	=	The Shannon-Wiener Index
	s	=	The total number of taxa in the sample

Simpson's Dominance Index (C) ranges from 0 to 1, and measures the probability of randomly drawing two individuals of any given species from the total sample. This index measures the degree by which a sample is numerically dominated by one or a few taxa. Values near 0 indicate a diverse array (the probability of drawing two individuals of the same taxon is small), while those near 1 reflect dominance by one taxon (the probability of drawing two individuals of the same species is large). The formulation for the Simpson's Index given here is the standard unmodified form (Poole 1974).

$$C = \sum_{i=1}^{s} \frac{n_i(n_i - 1)}{N(N - 1)}$$

Where:	n_i	=	The number of individuals in species "i"
	N	=	The total number of individuals in the sample
	s	=	The number of taxa in the sample

This form is then expressed and reported as "S" (or 1-C) so that high diversity will be indicated by high numbers, consistent with the other indices.

Dendrograms

The programs in the Community Analysis System (Bloom 1992) will be used to construct all dendrograms as well as to calculate or verify all quantitative indices. All dendrograms will be optimally rotated. Dendrograms will be based on Proportional Similarity, as described earlier, and constructed using group average sorting.

Statistical Analyses

Since distributions of abundances (counts) tend to be skewed, data will be log-transformed (ln[x+1]) prior to evaluating the parametric test assumptions. ANOVA tests for two samples will be conducted and the residuals will be recorded. The ANOVA residuals will be evaluated for

homogeneity of variance and normality. Homogeneity of variance will be tested using Levene's test in conjunction with box plots of residuals by sample. Other homogeneity of variance tests, such as Cochran's, Bartlett's, or Hartley's will also be considered. Normality will be evaluated using the Shapiro-Wilk test in conjunction with normal probability plots of residuals (U.S. EPA 1989, 1992).

Based on the results of the homogeneity of variance and normality tests, appropriate statistical tests (parametric or non-parametric) will be conducted. For each hypothesis tested, if most of the test groups examined meet the requirements for parametric tests, parametric tests will be conducted. Although the analysis of variance (ANOVA) test is robust, if these requirements are not met for any of the examined groups, non-parametric tests (Kruskal-Wallis or Mann-Whitney U tests) will also be conducted to verify the results of the parametric tests. These comparisons involving individual stations will be followed by a multiple comparisons test if the initial test indicates significant differences.

This basic statistical testing procedure will be applied to Analyses 1.1, 1.2, 1.5, and 2.1 through 2.3. For Analyses 1.1 and 1.5, several types of abundance data (described previously) will be examined and each will be individually tested as described here. For Analysis 1.2 tested data will be wet-weight biomass for major taxonomic groups. The several types of abundance data addressed in Analysis 1.5 will be tested individually. For Tier Two analyses, tested data will be abundances of selected taxa such as members of certain trophic guilds, key species, pollution sensitive taxa, or pollution tolerant taxa.

STATISTICAL POWER

Power analysis is used to determine the statistical validity of field or experimental data for any given analysis. Two kinds of errors are inherent in statistical analysis: Type I or α error, the error of rejecting a true null hypothesis; and type II or β error, the error of incorrectly specifying the hypotheses. For a given number of sample replicates, the value of α is related inversely to β (Sokal and Rohlf 1981; Zar 1984). Alpha error is commonly set at 0.05. Beta error is often set at 0.1 or 0.2. The "power" of a test is defined as $1 - \beta$, and is commonly referred to as a percentage; thus, a test with $\beta = 0.2$ can be considered to have a power of 80 percent.

The power of the test depends on the error variance of the population being sampled. This can be estimated by the error mean square of an ANOVA comparing the given taxon across the sampled stations (Zar 1984; C. Hogue, personal communication). This latter value is inversely proportional to the number of samples, consequently the power of a test can be related to the number of replicates. To assure consistency in the analyses, all data will be $\ln(x+1)$ transformed prior to the analyses of variance.

Power tables will be computed using methods presented in Zar (1984) to calculate minimum detectable differences (MDDs). The MDDs will then be reported as percent of reference station mean to determine whether each test can detect a reduction of 50 percent of reference mean with 80 percent of power.

The following constants will be held constant for the station-by-station comparisons: $k=8$, $v_1=6$, n=harmonic mean of station sample sizes (B1, B2, ..., B6, R1, R3), and $v_2=28$. A series of values for δ, the MDDs, will be obtained using formula 11.28 of Zar (1984).

For benthic two-sample analyses, equation 9.25 in Zar (1984) will be used to calculate MDDs (given below). The values for n, $t\alpha$, and t_β differ depending on the sizes of the samples being compared in each statistical test. If the sample sizes are equal, n is equal to that sample size; otherwise, n is the harmonic mean of the sample sizes.

$$\phi = \sqrt{\frac{n\delta^2}{2ks^2}}$$

Where:	n	=	The number of replicates
	δ	=	The mean detectable difference
	k	=	The number of samples
	s^2	=	The error mean square from a one-way analysis of variance for the given taxon done across all samples from the cap (Zar 1984)

The MDDs can be viewed as the limits on how similar two samples can be and still be discernible, both above and below the sampled mean. Thus, with an α of 0.5, a power of 0.8 implies the hypothesis that two means differing by at least the MDD will be correctly discriminated 95 percent of the time and that 80 percent of the time the difference between the two means can be correctly estimated (Zar 1984).

ECOLOGICAL STABILITY AND BACKGROUND STATIONS

It was difficult to find true background locations for comparison to the Project stations prior to 1993 because reference or background locations need to be chosen on the basis of relatively uncontaminated substrates and similar physical characteristics. The number of sites in and around Commencement Bay which fit this description is limited. Background locations provide unstressed environmental analogues similar, but not identical, to the study area. Such locations will presumably have a "natural" biota to use in comparisons to the biota of the Project stations. Previous work in Commencement Bay has shown that similar shallow-water background areas are difficult to find (Parametrix 1992, 1993). However, results for the 1993 background stations indicated that they were appropriate for comparison with the Project site.

As biological indicators, two types of comparisons are described; the first is a comparison with the background stations chosen to provide indications of changes in the bay-wide biota, and the second is a comparison with prior trends demonstrated in the Project fauna. The background stations, although nearby, are located across the Puyallup River in an area that is somewhat different hydrologically. Thus, the fauna of the background stations cannot be expected to respond exactly the same as fauna at the Project stations when environmental parameters change.

The background stations have their own peculiar location, history, physical regime, and biota. Similarly, the Project stations will also have changes that are unique to their conditions. Consequently, biological indicator comparisons should consider the trends and conditions occurring within the Project and background stations. Although these comparisons are likely to be more relevant to changes occurring at the Project stations, comparisons to background stations will need to be thoroughly evaluated.

Background Stations

Each year from 1988 through 1992 candidate background stations were examined for comparison with the Project habitat. In each case candidate background stations did not exhibit enough similarities to the Project stations to serve as a comparison site for future monitoring. Candidate background sites were tested in several areas of Commencement Bay including: the Puyallup River delta, clean areas immediately adjacent to the Project, near the Puyallup River delta, and near Vashon Island.

The difficulty of finding ideal background locations led to the choice in 1993 of two background locations near the peninsulas between the Puyallup River and Sitcum Waterway. Such comparative stations are desirable for two reasons. The first is to indicate overall basin-wide or bay-wide changes in the fauna. Numerous bay-wide changes have been documented in Puget Sound in the last twenty years, and the occurrence of such changes needs to be considered in the analyses of changes occurring in the biota of the Project site. Second, comparative areas are used as benchmarks to assess the "normality" of the Project site. The Project and background stations are statistically compared, and the results of those comparisons are used to assess whether or not the study area is normal.

Each background station approximates the mean depth and basic sediment parameters of one of the Project stations. Although the background stations are not a precise match for any particular Project station, they do provide a general benchmark in the event of bay-wide or basin-wide faunal changes.

Comparisons to background stations will be conducted for all Tier One and Tier Two biological indicators analyses. In the event that background stations change and become no longer comparable to the Project stations, additional stations will be investigated and sampled in the following year. Up to two stations will be chosen, with approval from EPA, for sampling in the following year. These new background stations will first be evaluated to determine if they can provide statistically comparable data before statistical tests are applied.

Ecologically Important Taxa

Biological indicators will focus on the defined ecologically important taxa, such as the numerically dominant taxa, and on specifically designated indicator taxa. These indicator taxa will include taxa that have previously been shown to be sensitive to environmental degradation or contamination.

The data collected will be analyzed to define and describe the population characteristics of these important taxa. During the basic analyses, the total number and abundance of all collected taxa will be determined; however, the important taxa will be the focus of all analyses for biological indicators.

CONCLUSIONS

The biological indicators approach was created because the Project Consent Decree requires biological measures of Project performance. The biological indicators approach presented here meets several objectives. One, it provides a clear approach through which decisions regarding the need for further action can be made. Two, it utilizes the wealth of data that was collected over the period from 1988 through 1998 in a process that will allow both present and past trends to be compared. Three, the biological indicators approach accounts for the variety of natural changes which can take place in a normal ecosystem by comparing different types of collected data to prior year's data and selected background stations. Four, the indicators approach provides some flexibility in evaluating results so that unnecessary action is not taken when clear natural phenomena may exist to explain observed changes. Five, it provides clear cut decision points in analyses with statistical tests which can be use to assess if additional evaluations need to take place. Because the biological indicators approach meets all of these objectives, it can be a useful tool for assessing the health and integrity of the Project habitat.

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